Massachusetts Income Eligible and Residential Coordinated Delivery Multifamily Impact Evaluation

(MA23R59-B-MFI)

Prepared for:

Massachusetts Program Administrators

Submitted by:

Guidehouse Inc.
2617 Broadway
Boulder, CO 80304
Telephone (303)728-2500
Guidehouse.com

Reference No.: 219516
September 2024

Table of Contents

Executive Summary **1**
1. Introduction **6**
1.1 About RCD MF 6
1.2 About IE MF 7
1.3 Key Research Questions 7
1.4 Participation Summary 8
1.4.1 Relevant Measures 8
1.4.2 2021 Savings Distribution 10
1.5 How to Use the Results of This Evaluation 13
1.6 Report Organization 14
2. Methodology **15**
2.1 Activities 15
2.2 Data Sources 17
3. Results Summary **19**
4. Key Findings – Weatherization **22**
4.1 Building Simulation Methodology 23
4.1.1 Baseline Model Selection 24
4.1.2 Account Matching 24
4.1.3 Efficient Model Development 28
4.1.4 Weighting and Normalizing Simulation Results 28
4.2 Natural Gas 29
4.2.1 Results 29
4.2.2 Validation 34
4.2.3 Gross Realization Rates 36
4.2.4 Benchmarking 37
4.3 Electricity 38
4.3.1 Results 38
4.3.2 Benchmarking 42
4.4 Delivered Fuels – Heating Oil and Propane 43
4.4.1 Calculating Annual Pre-Consumption 43
4.4.2 Estimating Percent Savings 46
4.4.3 Results 46
5. Key Findings – Heat Pumps **47**
6. Key Findings – Other Measures **53**
7. IE Custom Measure Process Review **64**

7.1 Task Goals 64
7.2 Stakeholder Interviews 64
7.3 Current IE MF Custom Measure Process 65
7.4 IE Custom Process Review Findings and Recommendations 71
7.4.1 Strength: IE MF Custom Project Screening Tool 71
7.4.2 Challenge: External Review of Project Savings Calculation Documentation 71
7.4.3 Challenge: One Customer Facing Program, but Different Customer Experiences 72
7.5 Conclusion 73
Appendix A. Additional Billing Analysis Details 74
A.1 Natural Gas 74
A.1.1 Unit-Level PPR Modeling 74
A.1.2 Building-Level PPR Modeling 76
A.2 Electricity 76
Appendix B. Additional Building Simulation Details 79
Appendix C. Gross Realization Rates 82
Appendix D. Copy of the Massachusetts and Connecticut Heat Pump Metering Study (MA22R51-B-HPMS/CT R2246) 85

List of Tables

Table 1. Evaluated Prescriptive MF Measures 9
Table 2. Summary of Evaluation Activities 15
Table 3. RCD – MF Evaluated Gross Energy Savings by Measure 19
Table 4. IE MF Evaluated Gross Energy Savings by Measure 20
Table 5. ResStock Building Characteristics Filtering Criteria 24
Table 6. Weighted Average Baseline Model Characteristics 25
Table 7. Efficient Model Input Values 28
Table 8. RCD Evaluated Weatherization Savings - Natural Gas 31
Table 9. IE Evaluated Weatherization Savings – Natural Gas 33
Table 10. RCD Building Simulation Weatherization Percent Savings per Dwelling Unit 35
Table 11. IE Building Simulation Weatherization Percent Savings per Dwelling Unit 35
Table 12. Comparison of Billing Analysis and Building Simulation Percent Savings 36
Table 13. RCD Evaluated Weatherization Savings – Electricity 40
Table 14. IE Evaluated Weatherization Savings – Electricity 41
Table 15. IE Benchmarking Weatherization Savings - Electricity 42
Table 16. Average RCD MF Dwelling Unit Size 43
Table 17. Average IE MF Dwelling Unit Size 44
Table 18. Equipment Efficiency Comparisons and Assumptions 44
Table 19. Estimating RCD MF Heating Oil Heating Consumption 45
Table 20. Estimating IE MF Heating Oil Heating Consumption 45
Table 21. Estimating RCD MF Propane Heating Consumption 45
Table 22. Delivered Fuel RCD MF Weatherization Results (2021 Participants) 46

Table 23. Delivered Fuel IE MF Weatherization Results (2021 Participants) 46
Table 24. Onsite Usage Metering 47
Table 25. Baseline HVAC Unit Efficiency Assumptions* 50
Table 26. Deemed Annual Energy Impacts (Per Ton) 51
Table 27. Deemed Annual Energy Impacts (Per Ton) – Remove Heat Pump Baseline Weights, Remove/Disconnect Pre-Existing Heat for FD 52
Table 28. Evaluated Savings Summary – Other RCD and IE Natural Gas Measures (therms/year) 54
Table 29. Evaluated Savings Summary – Other RCD and IE Electric Measures (kWh/year) 57
Table 30. Evaluated Savings Summary – Other RCD and IE Heating Oil Measures (MMBTUs/year) 60
Table 31. Evaluated Savings Summary – Other RCD and IE Propane Measures (MMBTUs/year) 62
Table 32. IE MF Interviewees 65
Table 33. Differences Between LVs Step 1: Project Application 66
Table 34. Differences Between LVs Step 2: Site Assessment/Project Scoping 66
Table 35. Differences Between LVs Step 3: Estimate Project Savings 67
Table 36. Differences Between LVs Step 4: Project Approval 68
Table 37. Differences Between LVs Step 5: Project Implementation 69
Table 38. Differences Between LVs Step 6: Project Submission to PA 69
Table 39. Differences Between PAs Step 7: PA Review/Approval of Payment to LV 69
Table 40. CAP/PA Software and Tools Used During Custom Review Process 70
Table 41. IE MF Billing Analysis Sample Attrition – Natural Gas 74
Table 42. IE MF Billing Analysis Results – Natural Gas 75
Table 43. RCD MF Billing Analysis Sample Attrition – Natural Gas 75
Table 44. RCD MF Billing Analysis Results – Natural Gas 76
Table 45. IE MF Billing Analysis Results, Whole Buildings – Natural Gas 76
Table 46. IE MF Billing Analysis Sample Attrition – Electricity 77
Table 47. IE MF Billing Analysis Results – Electricity 77
Table 48. RCD MF Billing Analysis Sample Attrition – Electricity 77
Table 49. RCD MF Billing Analysis Results – Electricity 78
Table 50. Statewide and PA Specific Comparison of RCD MF Evaluated and Vendor Estimated Weatherization Savings – Natural Gas 82
Table 51. Statewide and PA Specific Comparison of IE MF Evaluated and Vendor Estimated Weatherization Savings – Natural Gas 82
Table 52. Statewide and PA Specific Comparison of RCD MF Evaluated and Vendor Estimated Weatherization Savings – Electric 83
Table 53. Statewide and PA Specific Comparison of IE MF Evaluated and Vendor Estimated Weatherization Savings – Electric 83
Table 54. Statewide Comparison of RCD MF Evaluated and Vendor Estimated Weatherization Savings – Delivered Fuels 83
Table 55. Statewide Comparison of IE MF Evaluated and Vendor Estimated Weatherization Savings – Delivered Fuels 84

List of Figures

Figure 1. Percentage of Total Gross 2021 Annual Energy Savings by RCD and IE Prescriptive Measures 11
Figure 2. RCD and IE MF 2021 Annual Energy Savings by Fuel 12

Figure 3. Gross Energy Savings by Prescriptive Measure by Fuel Type, RCD and IE MF (2021) 13
Figure 4. Example Model Alignment to ASHRAE Guideline-14 25
Figure 5. RCD Monthly Electricity Use, Billed vs. Modeled 26
Figure 6. RCD Monthly Gas Use, Billed vs. Modeled 27
Figure 7. Observed Percent of Savings Histogram for RCD and IE Natural Gas Buildings Receiving Weatherization Measures 34
Figure 8. Market Rate and IE Average Heating Season Consumption Comparison 49
Figure 9. Measure Evaluation Framework 53
Figure 10. RCD MF Modeled Dwelling Unit Count by Unit Heating Fuel and Vintage 79
Figure 11. RCD MF Modeled Dwelling Unit Count by Unit Heating Fuel and Size 80
Figure 12. IE MF Modeled Dwelling Unit Count by Unit Heating Fuel and Vintage 80
Figure 13. IE MF Modeled Dwelling Unit Count by Unit Heating Fuel and Size 81

Executive Summary

As part of the 2022-2024 three-year energy efficiency plan, the Massachusetts (MA) Program Administrators (PAs) identified the need for an impact evaluation of the multifamily (MF) sub-offerings of the Income Eligible (IE) and Residential Coordinated Delivery (RCD) initiatives. The primary goal of the impact evaluation was to update the existing gross energy savings associated with prescriptive MF measures offered through both residential initiatives. The PAs will prospectively apply the updated MF gross energy savings (for measures with deemed savings) and gross realization rates (for measures with vendor-calculated savings) as part of the forthcoming 2025-2027 three-year implementation cycle.

Cadeo, as part of a Guidehouse-primed evaluation team, led this study (MA23R59-B-MFIMPACT), which is one of several concurrent studies informing the PAs' three-year planning process for the IE initiative. The other studies include an impact evaluation focused on IE single-family (SF) measures, a process evaluation of the entire IE initiative (SF and MF), and a robust heat pump metering study that includes IE and non-IE participants.

Methodology

The evaluation team used a combination **of building simulation, engineering algorithms, and billing data disaggregation** to evaluate the impact of every RCD and IE MF measure.[1] Through this multifaceted approach, the team applied the most appropriate methodology—or, in some cases, combination of approaches—to accurately evaluate each measure. The team also reviewed the current IE custom measure process to document and provide greater transparency for stakeholders statewide.

This study focused heavily on two specific RCD and IE MF measures: air sealing and insulation, collectively referred to as **weatherization**. This is because weatherization is the primary driver of RCD MF savings and a large driver of IE MF savings. In 2021, weatherization comprised over half (56%) of total RCD MF and about a third (29%) of annual savings across all fuel types.

The evaluation team used building simulation to evaluate weatherization savings for RCD and IE MF participants that heat their dwelling units with natural gas or electricity. The team evaluated heating oil or propane weatherization by leveraging the building simulation results for natural gas and applying engineering adjustments to account for differences between the fuel types. These adjustments accounted for key differences across fuel types that impact savings including dwelling unit size and heating equipment efficiency. For most other measures, the team relied on engineering algorithms.

Savings Summary

Table A (RCD) and Table B (IE) summarize this evaluation's findings for each evaluated prescriptive MF measure and relevant fuel. The table also indicates which methodology – or combination of methodologies – the evaluation team used to evaluate the savings. For more details about key measures – weatherization (air sealing and insulation) – please see the relevant Key Findings sections.

[1] The team also evaluated relevant commercial and industrial (C&I) measures, which align with RCD high rise measures.

Table A. RCD – MF Evaluated Gross Energy Savings by Measure[2]

Measure	Unit	Natural Gas (therms)	Electric (kWh)	Oil (MMBtu)	Propane (MMBtu)
BUILDING SHELL					
Insulation (Overall)	Dwelling unit	50	1,464	3.4	6.1
Distribution Savings[3]	Dwelling unit		29/29/29		
Cooling Savings[3]	Dwelling unit		21/21/21		
Air Sealing	Dwelling unit	61	1,277	4.1	7.4
Distribution Savings[4]	Dwelling unit		38/38/38		
Cooling Savings[4]	Dwelling unit		-12/-12/-12		
HVAC					
Pipe Wrap (Space Heating)	Linear ft	0.3		0.02	0.03
Programmable Thermostat					
Electric Resistance, no AC	Thermostat	-	475	-	-
Electric Resistance, with AC	Thermostat	-	499	-	-
Heat Pump	Thermostat		250		
Heating savings, Gas/Oil	Thermostat	13	-	0.9	-
AC Only	Thermostat	-	24	-	-
Wi-Fi Thermostat					
Heating Savings	Thermostat	16		1.1	2.0
AC Only	Thermostat	-	22	-	-
Duct Insulation	Dwelling unit	5	180	0.5	0.5
Duct Sealing	Dwelling unit	3	79	0.3	0.3
HOT WATER					
Low-Flow Showerhead	Showerhead	10	182	1.1	1.0
Low-Flow Showerhead with Thermostatic Valve	Showerhead	13	237	1.4	1.3
Thermostatic Shut-off Valve	Valve	4	76	0.4	0.4
Faucet Aerator	Aerator	3	50	0.3	03
Pipe Wrap (Water Heating)	Linear ft	0.6	9	0.07	0.06
PLUG LOAD					
Smart Strips	Smart Strip	-	105	-	-

Source: Cadeo analysis

Building Simulation
Engineering Adjusted Building Simulation
Engineering Algorithm

[2] Savings per unit applies to the RCD high rise and C&I MF measures.
[3]Associated with insulation for natural gas/oil/propane heated homes.
[4]Associated with air sealing for natural gas/oil/propane heated homes.

Table B: IE MF Evaluated Gross Energy Savings by Measure

Measure	Unit	Natural Gas (therms)	Electric (kWh)	Oil (MMBtu)	Propane (MMBtu)
BUILDING SHELL					
Insulation (Overall)	Dwelling unit	42	1,407	4.8	4.2
Distribution Savings[5]	Dwelling unit		30/30/30		
Cooling Savings[5]	Dwelling unit		32/32/32		
Air Sealing	Dwelling unit	62	1,676	7.1	6.2
Distribution Savings[6]	Dwelling unit		44/44/44		
Cooling Savings[6]	Dwelling unit		88/88/88		
HVAC					
Central Heat Pump (Propane Partial Displacement)	Ton	-	-839	-	9.8
Central Heat Pump (Oil Partial Displacement)	Ton	-	-832	10.5	-
Central Heat Pump (Natural Gas/Propane Full Displacement)	Ton	155	-1,249	-	15.5
Central Heat Pump (Oil Full Displacement)	Ton	-	-1,238	16.6	-
Mini-Split Heat Pump (Natural Gas/Propane Partial Displacement)	Ton	163	-960	-	16.3
Mini-Split Heat Pump (Oil Partial Displacement)	Ton	-	-961	15.9	-
Mini-Split Heat Pump (Electric Heat Full Displacement)	Ton	-	2,547	-	-
Mini-Split Heat Pump (Natural Gas/Propane Full Displacement)	Ton	175	-1,206	-	17.5
Mini-Split Heat Pump (Oil Full Displacement)	Ton	-	-1,208	17.1	-
Pipe Wrap (Space Heating)	Linear ft	0.2	-	0.03	-
Programmable Thermostat	Thermostat	13	276	1.3	1.3
Wi-Fi Thermostat Heating Savings	Thermostat	15		1.7	1.5
Wi-Fi Thermostat AC Only	Thermostat	-	20	-	-
Duct Insulation	Dwelling unit	0.3	49	0.03	0.03
Duct Sealing	Dwelling unit	0.2	23	0.02	0.02
PROCESS					
Refrigerator Replacement	Refrigerator	-	390	-	-
Freezer Replacement	Freezer	-	713	-	-

[5] Associated with insulation for natural gas/oil/propane heated homes.
[6] Associated with air sealing for natural gas/oil/propane heated homes.

Measure	Unit	Natural Gas (therms)	Electric (kWh)	Oil (MMBtu)	Propane (MMBtu)
Appliance Removal	Refrigerator or Freezer	-	968	-	-
HOT WATER					
Low-Flow Showerhead	Showerhead	11	204	1.2	1.1
Low-Flow Showerhead with Thermostatic Valve	Showerhead	15	266	1.5	1.5
Thermostatic Shut-off Valve	Valve	4.7	85	0.5	10.5
Faucet Aerator	Aerator	2	42	0.2	0.2
Pipe Wrap (Water Heating)	Linear ft	0.6	9	0.07	0.06
Indirect Water Heater	Water Heater	71	-	-	7.1
On Demand/Tankless Water Heater	Water Heater	42	-	4.2	4.2
Stand Alone Water Heater	Water Heater	38	-	3.8	3.8
MOTORS/DRIVES					
Variable Frequency Drive	VFD	-	392	-	-
REFRIGERATION					
Vending Misers	Vending Miser	-	1,612	-	-
PLUG LOAD					
Smart Strip	Smart Strip		105		

Source: Cadeo analysis

Building Simulation
Engineering Adjusted Building Simulation
Engineering Algorithm
Vendor Calculated
Heat Pump Metering Study

Recommendations

The evaluation team recommends the PAs:

- **Study the reduction in air infiltration due to air sealing.** Currently, the IE and RCD MF Lead Vendors (LVs) do not conduct pre- and post-blower door tests at MF buildings that receive air sealing. In the absence of measured data about the actual change in infiltration resulting from the initiative's air sealing efforts, the LVs – and the evaluation team – are forced to rely on the default assumption (20% reduction in air changes per hour or ACH) documented in the current Technical Reference Manual (TRM). Without primary data from air sealed MF participants, or a clear empirical basis for the current 20% reduction assumption, neither the LV nor evaluation team have reliable data to evaluate the actual energy savings associated with air sealing. The evaluation team recommends the PAs collect data to fill this critical information gap. As blower door testing at MF buildings is challenging, the evaluation team suggests the PAs commission a dedicated air sealing study or provide the LVs with additional technical field support to test a statistically significant sample of participating MF buildings. Either way, it is

essential the PAs facilitate the collection of reliable air sealing data so that LVs and evaluators alike can more accurately report savings for this key measure.

- **Improve statewide consistency of data tracking.** As part of this study, the evaluation team found National Grid's data provided the most consistent and clear mapping of initiative data across participating MF accounts, buildings, and facilities. For other PAs, the team had difficulty following the same connections between these important MF elements. Consequently, the evaluation team recommends the PAs collaborate to establish a consistent approach across PAs for reporting these critical linkages at participating IE MF and RCD MF properties. Clear and consistent documentation across PAs regarding which measures map to which accounts, how many units are served by each account, and which accounts map to participating buildings and facilities will remove uncertainty in the tracking data and increase the viability of future evaluations.

- **Continue using existing air sealing and insulation gross savings and gross realization rates.** The PAs determine savings for vendor-calculated measures, including air sealing and insulation, by applying evaluation-based gross realization rates to the gross savings reported by their LVs. Calculating the gross realization rate for any given measure requires two inputs: average evaluated savings for that measure (the calculation's numerator) and average reported savings for the same measure (the denominator). In the case of air sealing and insulation, uncertainty exists in both the evaluated savings (because, without data, the team had to assume a 20% reduction in air sealing) and in the reported savings (because of difficulty reliably converting account-level reported air sealing and insulation savings into unit-level savings). As a result, the evaluation team was unable to calculate reliable gross realization rates for the PAs. Therefore, the team recommends the PAs continue to use the existing per-unit gross savings (varies by PA) and gross realization (0.86) for RCD MF air sealing and insulation measures, as well as the PA-specific gas realization rates currently used for IE MF.

Considerations

The evaluation team suggests the PAs also consider:

- **Adopting a statewide IE MF custom project screening tool.** The in-development screening tool, which National Grid recently created by modifying an existing commercial and industrial (C&I) screening tool, has the potential to standardize and simplify the screening process for custom MF measures statewide. The team suggests the PAs continue working together to finalize the tool so that PAs and CAPs statewide can benefit from a standardized and streamlined vetting process for custom measures.

1. Introduction

As part of the 2022-2024 three-year energy efficiency plan, the Massachusetts (MA) Program Administrators (PAs) identified the need for an impact evaluation of the multifamily (MF) sub offerings of the Income Eligible (IE) and Residential Coordinated Delivery (RCD) initiatives. The primary goal of the impact evaluation was to update the existing gross energy savings associated with prescriptive MF measures offered through both residential initiatives. The PAs will apply the updated MF gross energy savings prospectively as part of the forthcoming 2025-2027 three-year implementation cycle.

Cadeo, as part of a Guidehouse-primed evaluation team, led this study (MA23R59-B-MFIMPACT). As discussed in this report, the evaluation team used a combination of billing analysis, building simulation, and engineering algorithms to evaluate savings for prescriptive MF measures. This multifaceted approach applies the most appropriate methodology—or, in some cases, multiple approaches—to each measure. Additionally, Cadeo completed a custom measure review to document the current custom measure process and provide greater transparency for stakeholders statewide.

This impact evaluation is one of three concurrent and complementary residential impact studies completed in 2024 to inform the PAs' efforts to plan the next three-year implementation cycle (2025-2027). **This impact evaluation focuses on MF participants** regardless of their income (i.e., residential customers living in buildings with more than five units). The other two studies, which both focus on single-family (SF) participants, are:

- **MA23R58-B-RCD.** The evaluation team's impact evaluation of the RCD initiative's SF sub offering is analogous to this study but focused on market rate customers that live in buildings with less than five units. Like MF participants, these SF customers are served through the PAs' RCD Lead Vendors (LVs), as well as Home Performance Contractors (HPCs) managed by Abode Energy Management (Abode). The RCD study offers a point of comparison with this IE SF study and highlights differences in Massachusetts across income thresholds.

- **MA23R56-B-IESF.** Similarly, the IE SF Impact Evaluation mirrors the MA23R58-B-RCD study by focusing on income-qualified customers that live in buildings with less than five units. These customers, like the MF participants discussed in this report, are served through the PAs' network of Community Action Program (CAP) agencies/vendors.

1.1 About RCD MF

The RCD initiative is the primary mechanism through which the PAs deliver energy efficiency to all non-IE residential customers—including those living in MF buildings. The initiative offers no-cost assessments to building owners or landlords of buildings with five or more dwelling units. The assessments identify energy savings opportunities for the whole building including tenant dwelling units and common areas, such as lobbies and hallways. These opportunities in tenant units (e.g., high-efficiency showerheads and faucet aerators, and programmable thermostats), common areas (e.g., lighting), and weatherization (air sealing and insulation) will improve tenant comfort, reduce building maintenance, and lower year-round energy use. Additionally, MF includes a commercial and industrial (C&I) component to address buildings with commercial accounts.

The PAs work with one of the following LVs to implement RCD MF on their behalf: CLEAResult, RISE Engineering (RISE), and Center for EcoTechnology (CET).[7] LVs complete energy assessments for customers that enter RCD through traditional channels, such as the Mass Save statewide phone number or MassSave.com. LVs are responsible for conducting energy assessments using in-house energy specialists, managing an extensive network of independent installation contractors (IICs) that air seal and insulate MF buildings, and providing quality assurance and quality control (QA/QC) services following installation. The LVs and PAs collaborate through a statewide RCD Working Group. While the LVs offer relatively consistent services statewide, some differences exist between them.

1.2 About IE MF

The PAs, in collaboration with the Low Income Energy Affordability Network (LEAN) and CAPs have implemented successful programming for IE customers for more than two decades. The IE program serves MF buildings owned by nonprofits, for profit entities, and public housing authorities. The LEAN MF program helps to reduce energy costs in MF buildings (five or more dwelling units) with at least 50% of households living at or below 60% of the area median income (AMI).

The LEAN MF program provides cost-effective weatherization, HVAC and water heating, appliances, and other energy efficiency measures to IE MF buildings. Property owners or managers of MF buildings submit applications through an online portal[8] by providing utility billing data, utility account numbers, and documentation of IE units.

Agencies/vendors use program funds to deliver one of two types of energy assessments through the LEAN MF program: the Appliance Management Program (AMP) audit and a Building Assessment (or Comprehensive Building Assessment):[9]

- **AMP.** This program is an electrical audit with two purposes. The first purpose is for auditors to install energy savings products at no cost to the owner/tenant. Types of measures typically installed include advanced power strips, low-flow showerheads, faucet aerators, and programmable thermostats. The second purpose is to identify larger equipment that may be eligible for replacement, such as refrigerators.
- **Building Assessment.** An auditor will visit the MF building and conduct a walk-through of all common areas and a few tenant units. During the walk-through the auditor will identify weatherization, space and water heating, and any other potential energy efficiency upgrades.

1.3 Key Research Questions

The team investigated the following key research question along with related sub-questions:

[7] CLEAResult is the LV for Eversource and National Grid, while RISE is the LV for Cape Light Compact, Liberty Utilities, and Unitil. (RISE also served natural gas National Grid customers on the Cape.) CET is the LV for Berkshire Gas.

[8] The Low Income Energy Affordability Network (LEAN) Multifamily program on portal, https://leanmultifamily.org/.

[9] The Cadmus Group, Massachusetts Low-Income Multifamily Initiative Impact Evaluation, October 2015, https://ma-eeac.org/wp-content/uploads/Low-Income-Multifamily-Impact-Evaluation-1.pdf.

What are the energy savings associated with each prescriptive RCD and IE MF measure?

Sub-questions:

- How do these savings vary across fuel types (including delivered fuels), between the two program delivery channels, and across different vendors/CAPs?
- Where is the program achieving the most energy impact (MMBTUs)? Which measures? Where is the opposite happening?
- How do the evaluated savings compare with the savings achieved in MF programs in other states around New England? What are the potential reasons for any observed differences?
- How do the energy impacts (i.e., change in total MMBTUs) associated with electrification measures such as heat pump water heaters compare with the impact associated with upgraded natural gas or delivered fuel-powered systems?
- How do whole building improvements such as air sealing, duct sealing, and insulation impact the energy use of individual building tenants?

1.4 Participation Summary

To provide readers with context for study findings, this section provides a brief overview of the evaluated MF measures for both initiatives.

1.4.1 Relevant Measures

As Table 1 shows, this study evaluated 15 and 25 RCD and IE MF prescriptive measures, respectively, the majority of which are evaluated at the dwelling unit level. The primary differences between the initiatives' offerings relate to HVAC and water heating. The IE initiative's comprehensive approach includes heating system and water heater retrofits, where MF RCD participants would either work through the PAs' HVAC Retail and other residential initiatives or pursue custom measures to upgrade similar mechanical equipment. HVAC and water heating savings are currently reported at the building level, instead of per dwelling unit.

There is also a notable end use not included in Table 1: lighting. Historically LEDs and before that CFLs have been a primary source of electric savings. As part of past implementation cycles, RCD and IE both directly installed more efficient lighting in participating tenants' units, as well as in MF common areas, include fixture upgrades and lighting controls. However, as a result of success in achieving market transformation, the PAs removed incentives for RCD MF lighting as part of the upcoming 2025-2027 three-year cycle. IE MF will continue to have lighting upgrades as an offering, but primarily through the custom process. Since evaluation results are applied prospectively, the team did not evaluate any lighting measures as part of this MF study.

Table 1. Evaluated Prescriptive MF Measures

Measure End Use	Measures	RCD	IE	Savings Types[10]
Envelope	• Air Sealing	✓	✓	Vendor Calculated
	• Insulation	✓	✓	Vendor Calculated
HVAC	• Heating System, Furnace	-	✓	Vendor Calculated
	• Heating System, Boiler	-	✓	Vendor Calculated
	• Heating System, Commercial Boiler	-	✓	Vendor Calculated
	• Boiler Reset Control	-	✓	Vendor Calculated
	• Central Heat Pumps (Full and Partial Displacement)	-	✓	Deemed
	• Mini-Split Heat Pumps (Full and Partial Displacement	-	✓	Deemed
	• Pipe Wrap (Space Heating)	✓	✓	Deemed
	• Programmable Thermostat	✓	✓	Deemed
	• Wi-Fi Thermostat	✓	✓	Deemed
	• Duct Sealing	✓	✓	Vendor Calculated
	• Duct Insulation	✓	✓	Vendor Calculated
	• Dehumidifier	-	✓	Deemed
	• Window AC Replacement	-	✓	Deemed
Process	• Refrigerator Replacement[11]	-	✓	Deemed
	• Freezer Replacement	-	✓	Deemed
	• Appliance Removal	-	✓	Deemed
Domestic Hot Water	• Faucet Aerator	✓	✓	Deemed
	• Low-Flow Showerhead	✓	✓	Deemed
	• Low-Flow Showerhead with Thermostatic Valve	✓	✓	Deemed

[10] Vendor-calculated measures are calculated and reported by each LV, typically using vendor proprietary software; TRM does not provide a deemed savings value for these measures. Measure savings designated as Deemed use a savings per unit value provided in the TRM. These deemed savings are often determined based on evaluation results.

[11] This measure was previously deemed for some PAs but VC for others.

Measure End Use	Measures	RCD	IE	Savings Types[10]
	• Thermostatic Shut-off Valve	-	✓	Deemed
	• Pipe Wrap (Water Heating)	✓	✓	Deemed
	• On Demand/Tankless Water Heater	-	✓	Vendor Calculated
	• Indirect Water Heater	-	✓	Vendor Calculated
	• Stand Alone Water Heater	-	✓	Vendor Calculated
	• Early Retirement CW Elec DHW & Elec Dryer	-	✓	Deemed
	• Early Retirement CW Gas DHW & Elec Dryer	-	✓	Deemed
	• Early Retirement CW Elec DHW & Gas Dryer	-	✓	Deemed
	• Early Retirement CW Gas DHW & Gas Dryer	-	✓	Deemed
	• Early Retirement CW Oil DHW & Elec Dryer	-	✓	Deemed
	• Early Retirement CW Propane DHW & Elec Dryer	-	✓	Deemed
Motors/Drives	• Variable Frequency Drive	-	✓	Vendor Calculated
Refrigeration	• Vending Misers	-	✓	Deemed
Plug Load	• Smart Strips	✓	✓	Deemed

Source: Cadeo analysis

1.4.2 2021 Savings Distribution

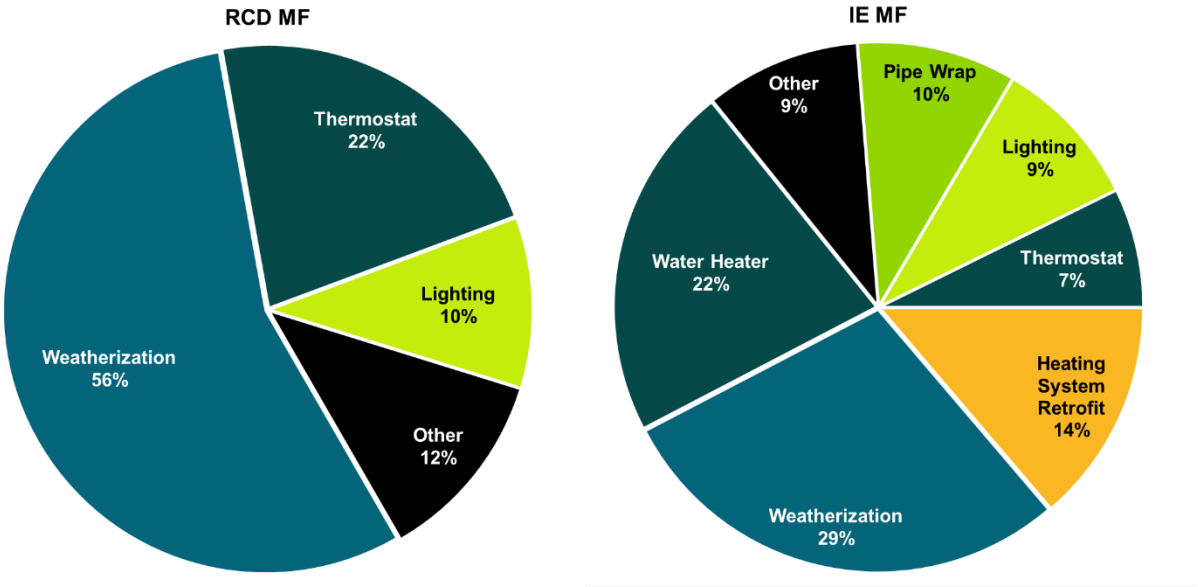
Figure 1 breaks down 2021 reported MF measure annual savings by end use across all fuel types[12] for RCD (left) and IE (right) in 2021.[13] As evident in the figure, weatherization (i.e., air sealing and insulation) represents over half (56%) of 2021 reported RCD's MF annual savings. Thermostats (22%) and lighting (10%) combine to constitute another third. The mix varies slightly for IE MF, which offers a larger set of measures than RCD MF. For IE MF, weatherization was the largest contributor to total savings (29%), closely followed by water heaters (22%) and heating system retrofits (14%). As a reminder, lighting will be going away in

[12] The team converted all reported savings to MMBTUs to assess each measure's contribution to total RCD savings across fuel types.

[13] The team used 2021 Electric Measures Savings Report and 2021 Gas Measures Savings Report that contain annual savings values by fuel.

the next three-year cycle, which means the relative importance of all these key measures will increase further.

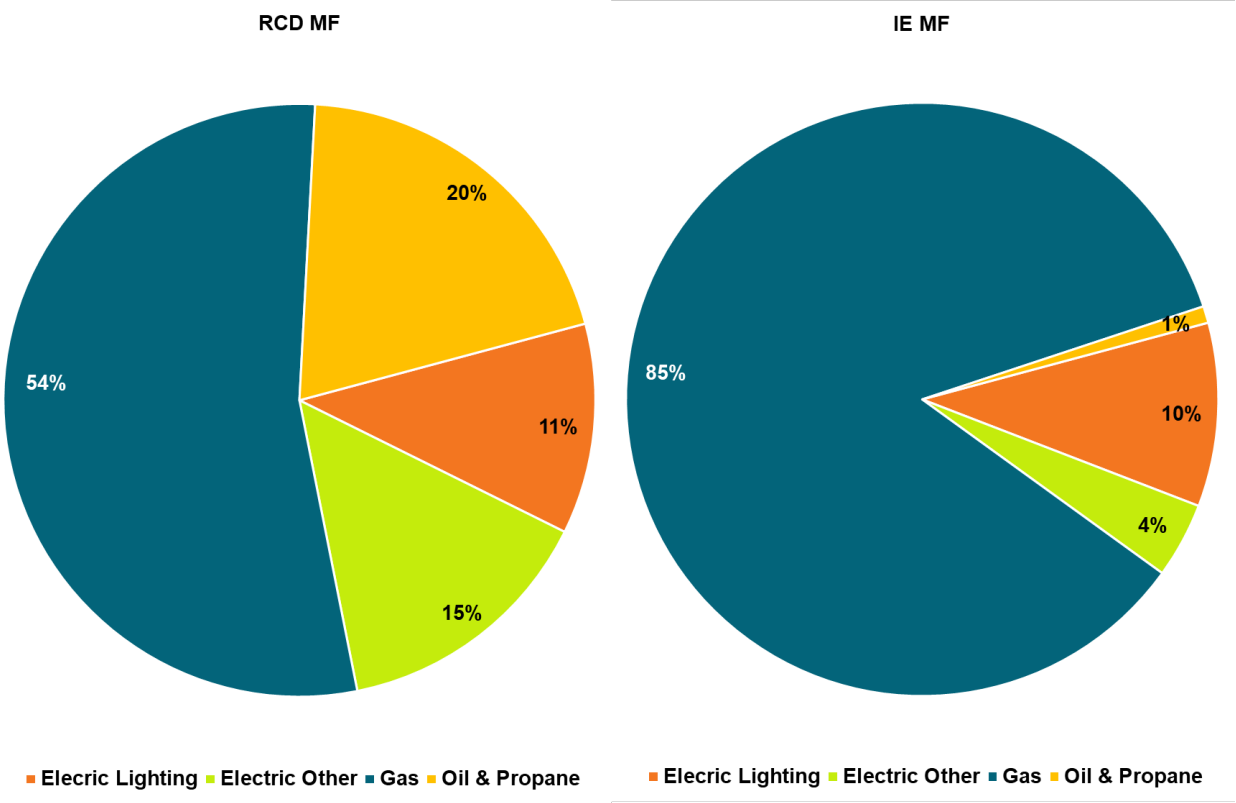
Figure 1. Percentage of Total Gross 2021 Annual Energy Savings by RCD and IE Prescriptive Measures



Source: MassSaveData.com

Figure 2 offers a different perspective on both initiatives: the portion of total savings (in MMBTUs) results from natural gas, electric and delivered fuel (i.e., heating oil and propane) measures. Natural gas savings were the largest contributors to both RCD and IE MF annual savings (54% and 85%, respectively). Electric and heating oil savings roughly split the remaining annual savings for RCD MF, while electric annual savings dominate the remaining annual savings for IE MF.

Figure 2. RCD and IE MF 2021 Annual Energy Savings by Fuel



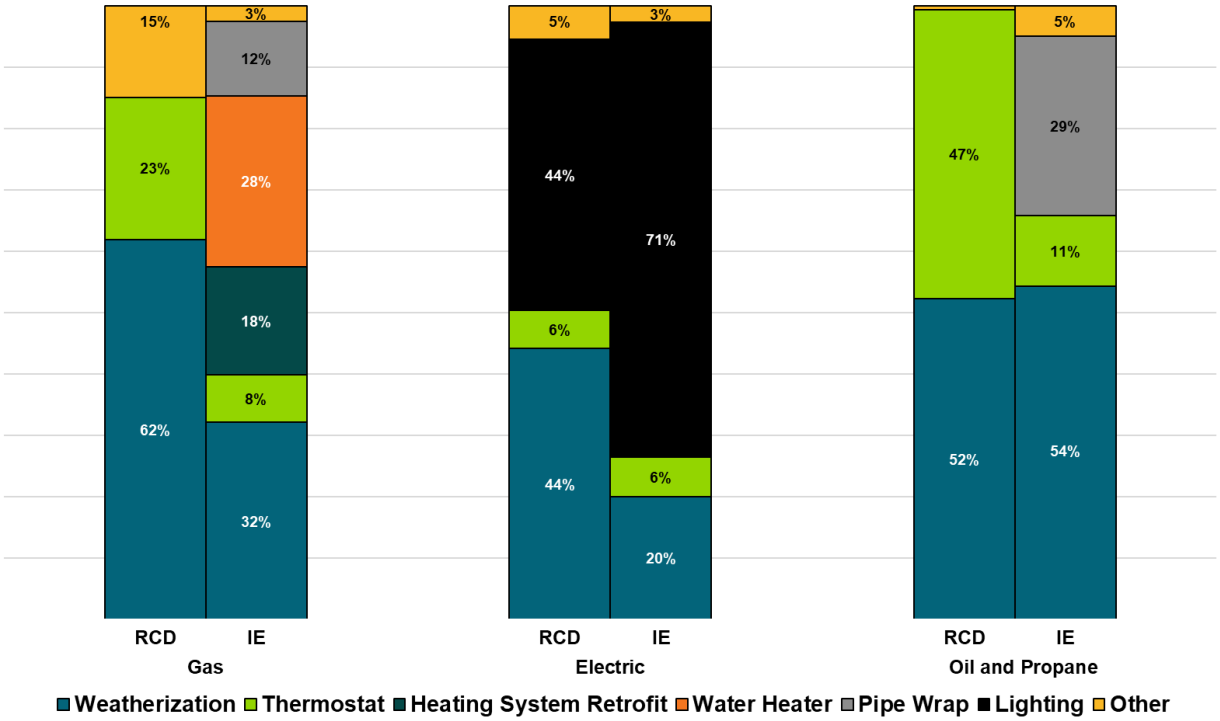
Source: MassSaveData.com

Figure 3 combines the previous two perspectives offering insight into the relative importance of each MF measure for each fuel type.

For RCD, weatherization represented over half of the initiative's prescriptive MF annual energy savings for natural gas and delivered fuels, and slightly less than half (44%) of electric savings. For natural gas and delivered fuels, significant annual energy savings also stemmed from Wi-Fi thermostats. Interestingly, for RCD MF gas and delivered fuels, programmable thermostat savings were small (<2% of savings for gas and 0.06% of savings for delivered fuels). The remaining 15% of "Other" RCD natural gas savings were spread out among the following measures: duct sealing, faucet aerators, programmable thermostats, low-flow showerheads, and pipe wrap. Unsurprisingly, lighting upgrades accounted for 44% of the annual energy savings associated with electricity.

For IE, weatherization plays a more modest role. Figure 3 illustrates that weatherization measures (air sealing and insulation), contribute 32% to natural gas savings, 20% to electric savings, and 54% to oil and propane savings. Like RCD, lighting upgrades accounted for a large portion (71%) of IE annual energy savings associated with electricity.

Figure 3. Gross Energy Savings by Prescriptive Measure by Fuel Type, RCD and IE MF (2021)



Source: MassSaveData.com

1.5 How to Use the Results of This Evaluation

This report summarizes the results of the RCD and IE MF evaluation, and the evaluation methodologies used to generate those results. For key RCD and IE MF measures, notably weatherization, the report includes a more detailed explanation of how the team developed evaluated savings.

This report does not include details such as the engineering algorithm and specific primary and secondary data used to develop savings less impactful RCD and IE MF measures (e.g., faucet aerators). For these types of details, users of this evaluation should rely on the report's supplementary **Engineering Workbook**.

This Excel workbook includes a tab for each RCD and IE MF measure that details the engineering algorithm used to evaluate that measure and all the values (and sources) for all inputs used in that algorithm. Each of these tab's link to common participant, housing stock, and engineering assumptions to ensure consistency across measures and complete transparency. The study determined, early in the evaluation process, that such a workbook (versus similar details provided in a static report appendix) was a more functional format for conveying these details.

Further, to aid the PAs' prospective application of the results, the team has also provided a second Excel workbook with measure-level results for **every relevant RCD and IE MF BCR**

(benefit cost ratio) measure ID (identification number). The PAs can directly use this workbook as part of their 2025-2027 planning process.

Readers interested in utilizing these supplementary evaluation outputs should request access from a PA evaluation manager.

1.6 Report Organization

This report is designed to prioritize summarizing the study's key findings while also providing insight into the evaluation's approach and information about all RCD and IE MF measures. To achieve this, the body of the report includes the following sections:

- Methodology
- Results Summary
- Key Findings: Weatherization
- Key Findings: Heat Pumps
- Key Findings: Other Measures
- IE Custom Measure Review Process

To supplement these summary sections, the report includes an appendix that elaborates upon billing analysis methodology.

- Appendix A: Additional Billing Analysis Details
- Appendix B: Additional Building Simulation Details
- Appendix C: Gross Realization Rates
- Appendix D: Copy of the Massachusetts and Connecticut Heat Pump Metering Study (MA22R51-B-HPMS/CT R2246)

2. Methodology

The evaluation team used a combination of calibrated building simulation, engineering algorithms, and billing data disaggregation to evaluate the impact of every prescriptive RCD and IE MF measure, as well as relevant C&I measures (C&I measures align with RCD High Rise measures). The team could not evaluate custom measures savings due to insufficient available data. Instead, the team completed an IE custom measure process review that documented the current custom measure process.

As noted in Table 2, the evaluation team's billing analyses to assess weatherization (RCD and IE) savings in dwelling units/MF buildings heated with natural gas did not yield statistically significant results (i.e., greater than 20% precision at the 90% confidence level) to official report savings. This is not uncommon for MF billing analyses given the heterogenous nature of MF housing and varied metering approaches (master versus individually metering). Consequently, the team used non-statistical approaches (i.e., calibrated building simulation and engineering analysis) to evaluate all RCD and IE MF measures.

2.1 Activities

Table 2 summarizes the methodology the team used to complete the four activities scoped as part of this impact evaluation.

Table 2. Summary of Evaluation Activities

	IE Custom Measure Process Review • Developed a conversation guide for discussions with National Grid and Eversource and their current LVs, Action and ABCD respectively. • Conducted four interviews, one with each stakeholder group to discuss their process for identifying, vetting, and implementing custom projects. • Reviewed process documentation and tools provided by PAs and LVs. • Documented process, tools and how individuals engage with the process.

Billing Analysis

- Attempted natural gas and electric billing analyses with the intention to report evaluated savings for weatherization).
- Analysis included matching each treatment group participant (RCD and IE MF participant from 2021) to a control group participant (participants from 2022) with a similar monthly pre-program energy consumption pattern.
- Specified, refined, and experimented with multiple monthly post-program regression (PPR) model specification, as well as other types of models and non-modeling approaches (i.e., difference-of-differences)
- Tried building-type specific models (i.e., identifying and separately modeling known master metered buildings and those known to have multiple individually metered units.
- None of the model specifications met the pre-determined qualifying threshold (per the study's Stage 3 plan) of better than ±20% precision at the 90% confidence level for reporting evaluation results.
- While the team did not use the billing analysis to evaluate savings, the team used the tasks' bill disaggregation subtask (i.e., breaking individual participants' annual consumption into heating, cooling, and baseload components), which informed the building simulation calibration process and served as an input for the engineering analysis.
- Using TMYx weather data from the nearest weather station, the team completed a variable degree day (VBDD) analysis to identify the optimal base temperatures for determining heating degree days (HDDs) and cooling degree days (CDDs) for each participant. 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.

For additional details about the attempted billing analysis, see Appendix A.

Engineering Algorithms

- Relied primarily on algorithms from the Massachusetts Technical Reference Manual (MA TRM)[14] or previous evaluations in Massachusetts, including relevant MF evaluations
- Leveraged RCD LV and IE PA data to calculate program-specific inputs for each measure.
- When these data were unavailable or insufficient (which was typically the case for IE participants) the team relied on regionally appropriate secondary data sources and other relevant studies – most notably the Massachusetts Residential Baseline Study,[15] ENERGY STAR® standards, Building America Benchmark Program Database, etc.
- Included literature review of recent relevant studies, US Department of Energy appliance standards, other state TRMs, and similar evaluations in other states.
- Made engineering adjustments to billing disaggregation-informed building simulated results to estimate savings for delivered fuel measures, particularly for air sealing and insulation.

[14] Massachusetts Technical Reference Manual, 2024 Prospective Version, https://www.masssavedata.com/TRL/Technical%20Reference%20Manual%202024%20Prospective.pdf.

[15] Massachusetts Residential Baseline Study, Appendix B-3 and B-4, March 2020, https://ma-eeac.org/wp-content/uploads/RES-1-Residential-Baseline-Study-Ph4-Comprehensive-Report-2020-04-02.pdf.

Building Simulation

- Used ResStock,[16] energy modeling tool developed by the National Renewable Energy Laboratory, that both contains hundreds of thousands of pre-run energy simulations and the capacity to run new energy models in EnergyPlus.
- Leveraged BuildStockBatch's building characteristic sampling functionality to create over 1,800 unique dwelling unit models with building characteristics representative of participant buildings.
- Matched model's simulated monthly consumption to normalized monthly consumption values from the billing data.
- Determined post-measure values, including air sealing infiltration rates, wall, attic, floor, and duct insulation, and duct sealing leakage rates through LV program data.
- Used post-measure values to update models and generate post-measure consumption for each model matched to billing data.
- Normalized and weighted model savings (difference between pre- and post-measure consumption) using modeled square footage (e.g., roof area for attic insulation savings).
- Incorporated installed measure square footage, found in the LV program data, to find the final statewide savings values.

For additional details about the building simulations methodology, see Section 4.1 Building Simulation Methodology.

Source: Cadeo analysis

2.2 Data Sources

The team used the following data sources to inform evaluation activities.

- **Billing data:** The PAs, via DNV (their data manager) provided three years of billing data (2020-2022) for each MF account that had an assessment and/or installed a measure in 2021 or 2022. This data set included both RCD and IE customers.
- **Weather data.** 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 2007-2021) from National Oceanic and Atmospheric Administration for all Massachusetts weather stations. The team mapped each customer account to the closest weather station based on the customer's ZIP code.
- **DNV MF measure data.** A list of all installed measures, including installation dates, BCR IDs, descriptions, and reported savings. Information for participating dwelling units or buildings including address, age of building, number of units, total and conditioned square footage was provided as linked Tax Parcel data.

[16] ResStock is well suited for this task as it relies on data-driven building characteristic probabilities to generate model's representative of specific regions (including Massachusetts), building types, and occupant characteristics (including income). More information can be found here: https://resstock.nrel.gov/.

- **Massachusetts Multifamily Census:** Guidehouse provided a data set providing a variety of variables describing all multi-family buildings. The MF Census was used to identify the total building units when not available in tracking data.
- **LV RCD tracking data.** CLEAResult, RISE, and CET provided the evaluation team with RCD tracking data for customers that received an HEA and/or installed measures in 2021 and 2022. The data included additional dwelling unit characteristics and measure properties that were not available in the DNV data.
- **IE PA tracking data.** National Grid and Eversource also provided the evaluation team with tracking data for IE MF customers that received an HEA and/or installed measures in 2021 and 2022. This data also provided dwelling unit characteristics and measure properties that were not available in the DNV data, although it was less detailed than the tracking data provided by the LV for RCD. The data National Grid provided mapped participating units to buildings and buildings to facilities, which offered the team significant insights.
- **Cross-program data.** As noted above, a subset of MF RCD participants installed measures incentivized by a different (i.e., not RCD) PA residential initiative before or after participating in MF. To avoid conflating the savings associated with non-MF measures when evaluating MF measures, the team requested and received a dataset containing all non-RCD measures installed in MF customer dwelling units in 2020, 2021, and 2022[17]. The team included variables in the billing analysis specification to account for the presence of these non-MF measures as part of the team's analysis. A similar approach was not necessary for MF IE participants as the IE offering is comprehensive.

[17] The data grouped measures by core initiative and sub-offering. The core initiatives include "C&I Existing Building Retrofit", "C&I New & Replacement Equipment", "C&I New Buildings & Major Renovations", "Residential Behavior", "Residential New Homes & Renovations", Residential Retail".

3. Results Summary

Table 3 (RCD) and Table 4 (IE) summarize this evaluation's findings for each evaluated prescriptive MF measure and relevant fuel. The table also indicates which methodology – or combination of methodologies – the evaluation team used to evaluate the savings. For more details about key measures – weatherization (air sealing and insulation) – please see the relevant Key Findings sections.

Table 3. RCD – MF Evaluated Gross Energy Savings by Measure

Measure	Unit	Natural Gas (therms)	Electric (kWh)	Oil (MMBtu)	Propane (MMBtu)
BUILDING SHELL					
Insulation (Overall)	Dwelling unit	50	1,464	3.4	6.1
Distribution Savings[18]	Dwelling unit		29/29/29		
Cooling Savings[18]	Dwelling unit		21/21/21		
Air Sealing	Dwelling unit	61	1,277	4.1	7.4
Distribution Savings[19]	Dwelling unit		38/38/38		
Cooling Savings[19]	Dwelling unit		-12/-12/-12		
HVAC					
Pipe Wrap (Space Heating)	Linear ft	0.3		0.02	0.06
Programmable Thermostat					
Electric Resistance, no AC	Thermostat	-	475	-	-
Electric Resistance, with AC	Thermostat	-	499	-	-
Heat Pump	Thermostat		250		
Heating savings, Gas/Oil	Thermostat	13	-	0.9	-
AC Only	Thermostat	-	24	-	-
Wi-Fi Thermostat					
Heating Savings	Thermostat	16		1.1	2.0
AC Only	Thermostat	-	22	-	-
Duct Insulation	Dwelling unit	5	180	0.5	0.5
Duct Sealing	Dwelling unit	3	79	0.3	0.3
HOT WATER					
Low-Flow Showerhead	Showerhead	10	182	1.1	1.0
Low-Flow Showerhead with Thermostatic Valve	Showerhead	13	237	1.4	1.3
Thermostatic Shut-off Valve	Valve	4	76	0.4	0.4
Faucet Aerator	Aerator	3	50	0.3	0.3
Pipe Wrap (Water Heating)	Linear ft	0.6	9	0.07	0.06

[18]Associated with insulation for natural gas/oil/propane heated homes.
[19]Associated with air sealing for natural gas/oil/propane heated homes.

Measure	Unit	Natural Gas (therms)	Electric (kWh)	Oil (MMBtu)	Propane (MMBtu)
PLUG LOAD					
Smart Strips	Smart Strip	-	105	-	-

Source: Cadeo analysis

Building Simulation
Engineering Adjusted Building Simulation
Engineering Algorithm

Table 4. IE MF Evaluated Gross Energy Savings by Measure

Measure	Unit	Natural Gas (therms)	Electric (kWh)	Oil (MMBtu)	Propane (MMBtu)
BUILDING SHELL					
Insulation (Overall)	Dwelling unit	42	1,415	4.8	4.2
Distribution Savings[20]	Dwelling unit	-	30/30/30	-	-
Cooling Savings[5]	Dwelling unit	-	32/32/32	-	-
Air Sealing	Dwelling unit	62	1,676	7.1	6.2
Distribution Savings[21]	Dwelling unit	-	44/44/44	-	-
Cooling Savings[6]	Dwelling unit	-	88/88/88	-	-
HVAC					
Central Heat Pump (Propane Partial Displacement)	Ton	-	-839	-	9.8
Central Heat Pump (Oil Partial Displacement)	Ton	-	-832	10.5	-
Central Heat Pump (Natural Gas/Propane Full Displacement)	Ton	155	-1,249	-	15.5
Central Heat Pump (Oil Full Displacement)	Ton	-	-1,238	16.6	-
Mini-Split Heat Pump (Natural Gas/Propane Partial Displacement)	Ton	163	-960	-	16.3
Mini-Split Heat Pump (Oil Partial Displacement)	Ton	-	-961	15.9	-
Mini-Split Heat Pump (Electric Heat Full Displacement)	Ton	-	2,547	-	-

[20] Associated with insulation for natural gas/oil/propane heated homes.
[21] Associated with air sealing for natural gas/oil/propane heated homes.

Measure	Unit	Natural Gas (therms)	Electric (kWh)	Oil (MMBtu)	Propane (MMBtu)
Mini-Split Heat Pump (Natural Gas/Propane Full Displacement)	Ton	175	-1,206	-	17.5
Mini-Split Heat Pump (Oil Full Displacement)	Ton	-	-1,208	17.1	-
Pipe Wrap (Space Heating)	Linear ft	0.2	-	0.03	-
Programmable Thermostat	Thermostat	13	276	1.3	1.3
Wi-Fi Thermostat Heating Savings	Thermostat	15		1.7	1.5
Wi-Fi Thermostat AC Only	Thermostat	-	20	-	-
Duct Insulation	Dwelling unit	0.3	49	0.03	0.03
Duct Sealing	Dwelling unit	0.2	23	0.02	0.02
PROCESS					
Refrigerator Replacement	Refrigerator	-	390	-	-
Freezer Replacement	Freezer	-	713	-	-
Appliance Removal	Refrigerator or Freezer	-	968	-	-
HOT WATER					
Low-Flow Showerhead	Showerhead	11	204	1.2	1.1
Low-Flow Showerhead with Thermostatic Valve	Showerhead	15	266	1.5	1.5
Thermostatic Shut-off Valve	Valve	4.7	85	0.5	10.5
Faucet Aerator	Aerator	2	42	0.2	0.2
Pipe Wrap (Water Heating)	Linear ft	0.6	9	0.07	0.06
Indirect Water Heater	Water Heater	71	-	-	7.1
On Demand/Tankless Water Heater	Water Heater	42	-	4.2	4.2
Stand Alone Water Heater	Water Heater	38	-	3.8	3.8
MOTORS/DRIVES					
Variable Frequency Drive	VFD	-	392	-	-
REFRIGERATION					
Vending Misers	Vending Miser	-	1,612	-	-
PLUG LOAD					
Smart Strip	Smart Strip	-	105	-	-

Source: Cadeo analysis

Building Simulation
Engineering Adjusted Building Simulation
Engineering Algorithm
Vendor Calculated
Heat Pump Metering Study

4. Key Findings – Weatherization

Because nearly half of all RCD MF gross energy savings in 2021 come from air sealing and insulation (as well as roughly a third of IE MF savings), the first key findings section focuses on weatherization.

As discussed in greater detail in Appendix A, the evaluation team attempted a billing analysis to estimate savings for weatherized buildings and dwelling units. However, the various model specifications used by the team did not achieve the pre-determined level of statistical significance (better than ±20% precision at the 90% confidence level) for use to officially report savings. The primary reasons for the low precision and reliability of MF billing analysis results include:

- **Heterogeneous MF building stock**. Unlike SF buildings, which tend to be generally similar in size and design, MF building construction vary widely (small/large, low-rise/high-rise, common area/no common area, mixed use construction/dedicated housing).[22] These differences add variability for the model to interpret that result in greater uncertainty and worse statistical precision.

- **Inconsistent tracking of individual accounts to participating buildings.** The evaluation team's primary dataset for the RCD and IE MF billing analysis (the DNV data) did not differentiate between accounts that represented entire buildings or individual tenant units. The team assigned the accounts into one of these categories based on report annual usage, but the lack of certainty about what an account represented, as well as which accounts were associated with each other, added uncertainty to the billing analysis.[23]

- **Less participants.** The total volume of weatherization participants in IE MF is smaller (relative to RCD MF), which results in smaller sample sizes for the billing analysis and, in turn, lower model precision and less reliable results.

As a result, the team used building simulation to evaluate savings for participants that weatherized their dwelling units. The following four subsections describe the evaluations team's building simulation methodology, and the evaluation results for weatherization participants that heat their dwelling units with natural gas, electricity, heating oil, and propane.

[22] To combat this variation, the team also ran dedicated models for various subsets of participating MF buildings (grouped based on their known building characteristics or observed annual energy consumption). However, these models also did not return statistically significant results.

[23] The team leveraged existing MF account mappings (completed as part of the PAs' recent MF Census studies) as part of this analysis.

4.1 Building Simulation Methodology

The evaluation used two building simulation tools—National Renewable Energy Laboratory (NREL) ResStock and BuildStockBatch—to evaluate the savings associated with weatherization installed in MF buildings through RCD and IE.[24]

Modeling MF buildings is different than modeling SF buildings, particularly SF detached homes. Successfully modeling changes in MF consumption, especially for individual tenant dwelling unit (how the PAs track and claim weatherization saving), requires an approach that accounts for the wide variations in orientation, exposure, and floor area inherent in MF buildings.

In other words, the approach needs to account for the location of a given dwelling unit within the entire weatherized building, which was not available within the RCD or IE MF tracking data. Even if this information was available, there are numerous locations and orientations of dwelling units and MF buildings exist in many shapes and sizes. This makes the standard energy modeling approach —create a set of representative homes—impractical.

To overcome this problem, the evaluation team turned to ResStock, a robust and highly granular resource for modeling buildings across the country. ResStock is well suited for this task as it relies on data-driven building characteristic probabilities to generate dwelling unit model's representative of specific regions (including Massachusetts), building types, and occupant characteristics (including income). This approach accounts for the variation seen in MF buildings. The pool of available customers included presents a sample of MF units with different orientations, exposures, and floor areas.

The team's building simulation-based methodology included the following steps:

- **Baseline Model Selection.** Leveraged BuildStockBatch's building characteristic sampling functionality to select 1,800 unique dwelling unit baseline models with building characteristics representative of MF units in MA. Monthly energy consumption was simulated for all dwelling unit models and was then matched to participant billing data in the next step.

- **Account Matching.** Matched participating MF RCD and IE accounts to dwelling unit baseline models based on the best fit using each account's disaggregated and weather normalized billing data.

- **Measure Modeling.** Ran simulations for each measure on over 1,300 matched dwelling unit models using updated building envelope input values to reflect post- RCD and IE weatherized building characteristics.

- **Weighting and Normalizing Results.** Weight to each dwelling unit model to find the average normalized annual energy end use savings for each MF RCD and IE weatherization measure.

[24] As discussed in greater detail in Appendix A, the evaluation team also attempted a billing analysis to estimate savings for weatherization (in natural gas and electrically heated MF buildings and units. However, the team's various model specifications did not achieve the pre-determined level of statistical significance (better than ±20% precision at the 90% confidence level) for use to officially report savings

4.1.1 Baseline Model Selection

First, the team created a list of building characteristics that reflected the buildings in the participant population. The team used BuildStockBatch's building characteristic sampling functionality, which enabled the team to filter and select a subset of ResStock's building models that are the most relevant MF buildings for this analysis based on specific criteria. The team defined the filtering criteria—summarized in Table 5—using available program data and participation requirements.

Table 5. ResStock Building Characteristics Filtering Criteria

Characteristic	RCD	IE
Location	MA	MA
Stories	3+	3+
Income level[25]	More than 300% of Federal Poverty Level (FPL)[26]	300% or less of FPL[26]
Wall insulation levels	R-11 or less	R-11 or less
Ceiling insulation levels	Less than R-38	Less than R-38
Floor insulation levels	Less than R-30	Less than R-30

Source: ResStock and Cadeo analysis

Using these sampling criteria, the team used BuildStockBatch to select 818 RCD and 982 IE dwelling unit models.[27] Next, the team used these dwelling unit models to simulate monthly energy consumption for each unique dwelling unit model using TMYx data from 2007-2021 for Worcester, Massachusetts. The team used the simulated monthly consumption from these dwelling unit models to complete the account matching discussed in the next section.

4.1.2 Account Matching

The team used a multistep matching process, described below, to assign each RCD and IE participant's account to the baseline dwelling unit model(s) that most closely reflects the participant's weather normalized consumption patterns.[28] After the team completed the matching process, only 714 of the original 818 RCD models and 672 or the original 982 IE models were kept as representative baseline models. Table 6 summarizes the weighted average building characteristics of these baseline models.

[25] Data derived from the 2013 American Housing Survey (AHS), the 2015 American Community Survey (ACS) 5-year tables (with 2011 data removed), and the 2015 ACS Public Use Microdata Sample (PUMS). https://data.nrel.gov/system/files/113/README.rtf

[26] The evaluation team used the threshold of "more than" or "less than" 300% of FPL to filter the ResStock building models to limit the number of models available for billing data matching. The evaluation team did not intent them to be an exact match to the IE MF program requirement.

[27] Each unique dwelling unit model represents a different combination of available building characteristics. Characteristics that vary include, but are not limited to, heating and cooling equipment efficiency and fuel type, plug loads, kitchen equipment, lighting, etc.

[28] Participants' billing data was weather normalized based on HDD and CDD calculated using the same weather data used in the model simulations

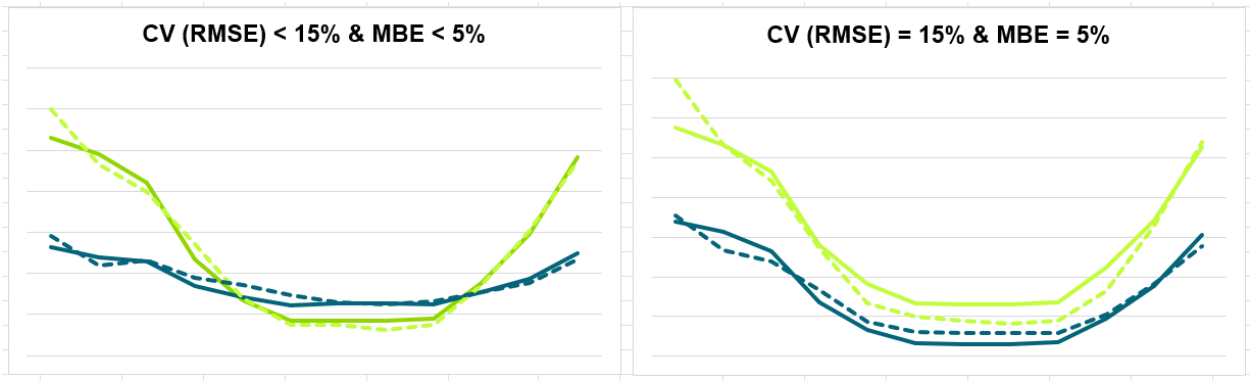
Table 6. Weighted Average Baseline Model Characteristics

Characteristic	RCD	IE
Wall insulation, effective R	6.0	5.9
Attic insulation, effective R	14.4	14.0
Floor insulation, effective R	5.3	4.6
Air sealing, ACH50	20.3	20.6
Duct leakage	2.1%	3.5%
Duct insulation	0.05	0

Source: ResStock and Cadeo analysis

The first step in the matching process was to use weather normalized billing data and simulated consumption data to calculate the Coefficient of Variation of Root Mean Squared Error CV (RMSE) and Mean Bias Error (MBE) for every combination of bill and modeled data. The second step was to use the following criteria to assign each participant account to every dwelling unit model: CV(RMSE) less than 15% and MBE less than 5% for a given billing data set to the associated participant.[29] Figure 4 provides an example of modeled to billing data alignment using ASHRAE Guideline-14.

Figure 4. Example Model Alignment to ASHRAE Guideline-14

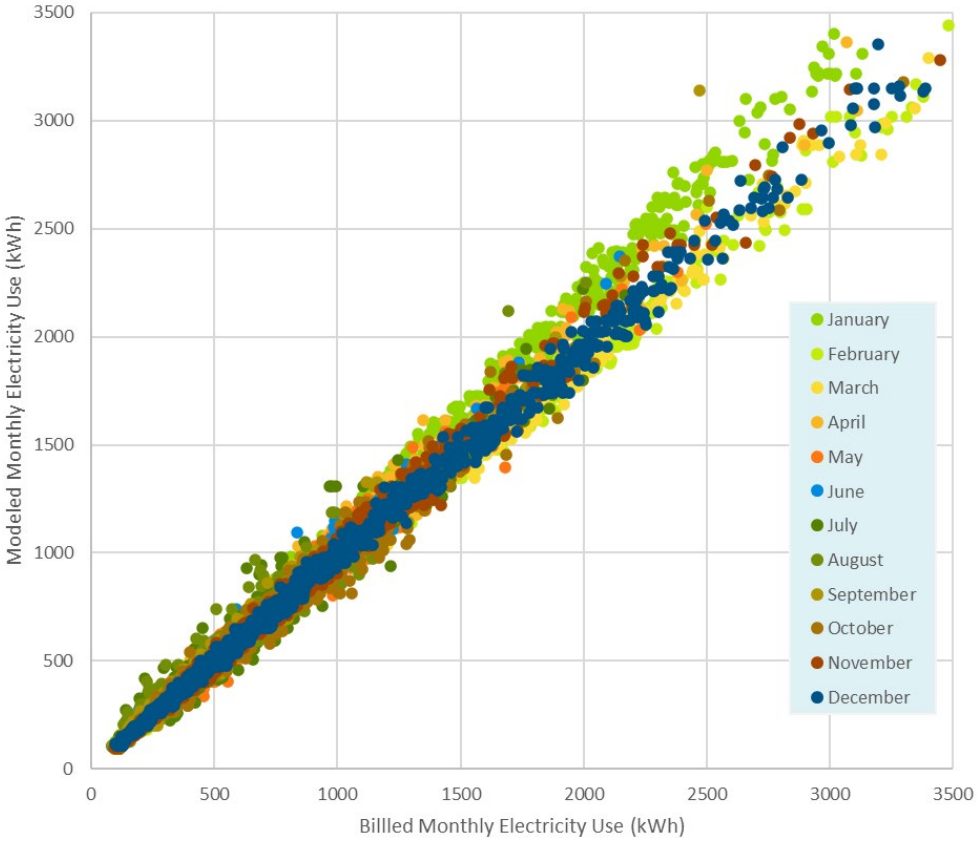


Source: ResStock and Cadeo analysis

Figure 5 and Figure 6 compare the monthly billed usage for MF RCD participant accounts with their matched baseline modeled usage for electricity and natural gas, respectively. Matched baseline models were models that met ASHRAE Guideline-14 thresholds. A perfect match between modeled data and normalized bill data would be 45 degrees. As seen in both Figure 5 and Figure 6, the data falls close to 45 degrees, which signifies, on average, a strong match profile for most participants.

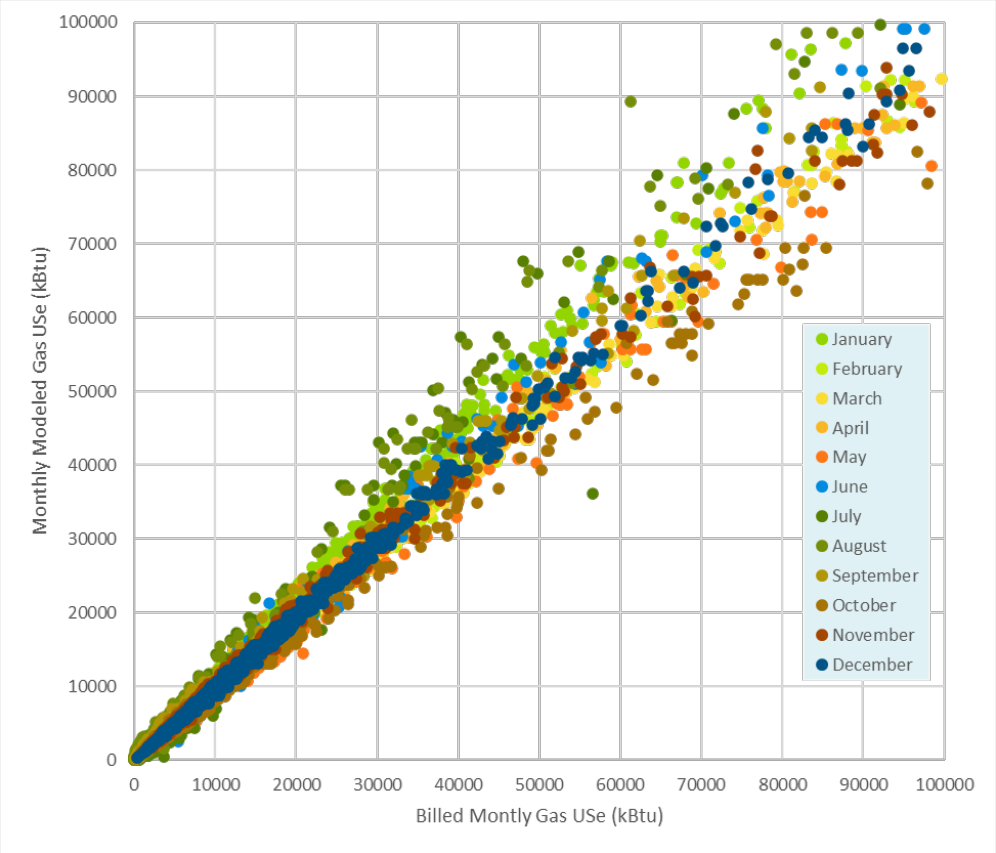
[29] CV(RMSE) and MBE thresholds align with AHSRAE Guideline-14.

Figure 5. RCD Monthly Electricity Use, Billed vs. Modeled



Source: Cadeo analysis

Figure 6. RCD Monthly Gas Use, Billed vs. Modeled



Source: Cadeo analysis

In cases where CV(RMSE) was greater than 15% or MBE was greater than 5%, the team completed additional analysis to identify a dwelling unit model for the participant account. The additional analysis found that in some cases weather normalized billing data was significantly higher than any simulated usage. In those cases, the team assumed that those participant accounts represent billing data for a whole building or multiple dwelling units. The team's simulated data is based on single dwelling unit models rather than whole building models. To adjust for assumed whole building accounts, the team scaled the simulated single dwelling unit consumption based on the ratio of annual normalized billed consumption to annual simulated consumption.[30] After scaling the simulated consumption, the team recalculated the CV(RMSE) and MBE using the scaled simulated consumption and assigned participant accounts using the lowest CV(RMSE) and MBE.

Collectively, these two matching steps resulted in over 90% of participant accounts in both initiatives matching to at least one dwelling unit model meeting the selection criteria discussed earlier. In cases where the team could not match a participant using the above criteria, the team matched the participant account to the dwelling unit model with the lowest CV(RMSE).

[30] The team did not need to scale many electric participant accounts, whereas gas participant accounts often required scaling, which is consistent with the whole building single meters for gas and tenant or dwelling unit submetering for electricity.

4.1.3 Efficient Model Development

The team developed post-weatherization building characteristics (measure model inputs) leveraging program data (when available) or TRM default values or values from previous analyses (when program data were unavailable). Table 7 summarizes the measure model input values and sources for RCD MF and IE MF weatherization measures. The team then used the dwelling unit models to map to at least one participant account and ran each measure resulting in a total of seven simulations per dwelling unit model (one baseline and six measures).

Table 7. Efficient Model Input Values

Input	RCD Value	IE Value	Source
Post-measure floor insulation, effective R-value	R17	R27	Program Data[31]
Post-measure wall insulation, effective R-value	R16	R12	Program Data[32]
Post-measure attic insulation, effective R-value	R32	R32	Program Data[33]
Air Sealing	ACH reduction of 20%	ACH reduction of 20%	TRM default assumptions[34]
Duct sealing	Leakage reduction of 50%	Leakage reduction of 50%	Engineering judgement
Post-measure duct insulation	R4	R4	Previous Massachusetts MF impact analyses

Source: Cadeo analysis

4.1.4 Weighting and Normalizing Simulation Results

After completing all the simulations, the team extracted the following key model output from each simulation (one baseline and six measures):

- Annual electricity used for heating

[31] The team determined insulation added for each shell measure and calculated a weighted average based on program data quantities.

[32] ibid

[33] ibid

[34] Massachusetts Technical Reference Manual 2024 Prospective Version, RCD measure *1.9 Building Shell – Air Sealing* and IE measure *2.8 Building Shell - Air Sealing - IE Multi-Family* use the same baseline and efficient case assumptions. Baseline will typically be a default value of a baseline/pre-retrofit ACH =0.5 and high efficiency will typically be a default value of a post-retrofit ACH =0.4.

- Annual electricity used for cooling
- Annual electricity used for fans during heating
- Annual electricity used for fans during cooling
- Annual gas used for heating
- Annual whole building gas use
- Annual whole building electricity use

For each dwelling unit model, the team calculated annual energy end-use savings for all six measure simulations and then normalized the measure savings for each dwelling unit model using the following model input assumptions:[35]

- Ground floor area for normalizing floor insulation savings
- Exterior wall area for normalizing wall insulation savings
- Exterior roof area for normalizing attic/roof insulation savings
- Conditioned floor area for normalizing air sealing savings
- Duct surface area exposed to unconditioned space for normalizing duct insulation and sealing savings

The team applied a weight to each dwelling unit model to find the average normalized annual energy end use savings for each MF RCD and IE weatherization measure.[36] The team then calculated program savings using the weighted average normalized savings (savings per sq. ft.) multiplied by the weighted average project area (e.g., sq. ft. of duct surface area) for each measure. When possible, the team used program data to determine project area, but when the data was not available, the team used modeled data.

4.2 Natural Gas

4.2.1 Results

Table 8 and Table 9 summarize the results of the team's building simulation modeling of weatherization RCD and IE MF participants, respectfully, that heat their dwelling units with natural gas. These results are based on the post-RCD and post-IE building envelope measure details in the DNV program data to the baseline dwelling unit models matched to the participant accounts. The evaluation team validated the building simulation results using a building level consumption data analysis. Additional details on this analysis are included in Appendix A.3

[35] (Baseline Energy End use – Measure Energy End Use) / measure specific sq. ft. per dwelling unit

[36] First, the team weighted model(s) matched to an account number. For example, if participant account XYZ mapped to 10 dwelling unit models, the team would weight each match as 0.1 for the participant account XYZ. Next, the team factored in the dwelling unit model scaler used during the matching process. The team used the scalers in the matching process as a proxy for the number of units represented by the billing data (participant account). This step was necessary due to the mix of unit-level and building-level data in the program data. In cases where the scalar was greater than one, for example, if dwelling unit model ABC had a scalar of 5 when mapped to participant account XYZ, the total weight for that dwelling unit model/participant account match would be 0.5. The final weight for each model was the sum of all the dwelling unit model/participant account weights for a given dwelling unit model

4.2.1.1 RCD

As part of the billing data disaggregation, the evaluation team determined that weatherized RCD participants (i.e., participants had their unit air sealed and/or insulated) used an average of 375 therms to annually *heat* their units before participating. Therefore, statewide savings of 61 therms/year (air sealing) and 50 therms/year (insulation) mean that a participant receiving each measure would save on average, 16% and 13% of their pre-program weather normalized annual heating consumption.

Per the DNV program data, the average RCD MF participant that received any insulation installed 1.39 different types of insulation: 85% attic insulation, 10% basement/floor insulation, and 44% wall insulation.[37] The team modeled these insulation types separately and used the reported installation type percentages to develop the initiative overall average insulation savings.

[37] The evaluation team developed percentages by combining natural gas and electric participants to increase sample size.

Table 8. RCD Evaluated Weatherization Savings - Natural Gas

Measure	Evaluated Savings (therms/year)					Percentage of Insulation Participants Receiving Insulation in Each Location				
	Statewide	National Grid	Eversource	EGMA	Berkshire Gas Liberty Utilities, and Unitil	Statewide	National Grid	Eversource*	EGMA	Berkshire Gas, Liberty Utilities, and Unitil*
N (Weatherization Participants)	**3,806**	3,175	183	384	64					
• Air Sealing	**61**	65	70	36	71					
• Insulation	**50**	55	51	21	53					
○ Attic Insulation	**17**	17	18	12	17	85%	86%	85%	90%	85%
○ Basement/Floor Insulation	**4**	4	5	2	4	10%	8%	10%	20%	10%
○ Wall Insulation	**79**	83	80	65	86	44%	49%	44%	15%	44%

*Data provided for these PAs did not breakout insulation measure by installation location; therefore, the percentages used for weighting insulation savings leverage statewide percentages.

Source: Cadeo analysis

4.2.1.2 IE

For IE, the team's bill disaggregation analysis found the average weatherization participant used 363 therms/year prior to participation in the program, slightly less than the RCD average. Statewide savings for IE of 62 therms (air sealing) and 42 therms (insulation) mean that a participant receiving each measure would save on average, 17% and 12% of their pre-program weather normalized annual heating consumption.

Unlike the RCD MF weatherization participants, the IE MF weatherization participants installed attic insulation far more frequently than any other type of insulation. Per the DNV program data, the average IE MF participant that received any insulation installed 1.1 different types of insulation: 97% attic insulation, 3% basement/floor insulation, and 10% wall insulation. As with the RCD modeling, the team modeled these insulation types separately and used the reported installation type percentages to develop the initiative overall average insulation savings.

Table 9. IE Evaluated Weatherization Savings – Natural Gas

Measure	Evaluated Savings (therms/year)					Percentage of Insulation Participants Receiving Insulation in Each Location				
	Statewide	National Grid	Eversource	EGMA	Berkshire Gas Liberty Utilities, and Unitil	Statewide	National Grid	Eversource*	EGMA	Berkshire Gas, Liberty Utilities, and Unitil*
N (Weatherization Participants)	1,022	220	147	655	0					
• Air Sealing	62	66	71	60	N/A					
• Insulation	42	43	49	40	N/A					
○ Attic Insulation	37	39	44	36	N/A	97%	96%	97%	97%	N/A
○ Basement/Floor Insulation	39	28	35	40	N/A	3%	1%	3%	3%	N/A
○ Wall Insulation	53	56	54	53	N/A	10%	8%	10%	7%	N/A

*Data provided for these PAs did not breakout insulation measure by installation location; therefore, the percentages used for weighting insulation savings leverage statewide percentages.

Source: Cadeo analysis

4.2.2 Validation

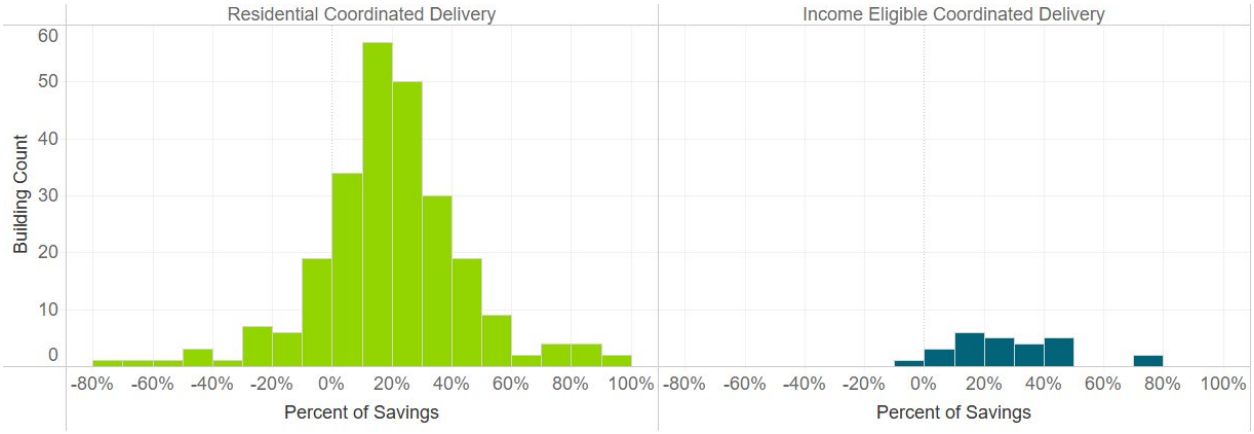
To validate the building simulation results, the team conducted a comparative consumption analysis that compared 2021 participant's building level annual consumption in 2020 (the year prior to participating in IE MF or RCD MF) and 2022 (the year after participating). To account for weather differences, the team normalized the observed yearly consumption in the post period (2022) based on the difference in HDD that occurred in 2020.

It is important to note that this analysis does not follow the team's preferred approach of conducting a quasi-experimental study with a known control group. (For more information on the team's attempts to conduct such modeling, see Appendix A.) However, this method does shed light on an important and fundamental question: Do the buildings that participate in IE MF and RCD MF demonstrate – on average – a decrease in energy consumption that is generally consistent with the savings modeled using building simulation?

Figure 7 includes histograms (RCD MF on the left, IE MF on the right) showing the percentage of pre-initiative annual consumption saved for participating buildings that received weatherization measures (i.e., air sealing and/or insulation). To focus on the impact of weatherization measures, the team excluded buildings from the comparative analysis that received major heating or cooling upgrades (e.g., heat pump installation, boiler replacement, etc.).[38]

As shown below, the histograms offer insights into the general direction and magnitude of air sealing and insulation savings. Both RCD MF (17%, n= 254) and IE SF (29%, n=26) demonstrated savings for the average participating building.

Figure 7. Observed Percent of Savings Histogram for RCD and IE Natural Gas Buildings Receiving Weatherization Measures



Source: Cadeo analysis

Again, this comparative analysis differs from a traditional billing analysis – namely that it does not include a control group that would account for non-initiative factors on the observed change

[38] Tenants in these building may have still received other non-mechanical efficiency measures through the initiatives, such as faucet aerators or showerheads.

in energy consumption. These factors include, but are not limited to, economic factors, rate changes, occupancy changes, and – for this particular window of time – COVID-19.

To create as close to an apples-to-apples comparison between this analysis and the building simulation, the team used building simulation results for air sealing and insulation, along with the percentage of participants that installed each of them, to evaluated weatherization savings. As shown in Table 10 and Table 11, the average weatherized dwelling units saved 16% of pre-initiative natural gas consumption.

Table 10. RCD Building Simulation Weatherization Percent Savings per Dwelling Unit

Measure	Evaluated Savings (therms/year)	Percent of Weatherization Participants that Received the Measure	Average Dwelling Unit Natural Gas Consumption	Building Simulation Weatherization Percent Savings
Weatherization	**88**	**N/A**	**545**	**16%**
• Air Sealing	61	78%	N/A	N/A
• Insulation	50	81%	N/A	N/A

Source: Cadeo analysis

Table 11. IE Building Simulation Weatherization Percent Savings per Dwelling Unit

Measure	Evaluated Savings (therms/year)	Percent of Weatherization Participants that Received the Measure	Average Dwelling Unit Natural Gas Consumption	Building Simulation Weatherization Percent Savings
Weatherization	**78**	**N/A**	**478**	**16%**
• Air Sealing	62	99%	N/A	N/A
• Insulation	42	39%	N/A	N/A

Source: Cadeo analysis

Viewing this analysis as a validation exercise for the building simulation results (versus a definitive estimation of actual savings), this method does show the energy savings in most participating buildings at a level that generally aligns with the building simulation findings as summarized in Table 12. (Please note the low sample size for IE MF means that value is less reliable.) Also, the higher percent savings produced by the comparative analysis are expected since the building simulation only modeled the weatherization measures (i.e., air sealing and insulation) while the comparative analysis captures the impact of other efficiency improvements (e.g., low flow shower heads, aerators, etc.).

In summary, the results of building level comparative usage analysis, while imperfect, substantiate the building simulation's dwelling unit savings and suggest the modeled values are reasonable.

Table 12. Comparison of Billing Analysis and Building Simulation Percent Savings

	Billing Analysis (% Savings/Building)	Building Simulation (% Savings/Unit)
RCD (n=252)	17%	16%
IE (n=23)	27%	16%

Source: Cadeo analysis

4.2.3 Gross Realization Rates

The PAs determine savings for vendor-calculated measures, including air sealing and insulation, by applying evaluation-based gross realization rates to the gross savings reported by their LVs.

Gross realization rates are ratios that explain the relationship between evaluated and reported savings. Calculating the gross realization rate for any given measure requires two inputs: average evaluated savings for that measure (the calculation's numerator) and average reported savings for the same measure (the denominator).

In Section 4.2.1, the team summarized the evaluated savings for air sealing and insulation by PA. The team used two approaches to develop corresponding reported savings to inform the other half of the gross realization rate calculation:

1. **Summarizing Tracking Data.** The data provided by DNV included reported savings for each measure and account, as well as the PA that served that account. With this information, the team should, in theory, be able to calculate the average reported air sealing and insulation savings by PA. However, since the account-level tracking data reflects a mix of dwelling unit and whole building records, the team first needed to convert the whole building accounts (with whole building savings) into unit-level savings for comparison with the building simulation results. Unfortunately, the unit counts contained in the tracking data reflected the number of total units in the MF building, which isn't always the number of units in the building that received air sealing or insulation. (This is particularly true for RCD MF.) Due to the mix of reported savings at the unit and whole building levels – and incomplete information about the number of units treated – the evaluation team was unable to develop sufficiently reliable unit-level reported savings using the tracking data.

2. **Aggregated Reporting Data.** Since the participant tracking data could not support the gross realization rate calculation, the team tried using aggregated savings data available on MassSaveData.com. The team ran into similar issues trying to use the aggregated data from the site since the participation counts listed were the number of accounts, not units served. As with the tracking data, this prevented the team from calculating unit-level savings for air sealing and insulation.

The team collaborated with the PAs to triage the issues mentioned above and identify reliable, per-unit savings that could inform a gross realization rate calculation. Unfortunately, the evaluation team and PAs were unable to identify a source.

However, when the team compared the evaluated per-unit air sealing and insulation savings to both imperfect reported savings estimates from the tracking and aggregated reporting data, as well as the per-unit savings in the most recent BCR models, we found that the evaluated savings were always higher.

For this reason – and because the team's billing analysis validated the building simulation results – the team is confident current per unit savings claimed by the PAs are conservative estimates of the actual energy savings. For that reason, the team recommends the PAs continue to use the existing per-unit savings (varies by PA) and existing gross realization (0.86) for RCD MF air sealing and insulation measures and existing PA-specific gas realization rates for IE MF.

4.2.4 Benchmarking

4.2.4.1 Relative to the Previous Evaluation

The evaluation team reviewed both the Massachusetts Multifamily Program Impact Analysis[39] and the Massachusetts Income Eligible Multifamily Initiative Impact Evaluation[40] reports to identify previous weatherization measure savings. Unfortunately, neither report had natural gas savings data available for comparison to the current results. The evaluation team also reviewed existing BCR model reported savings, which did not contain complete data for comparison purposes.

The Massachusetts Multifamily Program Impact Analysis did not provide statewide savings results due to the variability in documentation and methodology across PAs. Instead, the evaluation provided recommendations for improvements to savings calculation methodologies. Because the team used building simulation to develop weatherization savings, the team is unable to compare the team's methodologies with the proposed methodologies in this evaluation.

The Massachusetts Income Eligible Multifamily Initiative Impact Evaluation provided savings values for Air sealing and Insulation, but only for Electric measures, so the team is unable to compare the team's natural gas results to savings values in this evaluation.

4.2.4.2 Relative to the Other Initiatives

The evaluation team reviewed evaluation reports for states in the New England region including:

- Impact & Process Evaluation, EnergyWise & Income Eligible Multifamily Programs National Grid Rhode Island, 2020[41]
- New York Multifamily Program Evaluation Report, Program Years 2019-20[42]
- CT EEB X1941 Multifamily Impact Evaluation[43]

[39] https://ma-eeac.org/wp-content/uploads/Massachusetts-Multifamily-Program-Impact-Analysis-Report-Appendix.pdf
[40] https://ma-eeac.org/wp-content/uploads/Low-Income-Multifamily-Impact-Evaluation-1.pdf
[41] https://rieermc.ri.gov/wp-content/uploads/2020/10/ng-ri-mf-impact-and-process-comprehensive-report_final_04sept2020.pdf
[42] https://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId=%7B5EC2962D-4BEA-4785-A8B1-88B665615DFB%7D
[43] https://energizect.com/sites/default/files/2022-07/CT%20X1941%20MFFinalReport_072221.pdf

- EVT Program year 2021, 2022 report - verification of EVT savings and TRB[44]

In all cases, the team could not find natural gas savings values for weatherization measures that could be used to benchmark the team's savings values. The reports either did not include weatherization at all or when reports included weatherization, the report did not provide savings values or the savings values were not comparable (e.g., whole program savings instead of per participant savings).

4.3 Electricity

4.3.1 Results

Table 13 and Table 14 summarize the results of the team's building simulation modeling of weatherization RCD and IE MF participants, respectively, that heat their units with electricity. These results are based on applying the post-RCD and post-IE MF building envelope measure details in the DNV program data to the baseline dwelling unit models matched to the billing data. Unlike the natural gas weatherization results summarized in Table 8 and Table 9, which exclusively focused on natural gas heating savings, the electric weatherization savings in Table 13 and Table 14 reflects the full range of electric savings associated with weatherization: heating savings, cooling savings, and savings from reduced furnace fan usage.[45]

As part of the billing disaggregation, the evaluation team determined that weatherized RCD participants (i.e., participants had their unit air sealed and/or insulated) used an average of 10,067 kWh and 7,168 kWh, respectively, to annually heat their units before participating in their respective programs. Variation in dwelling unit size is likely the primary driver of the annual electric heating consumption difference between RCD and IE participants. The team's modeling process estimated that about 53% of RCD MF participants with electric heat live in dwelling units between 750 and 1,500 sq. ft. Whereas, 68% of IE MF participants dwelling units with electric heat are 750 sq. ft. or less. Additional details on the building simulation models are in Appendix B.

As Table 13 shows, RCD MF participants had slightly more of their modeled weatherization savings come from air sealing (1,277 kWh) than from insulation (1,464 kWh). Table 14 highlights that modeled air sealing savings (1,676 kWh) for IE MF are higher than RCD; however, IE insulation savings (1,415 kWh) are similar. These savings mean that an average air sealing participant for these respective programs saved 13% and 20% of their pre-program weather normalized annual heating consumption. Whereas insulation participants saved 17% and 20%. The team's modeling found that across IE MF participants in electrically heated units, improvements in attic insulation generated the most savings out of the three insulation measures.

As discussed in the Natural Gas results section, we found that all our evaluated electric savings were greater than the PA provided reported savings. The team was concerned that the

[44] https://publicservice.vermont.gov/sites/dps/files/documents/EVT%202022%20Savings%20Verification%20Report%20FINAL_2023.07.24.pdf

[45] 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.

comparison of evaluated savings to reported savings may not be an apples-to-apples comparison in all cases as there was some uncertainty that reported quantities do not consistently represent dwelling units serviced. For these reasons, the team recommends the PAs continue to use the existing per-unit savings (varies by PA) and existing gross realization (0.86) for RCD MF air sealing and insulation measures and existing PA-specific electric realization rates for IE MF.

Table 13. RCD Evaluated Weatherization Savings – Electricity

Measure	Evaluated Savings (kWh/year)				Percentage of Insulation Participants Receiving Insulation in Each Location			
	Statewide	National Grid	Eversource	Cape Light Compact, and Unitil	Statewide	Eversource*	EGMA	Cape Light Compact, and Unitil *
N (Weatherization Participants)	1,613	1,280	241	92				
• Air Sealing	1,277	1,297	1,224	1,195				
• Insulation	1,464	1,616	1,337	1,460				
○ Attic Insulation	548	580	432	554	85%	86%	85%	85%
○ Basement/Floor Insulation	129	117	141	137	10%	8%	10%	10%
○ Wall Insulation	2,215	2,275	2,148	2,193	44%	49%	44%	44%

*Data provided for these PAs did not breakout insulation measure by installation location; therefore, the percentages used for weighting insulation savings leverage statewide percentages

Source: Cadeo analysis

Table 14. IE Evaluated Weatherization Savings – Electricity

Measure	Evaluated Savings (kWh/year)				Percentage of Insulation Participants Receiving Insulation in Each Location			
	Statewide	National Grid	Eversource	Cape Light Compact, and Unitil	Statewide	Eversource*	EGMA	Cape Light Compact, and Unitil *
N (Weatherization Participants)	346	277	66	3				
• Air Sealing	1,676	1,590	1,930	2,573				
• Insulation	1,407	1,469	920	1,047				
○ Attic Insulation	1,310	1,416	783	672	97%	96%	97%	97%
○ Basement/Floor Insulation	498	439	585	1,168	3%	1%	3%	3%
○ Wall Insulation	1,222	1,175	1,381	3,530	10%	8%	10%	10%

*Data provided for these PAs did not breakout insulation measure by installation location; therefore, the percentages used for weighting insulation savings leverage statewide percentages

Source: Cadeo analysis

4.3.2 Benchmarking

4.3.2.1 Relative to the Previous Evaluation

As mentioned in the previous natural gas benchmarking section the evaluation team reviewed both the Massachusetts Multifamily Program Impact Analysis[46] and the Massachusetts Income Eligible Multifamily Initiative Impact Evaluation[47] reports to identify previous weatherization measure savings. Unfortunately, only the IE report contained savings values that the team could use for benchmarking results. Table 15 compares the current and previous savings values.

Table 15. IE Benchmarking Weatherization Savings - Electricity

Measure	Past Evaluated Savings (kWh/year)	Evaluated Savings (kWh/year)
Air Sealing	397	1,676
Insulation	1,377	1,415

Source: Cadeo analysis

4.3.2.2 Relative to the Other Initiatives

As discussed in the natural gas benchmarking section the evaluation team reviewed evaluation reports for states in the New England region including:

- Impact & Process Evaluation, EnergyWise & Income Eligible Multifamily Programs Nation Grid Rhode Island, 2020[48]
- Multifamily Program Evaluation Report, Program Years 2019-20[49]
- CT EEB X1941 Multifamily Impact Evaluation[50]
- EVT Program year 2021, 2022 report - verification of EVT savings and TRB[51]

In all cases, the team could not find electric savings values for weatherization measures that could be used to benchmark the team's savings values. Either the reports did not include weatherization at all or when reports included weatherization, the report did not provide savings values or savings values were not comparable (e.g., whole program savings instead of per participant savings).

[46] https://ma-eeac.org/wp-content/uploads/Massachusetts-Multifamily-Program-Impact-Analysis-Report-Appendix.pdf
[47] https://ma-eeac.org/wp-content/uploads/Low-Income-Multifamily-Impact-Evaluation-1.pdf
[48] https://rieermc.ri.gov/wp-content/uploads/2020/10/ng-ri-mf-impact-and-process-comprehe nsive-report_final_04sept2020.pdf
[49] https://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId=%7B5EC2962D-4BEA-4785-A8B1-88B665615DFB%7D
[50] https://energizect.com/sites/default/files/2022-07/CT%20X1941%20MFFinalReport_072221.pdf
[51] https://publicservice.vermont.gov/sites/dps/files/documents/EVT%202022%20Savings%20Verification%20Report%20FINAL_2023.07.24.pdf

4.4 Delivered Fuels – Heating Oil and Propane

The team did not have access to usage data for weatherized RCD MF and IE participants that heat their units with a delivered fuel (i.e., heating oil or propane.) This meant that the team could not use direct information about delivered fuel usage to determine annual pre-program consumption or to undertake a billing analysis to model savings.

Consequently, the team leveraged the natural gas building simulation results – first to estimate the annual pre-program heating consumption for delivered fuel participants and, second to estimate the percent of that consumption they saved after weatherizing their buildings through the RCD and IE MF programs in 2021.

4.4.1 Calculating Annual Pre-Consumption

The team estimated the delivered fuel pre-period heating consumption by adjusting the simulated natural gas pre-period heating consumption (375 therms per RCD MF dwelling unit and 363 therms per IE MF dwelling unit) by two factors: differences in **dwelling unit size** and **equipment efficiencies** between natural gas and delivered fuels participants.

- **Dwelling unit size.** The square footage of a dwelling unit impacts the volume of space that the heating system must heat (i.e., the size of the heating load). Since average dwelling unit sizes can differ by heating fuel type,[52] the team compared the average dwelling unit size for natural gas and delivered fuel heated participants in 2021. As Table 16 shows, RCD MF heating oil fueled dwelling units were smaller on average (704 square feet compared to 1,044 square feet), while propane/other heated dwelling units were larger on average (1,270 square feet). As a result, the team adjusted the observed natural gas pre-program heating consumption when converting it to reflect likely delivered fuel consumption (Table 16). The heating oil fueled dwelling units in the IE program (Table 17) were larger on average compared to natural gas heated dwelling units therefore the team made an upwards adjustment to the observed natural gas pre-program heating consumption to estimate heating oil consumption.

Table 16. Average RCD MF Dwelling Unit Size

Fuel Type	Dwelling Unit Floor Area (SF)[53]	Home Floor Area relative to Natural Gas
Natural Gas	**1,044**	**100%**
Heating Oil	704	67%
Propane/Other	1,270	122%

Source: Cadeo analysis

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

[53] Floor area extracted from combined CLEAResult and RISE program data for RCD dwelling units.

Table 17. Average IE MF Dwelling Unit Size

Fuel Type	Home Floor Area (SF)[54]	Home Floor Area relative to Natural Gas
Natural Gas	**627**	**100%**
Heating Oil	716	114%
Propane/Other	0	N/A

Source: Cadeo analysis

- **Heating equipment efficiency.** For delivered fuel heating equipment, the team reviewed the baseline equipment efficiencies contained within the Residential Baseline Study,[55] and applied derating factors before comparing the efficiencies across equipment types, as shown in Table 18.

Table 18. Equipment Efficiency Comparisons and Assumptions[56]

HVAC Type	Rated Efficiency	Derated Efficiency
Gas/Propane Furnace	80%	79%
Gas/Propane Boiler	82%	74%
Oil Furnace	83%	76%
Oil Boiler	84%	79%

Source: Cadeo analysis

Based on these two adjustments to the observed natural gas consumption, the team estimated 2021 heating oil-heated RCD MF weatherization participants used an average of 25.2 MMTBUs/year of heating oil and IE MF weatherization participants used an average of 41.3 MMBTUs/year to heat their units before they participated in the programs (Table 19, Table 21).

[54] Floor area extracted from National Grid program data for IE dwelling units.

[55] Guidehouse 2020. Residential Baseline Study Phase 4. Available at https://ma-eeac.org/wp-content/uploads/RES-1-Residential-Baseline-Study-Ph4-Comprehensive-Report-2020-04-02.pdf

[56] Multifamily-specific heating oil equipment efficiencies were not available within the Residential Baseline Study, therefore the evaluation team referenced IECC 2018 minimum required efficiencies consistent with the NY TRM v.11 approach.

Table 19. Estimating RCD MF Heating Oil Heating Consumption

Metric	Value	Notes
Natural Gas Heating Consumption (therms/year)	**375**	Based on building simulation analysis; average consumption per dwelling unit
Adjustment Factor #1: Home Size	67%	Heating oil heated dwelling unit are smaller than gas heated dwelling units
Adjustment Factor #2: Equipment Efficiency	99%	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)	**25.2**	

Source: Cadeo analysis

Table 20. Estimating IE MF Heating Oil Heating Consumption

Metric	Value	Notes
Natural Gas Heating Consumption (therms/year)	**363**	Based on building simulation analysis; average consumption per dwelling unit
Adjustment Factor #1: Home Size	114%	Heating oil heated dwelling unit are larger than gas heated dwelling units
Adjustment Factor #2: Equipment Efficiency	99%	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)	**41.3**	

Source: Cadeo analysis

For propane heated RCD MF weatherization participants, the team estimated propane consumption by applying two adjustments to the observed natural gas heating consumption (Table 21).

Table 21. Estimating RCD MF Propane Heating Consumption

Metric	Value	Notes
Natural Gas Heating Consumption (therms/year)	**375**	Based on building simulation analysis; average consumption per dwelling unit
Adjustment Factor #1: Home Size	122%	Propane heated homes are larger than gas heated homes
Fuel Conversion (therms-to-MMBtu)	0.1	
Propane Heating Consumption (MMBtu/year)	**45.6**	

Source: Cadeo analysis

The team did not identify propane heated IE MF weatherization participants in the available data, though there were some instances of unspecified heating fuel type. Therefore, without

information to inform an alternative estimate, the team assumed that if propane participants were present within the unspecified heating type group, the energy consumption would be equivalent to natural gas heated dwelling units, or 36.3 MMBTUs.

4.4.2 Estimating Percent Savings

Not having access to delivered fuel consumption records to determine average annual consumption also meant that the team could not conduct a delivered fuel-specific billing analysis. The team also did not have access to detailed information about the installed insulation characteristics or other pre-program conditions for buildings heated with delivered fuels. To overcome this and estimate how much energy weatherized delivered fuel participants saved, the team had to make an important assumption: holding other factors constant, the weatherized natural gas and delivered fuel participants save the same percentage of their pre-program heating consumption.

4.4.3 Results

The team used this approach to determine that RCD MF participants that use delivered fuels as their primary heating fuel saved 16% and 13%, air sealing and insulation respectively, of pre-participation household delivered fuel heating consumption, or 4.1 MMBTU/year for air sealing and 3.4 MMBTU/year for insulation on average for heating oil heated units and 7.4 MMBTU/year for air sealing and 6.1 MMBTU/year for insulation in propane heated units.

Table 22. Delivered Fuel RCD MF Weatherization Results (2021 Participants)

Measure	Fuel Type	Energy Savings (MMBtu/year)	Percentage of Heating NAC
Air Sealing	Heating Oil	4.1	16%
	Propane	7.4	
Insulation	Heating Oil	3.4	13%
	Propane	6.1	

Source: Cadeo analysis

Similarly, IE MF participants saved 17% and 12%, air sealing and insulation respectively, of pre-participation household delivered fuel heating consumption, or 7.1 MMBtu/year for air sealing and 4.8 MMBTU/year for insulation on average for heating oil heated units and 6.2 MMBtu/year for air sealing and 4.2 MMBTU/year for insulation in propane heated units.

Table 23. Delivered Fuel IE MF Weatherization Results (2021 Participants)

Measure	Fuel Type	Energy Savings (MMBtu/year)	Percentage of Heating NAC
Air Sealing	Heating Oil	7.1	17%
	Propane	6.2	
Insulation	Heating Oil	4.8	12%
	Propane	4.2	

Source: Cadeo analysis

5. Key Findings – Heat Pumps

As previously noted, Guidehouse completed a robust residential heat pump metering study (MA22R51-B-HPMS) in May 2024 on behalf of the Massachusetts PAs and the Sponsors of EnergizeCT. That study, which included metering at over 200 homes across both states, was undertaken in recognition of the essential role heat pumps will play achieving GHG goals in MA, as well as in the region more broadly. More specifically, the Massachusetts PAs (and Sponsors of EnergizeCT) undertook the metering study because of the importance of developing reliable estimates of the net change in energy consumption that results from heat pump installations under a variety of scenarios. The PAs needed this information to establish deemed, per-cooling ton energy impacts for prescriptive heat pump measures installed during the upcoming 2025-2027 cycle. Given the similar objectives of this study (i.e., developing prospectively appropriate savings estimates), the MF evaluation team began to collaborate with MA22R51-B-HPMS metering study team.

The original scope for MA22R51-B-HPMS, finalized in August 2022, focused exclusively on metering heat pumps incentivized through the PAs Retail HVAC initiative. It did not include any IE installed units. While not technically limited to market rate customers (i.e., non-income-eligible customers), the general understanding is that Retail HVAC initiative does not serve IE customers. Rather, IE customers are more likely to receive a heat pump by participating in the IE MF initiative through their local CAP.

Table 24 summarizing the sample of customers included by the multi-state study, including the IE-specific sample added to inform this evaluation. As shown below, the study collected heat pump usage data from Fall 2022 through Winter 2024 at a total of 204 homes (SF and MF) across Massachusetts and Connecticut. The sample included a mix of central heat pumps (CHPs), mini-split heat pumps (MSHPs), and ground source heat pumps (GSHPs) as well as a combination of full and partial displacement scenarios.

Table 24. Onsite Usage Metering

Building Type	System Type	Displacement Scenario	Market Rate Sites Installed in MA	Market Rate Sites Installed in CT	IE Sample Installed MA	Total Sites Installed
SF (Detached and Attached)	Mini-Split Heat Pump	FD	31	16	17	64
		PD	23	8	2	33
	Central Heat Pump	FD	29	9	0	38
		PD	12	25	0	37
	Ground Source Heat Pump	FD	1	25	0	26
MF (5+ units)	Mini-Split Heat Pump	FD	4	0	0	4

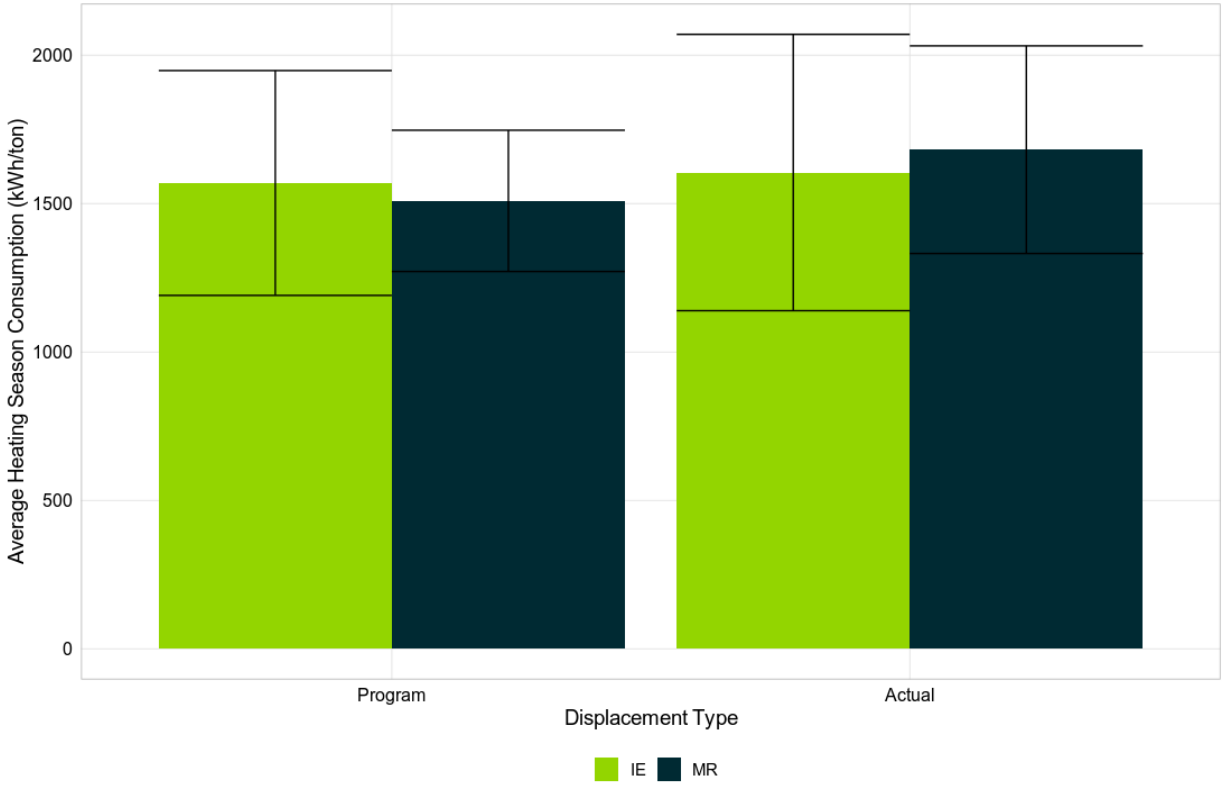
Building Type	System Type	Displacement Scenario	Market Rate Sites Installed in MA	Market Rate Sites Installed in CT	IE Sample Installed MA	Total Sites Installed
	Central Heat Pump	FD	1	1	0	2
Total			**101**	**84**	**19**	**204**

Source: MA22R51-B-HPMS

Leveraging results from fourteen[57] of the IE sites, the team compared average seasonal energy consumption for IE and non-IE metered sites. This comparison, illustrated in Figure 8, shows that IE and non-IE metered customers exhibited a very similar average heating season consumption when looking at Program or Actual groupings. Program values group metered data by displacement type listed in the program data. Actual values group metered data by displacement type as confirmed during field visits. The field team confirmed if a site was using their back-up heating system or if the backup heating system was removed/disconnected. As shown below (via the box and whisker plot), usage between IE and non-IE was not statistically different at the 90% confidence level.

[57] Five of the IE sites did not yield usable data.

Figure 8. Market Rate and IE Average Heating Season Consumption Comparison



Source: MA22R51-B-HPMS

Due to this similarity, as well as comparable results between Massachusetts and Connecticut,[58] the MA22R51-B-HPMS study team combined all metered sites (i.e., Massachusetts—both market rate and IE—and Connecticut) to bolster the sample size and generate more robust savings estimates for both states and income levels.

After establishing that it was appropriate to combine datasets, the study developed IE heat pump measures savings using the following methodology:

- Clean and process the metered data.
- Calculate in situ heat pump performance.
- Estimate typical-year heat pump usage with site-specific weather-normalization models.
- Estimate typical-year heat pump energy production using custom-fit models of heat pump performance.
- Estimate typical-year usage of hypothetical baseline heating and cooling systems based on assumed baseline system efficiencies.

[58] Similarly, the MA22R51-B-HPMS study also found no statistical difference between metered sites in Massachusetts and Connecticut.

- Estimate site-level measure impacts (savings) as the aggregate difference between typical year heat pump usage and typical year baseline usage.
- Aggregate site-level impacts to the stratum level (heat pump type and displacement type) and measure level (heat pump type, displacement type, and pre-existing fuel type). This step also uses weights for the baseline equipment types based on participant survey responses.

An important difference when calculating savings for IE heat pumps—relative to non-IE or market rate heat pump participants going through the Retail HVAC initiative—is the baseline system assumptions. For IE, the team used existing unit derated efficiencies for the baseline, which are consistent with the initiative's retrofit direct install delivery model and were agreed upon through a collaboration between the HPMS evaluation team, the PAs, and Energy Efficiency Advisory Council (EEAC) consultants. Table 25 summarizes the rated and derated baselines used to calculate IE measure savings.

Table 25. Baseline HVAC Unit Efficiency Assumptions*

HVAC Type	Existing Unit Efficiency	
	Rated	Derated
Central AC	13.0 *SEER* 12.4 *SEER2* 11.0 *EER*	10.4 *SEER* 9.9 *SEER2* 8.8 *EER*
Window AC	11.0 *CEER*	8.8 *CEER*
Gas Furnace	84.0%	80.0%
Propane Furnace	84.0%	80.0%
Oil Furnace	85.0%	81.0%
Gas Boiler	83.0%	75.0%
Propane Boiler	83.0%	75.0%
Oil Boiler	85.0%	77.0%
Electric Resistance	3.41 *HSPF*	3.41 *HSPF*

*SEER2 estimated as SEER/1.05, HSPF2 estimated as HSPF/1.17

Source: Massachusetts Residential Building Use and Equipment Characterization Study (2023), evaluation team analysis

Using the information above, the MA22R51-B-HPMS study team developed the deemed, per-ton savings for the program (Table 26) and actual displacement (Table 27) scenarios for all IE SF heat pumps. The study team determined that SF savings would be applied as is to MF measure.

Table 26. Deemed Annual Energy Impacts (Per Ton)

Heat Pump and Displacement Type	Pre-Existing Fuel	BCR Measure ID	Measure Name	kWh Electric Savings	MMBtu Fuel Savings	Average Installed Tonnage (Cooling)	Sites Included in Rollup (n)
Central Heat Pump - FD	Natural Gas	GB1a064	Central Heat Pump fully displacing Gas Heat (Multifamily)	-1,303	15.5	3.7	36
	Oil	EB1a297	Central Heat Pump fully displacing Oil Heat (Multifamily)	-1,293	16.6		
	Propane	EB1a298	Central Heat Pump fully displacing Propane Heat (Multifamily)	-1,303	15.5		
Central Heat Pump - PD	Natural Gas	GB1a062	Central Heat Pump partially displacing Gas Heat (Multifamily)	-839	9.8	4.4	32
	Oil	EB1a293	Central Heat Pump partially displacing Oil Heat (Multifamily)	-832	10.5		
	Propane	EB1a294	Central Heat Pump partially displacing Propane Heat (Multifamily)	-839	9.8		
Mini-Split Heat Pump - FD	Electric	EB1a292	MSHP displacing Electric Heat (Multifamily)	2,752	0	3.5	46
	Natural Gas	GB1a065	MSHP fully displacing Gas Heat (Multifamily)	-1,256	18.7		
	Oil	EB1a299	MSHP Fully Displacing Oil Heat (Multifamily)	-1,258	18.3		
	Propane	EB1a300	MSHP Fully Displacing Propane Heat (Multifamily)	-1,256	18.7		
Mini-Split Heat Pump - PD	Natural Gas	GB1a063	MSHP partially displacing Gas Heat (Multifamily)	-960	16.3	3.0	33
	Oil	EB1a295	MSHP partially displacing Oil Heat (Multifamily)	-961	15.9		
	Propane	EB1a296	MSHP partially displacing Propane Heat (Multifamily)	-960	16.3		

Based on full metered sample and program data designation of displacement type

Source: Guidehouse analysis, results are normalized using TMYx typical weather spanning the years of (2007-2021)

Table 27. Deemed Annual Energy Impacts (Per Ton) – Remove Heat Pump Baseline Weights, Remove/Disconnect Pre-Existing Heat for FD

Heat Pump and Displacement Type	Pre-Existing Fuel	BCR Measure ID	Measure Name	kWh Electric Savings	MMBtu Fuel Savings	Average Installed Tonnage (Cooling)	Sites Included in Rollup (n)
Central Heat Pump - FD	Natural Gas	GB1a064	Central Heat Pump fully displacing Gas Heat (Multifamily)	-1,249	15.5	3.8	14
	Oil	EB1a297	Central Heat Pump fully displacing Oil Heat (Multifamily)	-1,238	16.6		
	Propane	EB1a298	Central Heat Pump fully displacing Propane Heat (Multifamily)	-1,249	15.5		
Central Heat Pump - PD	Natural Gas	GB1a062	Central Heat Pump partially displacing Gas Heat (Multifamily)	-839	9.8	4.4	32
	Oil	EB1a293	Central Heat Pump partially displacing Oil Heat (Multifamily)	-832	10.5		
	Propane	EB1a294	Central Heat Pump partially displacing Propane Heat (Multifamily)	-839	9.8		
Mini-Split Heat Pump - FD	Electric	EB1a292	MSHP displacing Electric Heat (Multifamily)	2,547	0	4.0	12
	Natural Gas	GB1a065	MSHP fully displacing Gas Heat (Multifamily)	-1,206	17.5		
	Oil	EB1a299	MSHP Fully Displacing Oil Heat (Multifamily)	-1,208	17.1		
	Propane	EB1a300	MSHP Fully Displacing Propane Heat (Multifamily)	-1,206	17.5		
Mini-Split Heat Pump - PD	Natural Gas	GB1a063	MSHP partially displacing Gas Heat (Multifamily)	-960	16.3	3.0	33
	Oil	EB1a295	MSHP partially displacing Oil Heat (Multifamily)	-961	15.9		
	Propane	EB1a296	MSHP partially displacing Propane Heat (Single-Family)	-960	16.3		

Based on full metered sample for Partial Displacement, and the subset of Full Displacement installations that removed or disconnected the backup heating system

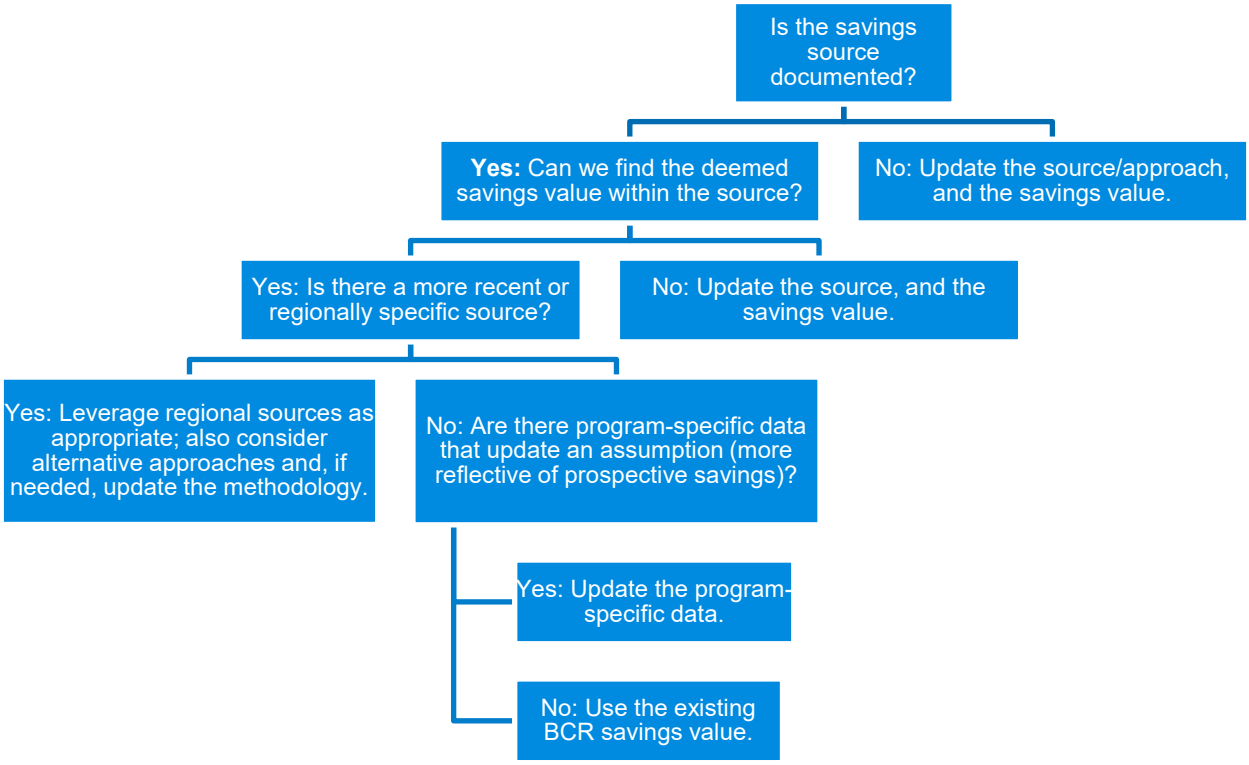
Source: Guidehouse analysis, results are normalized using TMYx typical weather spanning the years of (2007-2021)

6. Key Findings – Other Measures

As noted in the *About This Report* section early in this document, weatherization (RCD and IE) makes up most of the MF gross energy savings across every fuel type. While true, the PAs also incentivize a significant number of other efficiency measures that generate savings and increase comfort alongside these key measures.

The evaluation team followed the process outlined in Figure 9 to assess non-weatherization and non-heat heating system MF prescriptive measures. Applying this framework ensured the team applied a consistent approach across measures when considering updating savings inputs and results.

Figure 9. Measure Evaluation Framework



Source: Cadeo analysis

The next four tables summarize the evaluation team's findings for all non-weatherization and non-heating system measures. Each table includes both this study's evaluated results, the savings value the PAs currently use in their BCR models, and a brief explanation of why these savings may differ. As most of these measures were assessed using an engineering algorithm, the team refers readers to the report's supplementary **Engineering Workbook** for more detail.

Table 28. Evaluated Savings Summary – Other RCD and IE Natural Gas Measures (therms/year)

MF Measure	RCD Existing Savings (therms)	RCD Evaluated Savings (therms)	IE Existing Savings (therms)	IE Evaluated Savings (therms)	Details
Heating System Retrofit, Furnace[59]	N/A	N/A	VC	VC	The team attempted to calculate savings for Heating System Measures using the algorithm specified in the TRM. However, the detailed program data that the team received did not include information on existing equipment size (input capacity) or efficiency. Furthermore, in some instances, the program data categorized the measure activity as custom indicating calculation methodologies outside the scope of this evaluation. In addition, the TRM does not specify default assumptions for the required algorithm inputs, and other sources such as the Residential Baseline study provided minimal information on MF specific information. In absence of more specific data to inform savings calculations, the evaluation team recommends maintaining the existing vendor-calculated/custom savings approach.
Heating System Retrofit, Boiler[59]	N/A	N/A	VC	VC	
Heating System, Commercial Boiler[59]	N/A	N/A	VC	VC	
Boiler Reset Controls	N/A	N/A	VC	VC	Boiler reset controls savings are currently vendor calculated and represent savings per boiler. The team attempted to calculate a deemed savings per dwelling unit using a percent savings applied to the building simulated pre-program heating load per dwelling unit. However, the evaluation team was not able to identify the average assumption for the number of dwelling units served by a boiler, so the resulting savings are not comparable to the existing savings. The evaluation team recommends maintaining the existing vendor-calculated savings approach.
Pipe Wrap (Space Heating)	0.16	0.3	1.14	0.2	Savings for Pipe Wrap for space heating pipes, are calculated using a percent savings (1.5%) applied to the building simulated pre-program heating consumption. The RCD existing savings represent savings per linear foot while the IE existing savings represent savings per dwelling unit. The evaluated savings are calculated per linear foot of piping insulation installed for both RCD and IE.

[59] RCD MF HVAC savings are considered custom measures and were not evaluated in detail for this study.

MF Measure	RCD Existing Savings (therms)	RCD Evaluated Savings (therms)	IE Existing Savings (therms)	IE Evaluated Savings (therms)	Details
Programmable Thermostat	20	12	20	13	The evaluation team's approach leverages the average percent savings results from the 2021 Guidehouse Wi-fi Thermostats study and applies the savings to the building simulated heating and cooling savings from this evaluation.
Wi-Fi Thermostat	28	16	28	1.5	The evaluation team's approach leverages the average percent savings results from the 2021 Guidehouse Wi-fi Thermostats study and applies the savings to the building simulated heating and cooling savings from this evaluation.
Faucet Aerators	9	3	3	2	The team updated MF occupancy information, quantity installed per dwelling unit, and hot water heater efficiency data leveraging Residential Baseline Study results as well as baseline flow using an updated source. Other measure input points did not change. Overall savings values decreased compared to the existing savings for both RCD and IE.
Showerheads	11	10	10	11	The team updated MF occupancy information, quantity installed per dwelling unit, and hot water heater efficiency data leveraging Residential Baseline Study results. Other measure input points did not change. Overall savings values resulted in marginal changes relative to existing savings.
Showerheads with Thermostatic Valve	14	13	14	15	The team updated MF occupancy information, quantity installed per dwelling unit, and hot water heater efficiency data leveraging Residential Baseline Study results. Other measure input points did not change. Overall savings values resulted in marginal changes compared to existing savings.
Pipe Wrap (Water Heating)	11	0.6	11	0.7	The team updated the baseline hot water tank efficiency assumptions to align with current metrics, used Residential Baseline Study results where relevant, and leveraged RCD program data in absence of IE-specific program data for installed pipe length. The existing savings represent savings per dwelling unit, while the evaluated savings represent savings per linear foot of installed insulation.

MF Measure	RCD Existing Savings (therms)	RCD Evaluated Savings (therms)	IE Existing Savings (therms)	IE Evaluated Savings (therms)	Details
Thermostatic Shut-off Valve	3.4	4.2	3.4	4.7	The team updated MF occupancy information and hot water heater efficiency data leveraging Residential Baseline Study results. Other measure input points did not change. Overall savings values resulted in marginal changes compared to existing savings.
Indirect Water Heater	N/A	N/A	VC	71	The evaluation team followed the general algorithmic approach presented in the MA TRM, referencing the Residential Baseline Study for inputs where program data was not available. The team also leveraged the NY TRM for inputs where a MA-specific value was outdated or not available. The resulting savings values provide a savings per dwelling unit, which could be multiplied by the total number of dwelling units served by the water heater and could then be compared to the Existing Savings value (which is vendor calculated).
On Demand Water Heater	N/A	N/A	VC	42	The evaluation team followed the general algorithmic approach presented in the MA TRM, referencing the Residential Baseline Study for inputs where program data was not available. The team also leveraged the NY TRM for inputs where a MA-specific value was outdated or not available. The resulting savings values provide a savings per dwelling unit, which could be multiplied by the total number of dwelling units served by the water heater and could then be compared to the Existing Savings value (which is vendor calculated).
Stand Alone Water Heater	N/A	N/A	VC	38	The evaluation team followed the general algorithmic approach presented in the MA TRM, referencing the Residential Baseline Study for inputs where program data was not available. The team also leveraged the NY TRM for inputs where a MA-specific value was outdated or not available. The resulting savings values provide a savings per dwelling unit, which could be multiplied by the total number of dwelling units served by the water heater and could then be compared to the Existing Savings value (which is vendor calculated).

Source: Cadeo analysis

Table 29. Evaluated Savings Summary – Other RCD and IE Electric Measures (kWh/year)

MF Measure	RCD Existing Savings (kWh)	RCD Evaluated Savings (kWh)	IE Existing Savings (kWh)	IE Evaluated Savings (kWh)	Details
Programmable Thermostat	N/A	N/A	257	276	The evaluation team's approach leverages the average percent savings results from the 2021 Guidehouse Wi-fi Thermostats study and applies the savings to the building simulated heating and cooling savings from this evaluation.
Programmable Thermostat, Electric Resistance, no AC	257	475	N/A	N/A	The evaluation team's approach leverages the average percent savings results (5.5%) from the 2021 Guidehouse Wi-fi Thermostats study and applies the savings to the building simulated heating and cooling savings from this evaluation.
Programmable Thermostat, Electric Resistance, with AC	281	499	N/A	N/A	The evaluation team's approach leverages the average percent savings results from the 2021 Guidehouse Wi-fi Thermostats study and applies the savings to the building simulated heating and cooling savings from this evaluation.
Programmable Thermostat, AC Only	25	24	N/A	N/A	The evaluation team's approach leverages the average percent savings results (5.2%) from the 2021 Guidehouse Wi-fi Thermostats study and applies the savings to the building simulated heating and cooling savings from this evaluation.
Wi-Fi Thermostat, AC only	64	22	64	20	The evaluation team's approach leverages the average percent savings results (5.2%) from the 2021 Guidehouse Wi-fi Thermostats report and applies the savings to the building simulated cooling consumption from this evaluation.
Refrigerator Replacement	N/A	N/A	330	309	The team referenced the Residential Baseline Study for both the existing unit consumption (665 kWh) as well as the newly installed unit consumption (372 kWh). The difference between the two values (293 kWh) was marginally lower than the existing deemed savings.

MF Measure	RCD Existing Savings (kWh)	RCD Evaluated Savings (kWh)	IE Existing Savings (kWh)	IE Evaluated Savings (kWh)	Details
Freezer Replacement	N/A	N/A	158	713	Freezer consumption data was not provided for MF homes in the Residential Baseline Study data, but the study did provide freezer characteristics such as model year and capacity. The team used this information along with other assumptions as inputs to the ENERGY STAR freezer calculator to calculate freezer replacement savings. The resulting savings are greater than the existing deemed savings.
Appliance Removal	N/A	N/A	874	968	The team leveraged the results from the Appliance Recycling 2019 Impact Evaluation (MA 21R33-E-ARI) to calculate the deemed savings, which are slightly higher than the existing deemed savings.
Smart Strips	105	105	105	105	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	97	50	62	42	The team updated MF occupancy information and hot water heater efficiency data leveraging Residential Baseline Study results as well as baseline flow using an updated source. Other measure input points did not change. Overall savings values decreased compared to the existing deemed savings.
Showerheads	129	182	217	204	The team updated MF occupancy information and hot water heater efficiency data leveraging Residential Baseline Study results. Other measure input points did not change. Overall savings values resulted in marginal changes compared to existing savings.
Showerheads with Thermostatic Valve	183	237	335	266	The team updated MF occupancy information and hot water heater efficiency data leveraging Residential Baseline Study results. Other measure input points did not change.
Thermostatic Shut-off Valve	69	76	69	85	The team updated MF occupancy information and hot water heater efficiency data leveraging Residential Baseline Study results. Other measure input points did not change. Overall savings values resulted in marginal changes compared to existing savings.

MF Measure	RCD Existing Savings (kWh)	RCD Evaluated Savings (kWh)	IE Existing Savings (kWh)	IE Evaluated Savings (kWh)	Details
Pipe Wrap (Water Heating)	84	9	129	9	The team updated the baseline hot water tank efficiency assumptions to align with current metrics, used Residential Baseline Study results where relevant, and leveraged RCD program data in absence of IE-specific program data for installed pipe length. The existing savings represent savings per dwelling unit, while the evaluated savings represent savings per linear foot of installed insulation.
Variable Frequency Drive	N/A	N/A	392	392	The team reviewed the existing source referenced in the TRM and compared the input values to detailed adjustable speed drive market model data collected in the Pacific Northwest region. The input values are reasonable assumptions when compared to the market model data and thus the evaluation team recommends maintaining the existing savings value.
Vending Miser	N/A	N/A	1,612	1,612	According to masssavedata.com data, the vending miser measure has not seen program activity since 2016. While the sources listed for this measure are from 2006 and could warrant updating, given the minimal program activity, the evaluation team did not update the savings value. PAs could consider retiring this measure as an active measure in future programs.

Source: Cadeo analysis

Table 30. Evaluated Savings Summary – Other RCD and IE Heating Oil Measures (MMBTUs/year)

MF Measure	RCD Existing Savings (MMBTUs)	RCD Evaluated Savings (MMBTUs)	IE Existing Savings (MMBTUs)	IE Evaluated Savings (MMBTUs)	Details
Pipe Wrap (Space Heating)	0.16	0.03	1.14	0.03	Savings for Pipe Wrap for space heating pipes, like boiler reset controls, are calculated using a percent savings applied to the building simulated pre-program heating load. The RCD existing savings represent savings per linear foot while the IE existing savings represent savings per dwelling unit. The evaluated savings are calculated per linear foot of piping insulation installed for both RCD and IE.
Programmable Thermostats, Heating Savings	2.1	0.9	2.1	1.3	The evaluation team's approach leverages the average percent savings results from the 2021 Guidehouse Wi-fi Thermostats study and applies the savings to the building simulated heating and cooling savings from this evaluation.
Wi-Fi Thermostat, Heating Savings	2.8	1.1	2.8	1.7	The evaluation team's approach leverages the average percent savings results from the 2021 Guidehouse Wi-fi Thermostats study and applies the savings to the building simulated heating and cooling savings from this evaluation.
Faucet Aerators	0.86	0.3	0.28	0.2	The team updated MF occupancy information and hot water heater efficiency data leveraging Residential Baseline Study results as well as baseline flow using an updated source. Other measure input points did not change.
Showerheads	1.1	1.1	1.1	1.2	The team updated MF occupancy information and hot water heater efficiency data leveraging Residential Baseline Study results. Other measure input points did not change.
Showerheads with Thermostatic Valve	1.4	1.4	1.9	1.5	The team updated MF occupancy information and hot water heater efficiency data leveraging Residential Baseline Study results. Other measure input points did not change.

MF Measure	RCD Existing Savings (MMBTUs)	RCD Evaluated Savings (MMBTUs)	IE Existing Savings (MMBTUs)	IE Evaluated Savings (MMBTUs)	Details
Thermostatic Shut-off Valve	0.4	0.4	0.4	0.5	The team updated MF occupancy information and hot water heater efficiency data leveraging Residential Baseline Study results. Other measure input points did not change. Overall savings values saw marginal changes compared to existing savings.
Pipe Wrap (Water Heating)	0.4	0.07	1.1	0.07	The team updated the baseline hot water tank efficiency assumptions to align with current metrics, used Residential Baseline Study results where relevant, and leveraged RCD program data in absence of IE-specific program data for installed pipe length. The existing savings represent savings per dwelling unit, while the evaluated savings represent savings per linear foot of installed insulation.
Tankless Water Heater	N/A	N/A	VC	4.2	Savings align with Natural Gas approach for On Demand Water Heaters: The evaluation team followed the general algorithmic approach presented in the MA TRM, referencing the Residential Baseline Study for inputs where program data was not available. The team also leveraged the NY TRM for inputs where a MA-specific value was outdated or not available.
Stand Alone Water Heater	N/A	N/A	VC	3.8	Savings align with Natural Gas Stand Alone Water Heaters approach: The evaluation team followed the general algorithmic approach presented in the MA TRM, referencing the Residential Baseline Study for inputs where program data was not available. The team also leveraged the NY TRM for inputs where a MA-specific value was outdated or not available.

Source: Cadeo analysis

Table 31. Evaluated Savings Summary – Other RCD and IE Propane Measures (MMBTUs/year)

MF Measure	RCD Existing Savings (MMBTUs)	RCD Evaluated Savings (MMBTUs)	IE Existing Savings (MMBTUs)	IE Evaluated Savings (MMBTUs)	Details
Programmable Thermostat	2.1	1.3	2.1	1.3	The evaluation team's approach leverages the average percent savings results from the 2021 Guidehouse Wi-fi Thermostats study and applies the savings to the building simulated heating and cooling savings from this evaluation.
Wi-Fi Thermostat, Heating Savings	2.8	2.0	2.8	1.5	The evaluation team's approach leverages the average percent savings results from the 2021 Guidehouse Wi-fi Thermostats study and applies the savings to the building simulated heating and cooling savings from this evaluation.
Faucet Aerators	0.9	0.3	0.3	0.2	The team updated MF occupancy information and hot water heater efficiency data leveraging Residential Baseline Study results as well as baseline flow using an updated source. Other measure input points did not change.
Showerheads	1.1	1.0	1.1	1.1	The team updated MF occupancy information and hot water heater efficiency data leveraging Residential Baseline Study results. Other measure input points did not change.
Showerheads with Thermostatic Valve	1.4	1.3	1.7	1.5	The team updated MF occupancy information and hot water heater efficiency data leveraging Residential Baseline Study results. Other measure input points did not change.
Thermostatic Shut-off Valve	0.3	0.4	0.3	0.5	The team updated MF occupancy information and hot water heater efficiency data leveraging Residential Baseline Study results. Other measure input points did not change.
Pipe Wrap (Water Heating)	0.4	0.06	0.4	0.06	The team updated the baseline hot water tank efficiency assumptions to align with current metrics, used Residential Baseline Study results where relevant, and leveraged RCD program data in absence of IE-specific program data for installed pipe length. The existing savings represent savings per dwelling unit, while the evaluated savings represent savings per linear foot of installed insulation.

MF Measure	RCD Existing Savings (MMBTUs)	RCD Evaluated Savings (MMBTUs)	IE Existing Savings (MMBTUs)	IE Evaluated Savings (MMBTUs)	Details
Tankless Water Heater	N/A	N/A	VC	4.2	Savings align with Natural Gas approach for On Demand Water Heaters: The evaluation team followed the general algorithmic approach presented in the MA TRM, referencing the Residential Baseline Study for inputs where program data was not available. The team also leveraged the NY TRM for inputs where a MA-specific value was outdated or not available.
Indirect Water Heater	N/A	N/A	VC	7.1	Savings align with Natural Gas approach for Indirect Water Heaters: The evaluation team followed the general algorithmic approach presented in the MA TRM, referencing the Residential Baseline Study for inputs where program data was not available. The team also leveraged the NY TRM for inputs where a MA-specific value was outdated or not available.
Stand Alone Water Heater	N/A	N/A	VC	3.8	Savings align with Natural Gas Stand Alone Water Heaters approach: The evaluation team followed the general algorithmic approach presented in the MA TRM, referencing the Residential Baseline Study for inputs where program data was not available. The team also leveraged the NY TRM for inputs where a MA-specific value was outdated or not available.

Source: Cadeo analysis

7. IE Custom Measure Process Review

The IE MF program plays a crucial role in delivering energy efficiency services to IE residents across the state. As the program has evolved, custom measures have become an increasingly important component, allowing for tailored solutions that address the unique needs of each MF property.

Custom measures allow for the implementation of energy efficiency solutions that do not fit into standard prescriptive paths with deemed or approved savings algorithms from the MA TRM. MF buildings are often more complex and varied than SF homes, requiring custom engineering approaches to accurately model and calculate savings for non-prescriptive measures.

While other sections of this impact report focus on customers that participated in IE MF or RCD MF in 2021, the evaluation team's review of the custom measure review process reflects how the IE MF initiative delivered custom measures as of April 2024. That is because April 2024 (through August 2024) is when the evaluation team interviewed, as well as gathered documentation from, the PA and CAP stakeholders that lead the IE MF custom measure process. For this reason, this custom measure review offers near-real-time insight into each step of the current process, who is involved, their role, and how they use the current custom measure tools and systems.

7.1 Task Goals

CAPs ABCD and Action deliver the IE MF program on behalf of Eversource and National Grid, respectively. As part of this review, the evaluation team completed individual interviews with CAPs ABCD and Action as well as PAs Eversource and National Grid.

Per discussions with these CAPs and PAs, the team understands that the other PAs—Berkshire Gas, Cape Light Company, Liberty Utilities, and Unitil Gas—follow similar processes as either Eversource or National Grid, albeit at much lower customer volume. Consequently, the findings of this review are also applicable to them. Each CAP and PA uses different processes to develop savings estimates and track information for these custom measures. As a result, the goals of this research include:

- Improve transparency in how custom measure savings are developed.
- Make recommendations, where appropriate, to improve PAs' current processes.
- While maintaining the relevant and intentional differences associated with each PA's process, identify opportunities, and make recommendations, where appropriate, to align or standardize assumptions and inputs across PAs.

The primary outcome of this study is increased confidence in custom measure savings via clear documentation and greater transparency of the custom measure process.

7.2 Stakeholder Interviews

In April 2024, the team began the review with stakeholder interviews to better understand how each organization delivered IE MF custom measures. The team held four interviews, one with each PA and each CAP, with 11 individuals that support the IE MF program. These interviews

also helped identify relevant documentation for the team's process review. Table 32 includes a full list of interviewees.

Table 32. IE MF Interviewees

CAP/PA	Name	Title
ABCD	Olivia Hathaway	Multifamily Program Manager
ABCD	Art Wilcox	Independent Consultant (Energy Savings Modeling)
Eversource	Riley Hastings	Lead Analyst, Energy Efficiency
Eversource	Stephen Cochrane	Analyst, Regulatory and Planning
Eversource	Christopher McClellan	Res Program Supervisor (Market Rate and Income Eligible)
Eversource	Marylene Marcelino	Program Manager, Income Eligible Multifamily
Action	Brian Beote	Director of Energy Efficiency
Action	Colin Heneghan	Heating Systems Specialist
National Grid	Whitney Brougher	Lead Analyst, Product Growth
National Grid	Gianni Figueroa	Engineer, Engineering Project and Program Manager
National Grid	Adam Wirtshafter	Lead Analyst, EM&V

Source: Cadeo analysis

The following section documents the existing process for both CAPs/PAs based on the team's findings.

7.3 Current IE MF Custom Measure Process

IE MF custom measures fall into one of three pathways. Standard energy efficiency custom measures, electrification custom measures, and deep energy retrofit (DER) custom measures.[60] The team's process review focuses on the first pathway, standard energy efficiency custom measures.

The following subsections document the National Grid and Eversource current custom measure review process starting with their LVs, CAPs Action and ABCD, respectively.

1. Project Application
2. Site Assessment/Project Scoping
3. Estimate Project Savings
4. Project Approval

[60] Interviews with program managers also highlighted the growing importance of custom measures in the electrification and DER space. These projects often involve non-traditional equipment replacements, weatherization strategies, and envelope improvements that require site-specific analysis and design. ABCD has taken the lead on providing technical assistance for DER projects, even those in National Grid territory, suggesting a need for greater coordination and knowledge sharing across PAs.

5. Project Implementation
6. Project Submission to PA
7. PA Review/Approval of Payment to LV

Although there are differences in how each PA/LV implements them, all custom projects go through these same steps. For each step, the team starts by providing a summary of the activities that are the same across PAs/LVs followed by tables highlighting key differences between the PA/LV activities, tools, and software. Meaningful differences are noted below. The evaluation team used green text in the tables to identify tools and software used in the process. Table 40 at the end of this section summarizes and provides more detail on each tool and software program mentioned.

Step 1: Project Application

Customers submit project requests through a statewide portal. ABCD acts as statewide intake for the IE MF program and vets the leads to ensure they meet program requirements (e.g., MF, IE). Each LV assigns project requests to their internal team or network of contractors based on project geography and type of measure as well as team/contract bandwidth.

Table 33. Differences Between LVs Step 1: Project Application

LV (PA)	Activities, Tools, and Software
ABCD (Eversource)	• All project requests with Eversource as the heating PA go to ABCD.
Action (National Grid)	• All project requests with National Grid as the heating PA go to Action.

Source: Cadeo analysis

Step 2: Site Assessment/Project Scoping

Both LVs conduct site visits for their own project requests to collect site-specific existing conditions, identify potential energy efficiency measures, and develop proposed project scopes. Project scoping includes cost estimates, which the LVs and PAs use in combination with project savings to determine project benefit cost ratio (BCR).

Table 34. Differences Between LVs Step 2: Site Assessment/Project Scoping

LV (PA)	Activities, Tools, and Software
ABCD (Eversource)	• ABCD has contractors use an **Audit Form**[61] to consistently collect site data. • Contractors upload **Audit Form** to **Monday.com**.
Action (National Grid)	• Actions contractors collect site data.

Source: Cadeo analysis

[61] The evaluation team reviewed one assessment document provided by ABCD as part of the process review; however, the team did not do a comprehensive review across multiple projects.

Step 3: Estimate Project Savings

Both LVs use the site-specific data and project proposals to estimate project savings and costs to determine project cost-effectiveness.

Table 35. Differences Between LVs Step 3: Estimate Project Savings

LV (PA)	Activities, Tools, and Software

ABCD (Eversource)	• ABCD sends approved project proposals to an independent contractor.
	  ○ The independent contractor typically uses an audit tool called **MINT** to estimate project savings and cost-effectiveness for all measures identified onsite. The contractor also bases calculations on MA TRM algorithms.
	  ○ **MINT** produces an **Energy Savings (ES) Report** as an output, which the contractor uses to populate the **Screening Cost Effectiveness Report** and **Screening Calcs**[62]. The contractor then uploads all files to **Monday.com**.

Action (National Grid)	• Action separates project measures into two buckets:
	  ○ **Prescriptive measures**[63] do not require custom modeling or engineering analysis because when Action enters them into **InDemand** it calculates the measure savings.
	  ○ **Custom measures**, which require custom modeling or engineering analysis.
	• An engineering firm, National Grid Tech Reps/Engineers, or Action will provide custom modeling or engineering analysis for all custom measures. The engineering firm provides a report that summarizes savings and costs for the custom measures, which the PAs use to determine project cost-effectiveness during Step 4: Project Approval.

Source: Cadeo analysis

ABCD's independent contractor plays a central role in estimating custom project energy savings. ABCD includes all proposed measures, even prescriptive measures, in the custom savings analysis. The custom savings analysis utilizes MA TRM algorithms and historic project data to estimate savings. This approach allows for a high degree of customization but can also be time-consuming and is difficult to evaluate or replicate by others.

In contrast, Action relies heavily on prescriptive measures with savings calculated in National Grid's InDemand system. Custom measures require an outside engineering firm, National

Custom Express Tool

A promising development has been the introduction of National Grid's custom express tool recently developed for low temperature baseboard measure. Action will still enter this measure through InDemand as a custom measure, but the custom express tool allows streamlining and standardization of the calculation methodology and input assumptions and integrates evaluation assumptions.

[62] The contractor populates the screening tools (Cost Effectiveness Report and Calcs) used by ABCD to determine cost-effectiveness, but they do not determine cost-effectiveness of the project. ABCD reviews the screening tools in Step 4: Project Approval.

Grid Tech Reps/Engineers, or Action to develop savings using their own calculators. Action reviews the engineering report and uses the results to populate InDemand.

Step 4: Project Approval

LVs and PAs approve projects based on project meeting screening criteria.[64]

Table 36. Differences Between LVs Step 4: Project Approval

LV (PA)	Activities, Tools, and Software
ABCD (Eversource)	• ABCD compiles the project package and conducts a technical and full project package review before project screening. ABCD address errors and omissions as needed and re-screens projects if necessary. • Directors review project packages weekly and decide whether to approve the project.[65] ○ In some situations, ABCD will consult with Eversource regarding a specific project. These situations include large or complex projects, projects with low BCRs, or new measures.
Action (National Grid)	• Action enters savings, cost, etc. into **InDemand** and uses the **Custom Screening Tool** to validate project cost-effectiveness. Action also uploads supporting documentation including engineering reports, cost estimates, etc. • National Grid Tech Reps/Engineers review the project and provide directions on what baseline Action should be using or points out concerns with savings calculations or assumptions.

Source: Cadeo analysis

Interviews with program staff underscored the importance of considering non-energy benefits and the economic impacts of custom measures on building owners and tenants. LVs found improved comfort, reduced maintenance costs, and increased property values as key drivers of program participation and satisfaction, even if cost-effectiveness screening tools do not always consider all these factors.

Step 5: Project Implementation

Action and ABCD review approved project proposals with customers. Once customers approve the project, the LV assigns the project to a pool of pre-approved contractors or solicits competitive bids based on price and qualifications.

[63] One notable success identified in the evaluation was the ongoing effort to convert frequently used custom measures into prescriptive offerings. This process, which involves collaboration between PAs, implementers, and other stakeholders, helps to streamline program delivery, reduce administrative burdens, and improve the consistency and reliability of savings estimates. However, interviews with Action and ABCD staff suggested there may be opportunities to clarify and standardize the process for identifying and prioritizing custom measures for prescriptive development.

[64] The PAs are working to build more consistent and clear requirements, methodology, and thresholds for custom project BCR screening. Currently, they have specific screening criteria depending on project type. Generally, projects converting from gas heating to heat pump need to be above 0.5, DER projects have no threshold, and other custom projects need to be above 1.

[65] Project approval is based on specific criteria including project costs, savings, and cost-effectiveness.

Table 37. Differences Between LVs Step 5: Project Implementation

	LV-Specific Activities, Tools, and Software
ABCD (Eversource)	• ABCD or an external company, such as New Ecology, conduct an inspection once the work is complete
Action (National Grid)	• Action performs all post-installation inspections.[66][67]

Source: Cadeo analysis

Step 6: Project Submission to PA

LVs review all final project documentation prior to submitting it to PAs. If any changes are made to the project during implementation, the LVs update their documentation prior to submitting it to the PAs.

Table 38. Differences Between LVs Step 6: Project Submission to PA

LV (PA)	Activities, Tools, and Software
ABCD (Eversource)	• ABCD enters data into **e-assist**. • ABCD submits an invoice through **Tracksys**. The invoice includes all project details (project costs, kWh savings, fuel savings, MMBtu savings, incentives, etc.).
Action (National Grid)	• Action uploads all documentation into **InDemand**.

Source: Cadeo analysis

Step 7: PA Review/Approval of Payment to LV

Table 39. Differences Between PAs Step 7: PA Review/Approval of Payment to LV

PA (LV)	Activities, Tools, and Software
Eversource (ABCD)	• An Eversource Program Manager and Compliant Analyst review project details in **Tracksys** and compare details to submitted backup documentation.[68]
National Grid (Action)	• National Grid reviews to determine whether an implemented project aligns with the previously approved project.

Source: Cadeo analysis

Table 40 summarizes all the software and tools mentioned in each step of the custom review process.

[66] Action stated that conducing all their own post-installation inspections is a point of pride and a way to build trust with building owners and tenants. They also provide education in multiple languages to ensure owners and tenants operate and maintain new equipment correctly. Examples of training include operation training (heat pumps, thermostats, etc.) and maintenance training (property manager/maintenance) so that they know how to troubleshoot and know who to call. Action leaves owners with owner manuals, warranty documents, quick start guide, etc.

[67] During the evaluation team interview, ABCD did not mention whether they provide educational materials or training.

[68] Eversource reviews projects to confirm the contract-installed equipment, but they do not review savings calculations.

Table 40. CAP/PA Software and Tools Used During Custom Review Process

Tool/Software	User	Description
Audit Form	ABCD Contractor (auditor)	Multi-tab Excel used for data collection that ABCD maintains and provides to contractors visiting projects sites to maintain consistent data collection
Monday.com	ABCD	Online software platform ABCD leverages for project tracking and document storage
MINT	ABCD's Independent Contractor	Hancock audit software used to estimate custom project savings
Energy Savings (ES) Report	ABCD's Independent Contractor	Output from MINT audit software
Screening Cost Effectiveness Report	ABCD	Report manually populated with ES Report details; this report is used internally by ABCD but is not submitted to Eversource
Screening Calcs	ABCD	Excel file used to calculate savings and cost-effectiveness using ES Report details
InDemand	Action/National Grid	Demand-side management software
Custom Express Tools	Action	Excel workbook-based savings tools developed and maintained by National Grid for use in C&I programs; recently, National Grid developed a low temperature baseboard workbook for IE MF use; these workbooks do not make measures prescriptive, but they do eliminate the need for a full custom engineering analysis or model
Custom Screening Tool	Statewide	An Excel tool developed and maintained by National Grid that requires LVs to enter custom details such as total energy savings, load profile, project cost, etc. to determine whether the project is cost-effective
e-assist	ABCD	It is not a database that is searchable by an outside party for pre/post conditions; however, ABCD does enter basic information (heating system type, sq. ft., account info, etc.) into the system and can extract data as requested
Tracksys	Eversource	Tracking system

Source: Cadeo analysis

7.4 IE Custom Process Review Findings and Recommendations

The PAs/CAPs follow relatively similar IE custom process reviews, but the team identified nuanced differences during review. The following sections describe the strengths, weaknesses, and, in some cases, risks associated with some of the differences.

7.4.1 Strength: IE MF Custom Project Screening Tool

A promising recent update to the process is National Grid's development of an IE MF custom project screening tool. The tool is a modified version of MassSave's C&I custom screening tool, but it automatically applies appropriate IE MF-specific evaluation assumptions for certain inputs such as non-energy impacts, energy load shapes, and demand savings. These values are not provided in the C&I custom screening tool and are not typically developed as part of custom projects, leading to confusion, missing information, and inconsistencies when IE MF contractors used the C&I tool.[69] The tool will also streamline data entry into InDemand by structuring project information into InDemand required fields.

The IE MF custom project screening tool has the potential to standardize and simplify the screening process for custom measures for both PAs and CAPs. National Grid recently shared the IE MF custom project screening tool with Eversource and Action. The next step will be for Eversource and Action to provide feedback to National Grid.

Recommendation: The team recommends that the PAs continue down this path and work to finalize a tool that both PAs and CAPs statewide can use to standardize and streamline the process of vetting custom projects. The approach could also benefit the RCD MF initiative.

7.4.2 Challenge: External Review of Project Savings Calculation Documentation

The documentation initially provided by PAs did not consistently include transparent calculation methodologies and sufficient detail (e.g., pre- and post-conditions) needed for the evaluation team to complete engineering desks that could result in an independent estimate of the custom measures savings and, relatedly, a gross realization rate. The team followed up on these data challenges.

Through interview with ABCD, the team learned ABCD maintains more detailed project files, including audit reports and contractor invoices, which they do not pass along to Eversource unless requested. (Eversource systems only include final savings numbers needed for their reporting, not the calculation methodology or pre/post needed by an evaluator to independently estimate savings.) Consequently, the team requested and received documentation directly from ABCD. The documentation the team received from ABCD provided significantly more details but was still insufficient to complete an engineering desk review – primarily because the project calculation methodology and input assumptions used in MINT (audit software used to estimate savings) were not clearly documented.[70]

[69] For example, an MF contractor may have calculated annual savings rather than monthly load savings. The IE MF tool will automatically generate a load profile based on a common measure name the contractor enters.

[70] ABCD utilizes the statewide screening tool, eTRM algorithms, and historic data to estimate savings, and ABCD calibrates savings against two additional modeling software systems. Reviewing ABCD's modeling software was outside the scope of this project.

With regard to Action, the team found that National Grid's InDemand system included high-level data on custom projects and supporting files such as engineering reports and cost-effectiveness tools. While the engineering report documents final savings values, as well as pre/post assumptions, it did not identify the relevant savings calculation methodology used, which an evaluator would need to validate the savings calculation.

As this task focused on evaluating the custom measure delivery process in general – not calculating gross realization rates – the team could complete this review without the more detailed data. However, the review, and its associated data collection process, did reveal that a future gross realization rate analysis will require information beyond what was provided as part of this study. The PAs and CAPs should be aware of this and plan accordingly for future gross realization rate analyses.

Recommendation: PAs should ensure that they are collecting or have easy access to all project documentation that a future evaluation team will need to complete a desk review, including site assessment (baseline conditions), proposed equipment with invoices, calculation methodology (transparent calculation), and other assumed inputs (hours of operation, thermostat set points, etc.). The evaluation team realizes that in many cases PAs and LVs have this documentation; however, the team found it was either inconsistent or missing from the project documentation the team received. ABCD's independent contractor should provide documentation of the audit tool's inputs and outputs, which are sufficient for a third party to review assumptions and replicate the results.[71]

7.4.3 Challenge: One Customer Facing Program, but Different Customer Experiences

During the interview with ABCD, they shared an anecdote about a client that owned multiple MF buildings across Massachusetts. Per ABCD, the client expressed frustration that they had a very different experience working with the MF initiative to install custom measures across their properties. The client's disparate experiences – successfully installing a custom measure at one property and unsuccessfully installing the same custom measure at another property – highlighted (as evident in earlier sections) that each CAP and PA uses slightly different processes to move customers through the custom process. Although there may be valid reasons the custom measure made sense in one building and not in another, these differences can cause frustration or confusion for impacted clients. This situation may become more common or pronounced as MF building owners and managers look to take advantage of the nascent Inflation Reduction Act (IRA) program and funding, which could happen alongside participation in the PAs' programs.

Consideration: Consider alignment with state-level IRA programs: As the state develops its plans for implementing programs funded through the Inflation Reduction Act (IRA), PAs should explore opportunities to align their custom measure offerings with these initiatives. This could include adopting consistent technical standards, data collection requirements, and reporting protocols across programs.[72]

[71] ABCD is currently working with software developer on the implementation of a digital audit tool to be able to capture auditing data.

[72] Additional state guidance for calculating savings can be found at https://www.energy.gov/sites/default/files/2024-05/ira-home-energy-rebates-data-and-tools-requirements-guide-version-1.2.pdf.

7.5 Conclusion

This custom process review aimed to gather insights and document the current custom measure implementation process within the IE MF program. The review revealed that while there were similarities between the CAP/PA approaches to developing, screening, and approving custom measures, there are also reasonable differences in tools and software used by CAPs/PAs. The PAs are actively working to align screening criteria across the state.

The team identified several challenges related to data management and consistency across PAs/CAPs. The lack of standardized data collection and review processes can hinder program evaluation and cause confusion for customers. To address these challenges, the team suggests the following steps:

- Improve project documentation access (e.g., engineering firm savings calculators, audit tool input and output data).
- Continue to develop common screening tools, savings calculators, and input assumptions to promote alignment across the programs.

By taking these steps, PAs/CAPs can continue to work toward a more cohesive statewide implementation of the IE MF program. Ongoing collaboration, knowledge sharing, and a commitment to continuous improvement among all stakeholders is essential to the success of custom measures within this program and the delivery of meaningful energy savings and benefits to IE MF communities across Massachusetts.

Appendix A. Additional Billing Analysis Details

A.1 Natural Gas

The team completed several types of billing analyses to evaluate the natural gas savings associated with MF initiative participation, particularly for air sealing and insulation. These different approaches included:

1. Unit-Level PPR Modeling
2. Whole Building PPR Modeling

A.1.1 Unit-Level PPR Modeling

The TRM claims air sealing and insulation savings at the MF unit level (i.e., saving per air sealed and/or insulated tenant space). As such, the team first specified a Post-Program Regression (PPR) model specification to assess the impact of RCD and IE MF weatherization in natural gas heated dwelling units. The team used a PPR model specification consistent with the concurrent RCD Single Family impact evaluation, which yielded statistically significant results for natural gas weatherization customers participating in that initiative.

Like the RCD SF analysis, the evaluation team accounted for the impact of non-programmatic factors on consumption using a matched control group of "future" participants (i.e. customers weatherized through MF in 2022).

To further ensure the reliability of the billing analysis results, the evaluation team removed participants without a sufficient number of pre- or post-initiative billing records or that exhibited extreme or counter-intuitive energy consumption. Removal of these customers mitigates their potential to bias the billing analysis result. The team also removed accounts explicitly identified as associated with whole buildings (i.e., master metered) or, based on the team's analysis of annual usage, was most likely to be associated with a whole building. As Table 41 shows, the team modeled consumption for 437 unique unit-level PPR modeling had a sample of

Table 41. IE MF Billing Analysis Sample Attrition – Natural Gas

Attrition Metric	Excluded	Percentage	Remaining
Total gas accounts[73] receiving weatherization	-	-	1,052
Represent Whole Buildings	78	7%	974
Unable to map to billing data	203	19%	771
Incomplete billing data (Less than 12 months pre- and post-periods)	107	10%	664
Extreme consumption (< 150 therms or > 2,500 therms annually in pre- or post)	43	4%	621
Significant change (> ±50% change between pre- and post-period)	184	17%	437
Total	**615**	**58%**	**437**

[73] Accounts were a mix of whole building (master meters), individual dwelling unit, and common area meters.

Source: Cadeo analysis

Unfortunately, the evaluation team's IE MF PPR dwelling unit level models did not yield statistically significant results (i.e., better than ±20% precision at the 90% confidence level) to report weatherization savings using billing analysis.

Table 42. IE MF Billing Analysis Results – Natural Gas

PA	Sample size	Savings Estimate (therms)	Precision (90% confidence level)
Statewide	**437**	**22**	**278%**

Source: Cadeo analysis

The evaluation team used an identical \ approach to model RCD MF dwelling units to assess weatherization savings. As seen in Table 43, the evaluation team had a significantly larger sample size compared to IE MF.

Table 43. RCD MF Billing Analysis Sample Attrition – Natural Gas

Attrition Metric	Excluded	%	Remaining
Total gas accounts receiving weatherization			3,831
Represent whole buildings	23	<1%	3,808
Unable to map to billing data	713	19%	3,095
Incomplete billing data (Less than 12 months pre- and post-periods)	644	17%	2,451
Extreme consumption (< 150 therms or > 2,500 therms annually in pre- or post)	65	2%	2,386
Significant change (> ±50% change between pre- and post-period)	394	10%	1,992
Unable to match with control customers	308	8%	1684
Total	**2,147**	**56%**	**1,684**

Source: Cadeo analysis

The larger sample size for RCD MF resulted in better precision relative to IE MF, but the RCD MF billing analysis results were still well outside the evaluation team's reporting threshold (±20% precision at the 90% confidence level).

Table 44. RCD MF Billing Analysis Results – Natural Gas

PA	Sample size	Savings Estimate (therms)	Precision (90% confidence level)
Statewide	1,684	16	117%

Source: Cadeo analysis

A.1.2 Building-Level PPR Modeling

In addition to modeling individual dwelling unit-level consumption, the evaluation team also attempted a PPR model using MF billing data explicitly identified as representing whole buildings or based on total annual usage, is likely representing the usage for an entire building. The team used information from the recent series of MF Census Studies to roll up individual accounts to the entire building they served. The number of accounts representing whole buildings for RCD MF were too few to run a dedicated building-level model, but sufficient accounts existed to model IE MF whole building natural gas accounts.

As true for the unit-level analysis, the whole building model did not provide statistical valid results. However, it is worth nothing that the precision was better than the dwelling unit models for RCD and IE MF.

Table 45. IE MF Billing Analysis Results, Whole Buildings – Natural Gas

PA	Sample size	Savings Estimate per building (therms)	Average units per building	Savings Estimate per unit (therms)	Precision (90% confidence level)
Statewide	**78**	**740**	**10**	**74**	**80%**

Source: Cadeo analysis

The team also ran versions of the whole building model for various subsets of building - stratified by annual consumption, which would minimize variance for each model. None of these models produced statistically significant results either as the benefit of the minimized consumption variation was offset by smaller sample size.

A.2 Electricity

The evaluation team used a Post-Program Regression (PPR) model specification to assess the impact of RCD and IE MF weatherization in electrically heated homes. The evaluation team accounted for the impact of non-programmatic factors on consumption using a matched control group of “future” participants (i.e. customers weatherized through MF in 2022). To further ensure the reliability of the billing analysis results, the evaluation team removed participants without sufficient billing records or that exhibited extreme or counter-intuitive energy consumption. Removal of these customers mitigates their potential bias on the billing analysis result.

Table 46. IE MF Billing Analysis Sample Attrition – Electricity

Attrition Metric	Excluded	%	Remaining
Total electric accounts receiving weatherization			187
Remove non electrically heated dwelling units	24	13%	163
Unable to map to billing data	64	34%	99
Incomplete billing data (Less than 12 months pre- and post-periods)	7	4%	92
Significant change (> ±50% change between pre- and post-period)	8	4%	84
Total	**103**	**55%**	**84**

Source: Cadeo analysis

Despite the small sample size, the evaluation team performed several PPR model specifications on IE MF participants, but the results did not pass the team's reporting threshold (±20% precision at the 90% confidence level).

Table 47. IE MF Billing Analysis Results – Electricity

PA	Sample size	Savings Estimate (kWh)	Precision (90% confidence level)
Statewide	**84**	**158**	**120%**

Source: Cadeo analysis

The evaluation team had access to a larger sample of participants for RCD MF billing analysis compared to IE MF. Table 48 shows the number of unique accounts excluded and remaining after each attrition step.

Table 48. RCD MF Billing Analysis Sample Attrition – Electricity

Attrition Metric	Excluded	%	Remaining
Total electric accounts receiving weatherization			867
Unable to map to billing data	192	22%	675
Incomplete billing data (Less than 12 months pre- and post-periods)	233	27%	442
Extreme consumption (< 500 kWh or > 30,000 kWh annually in pre- or post)	59	7%	383
Significant change (> ±50% change between pre- and post-period)	9	1%	374
Total	**506**	**58%**	**361**

Source: Cadeo analysis

The RCD MF billing analysis yielded better precision compared to IE MF, but the results were still outside the evaluation team's reporting threshold (±20% precision at the 90% confidence level) ±20% precision at the 90% confidence level).

Table 49. RCD MF Billing Analysis Results – Electricity

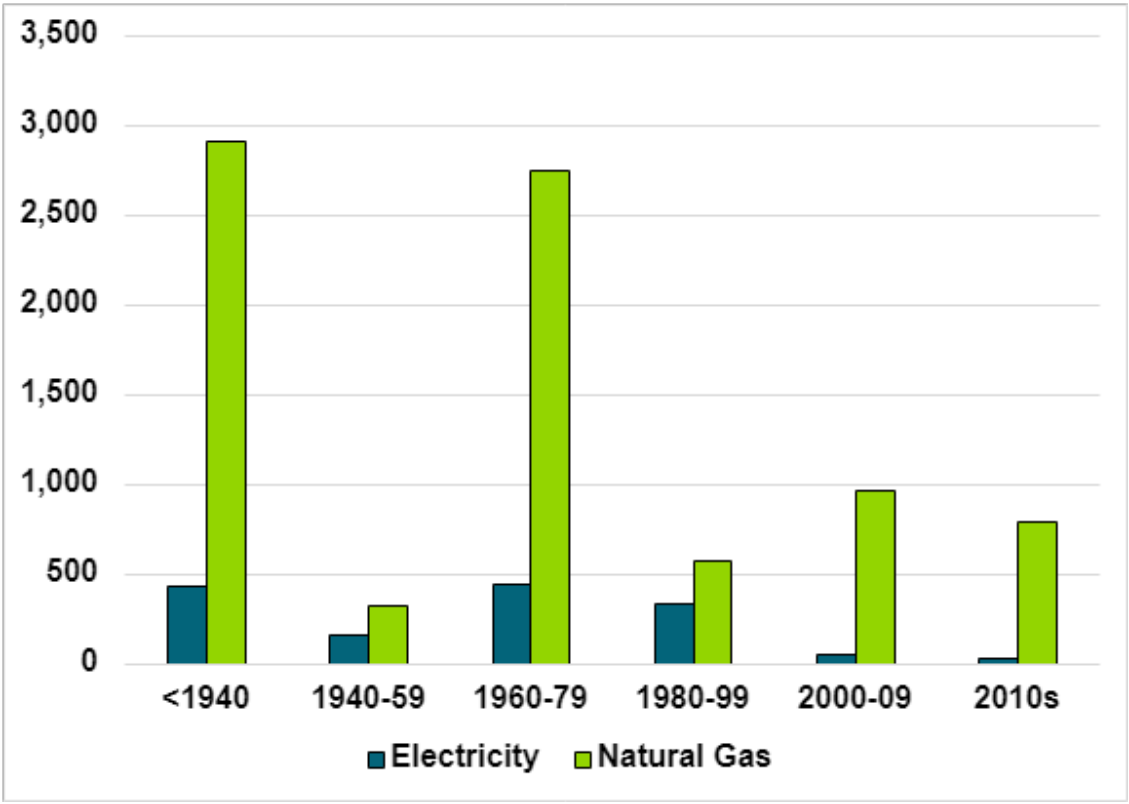
PA	Sample size	Savings Estimate (kWh)	Precision (90% confidence level)
Statewide	**335**	**1,157**	**30%**

Source: Cadeo analysis

Appendix B. Additional Building Simulation Details

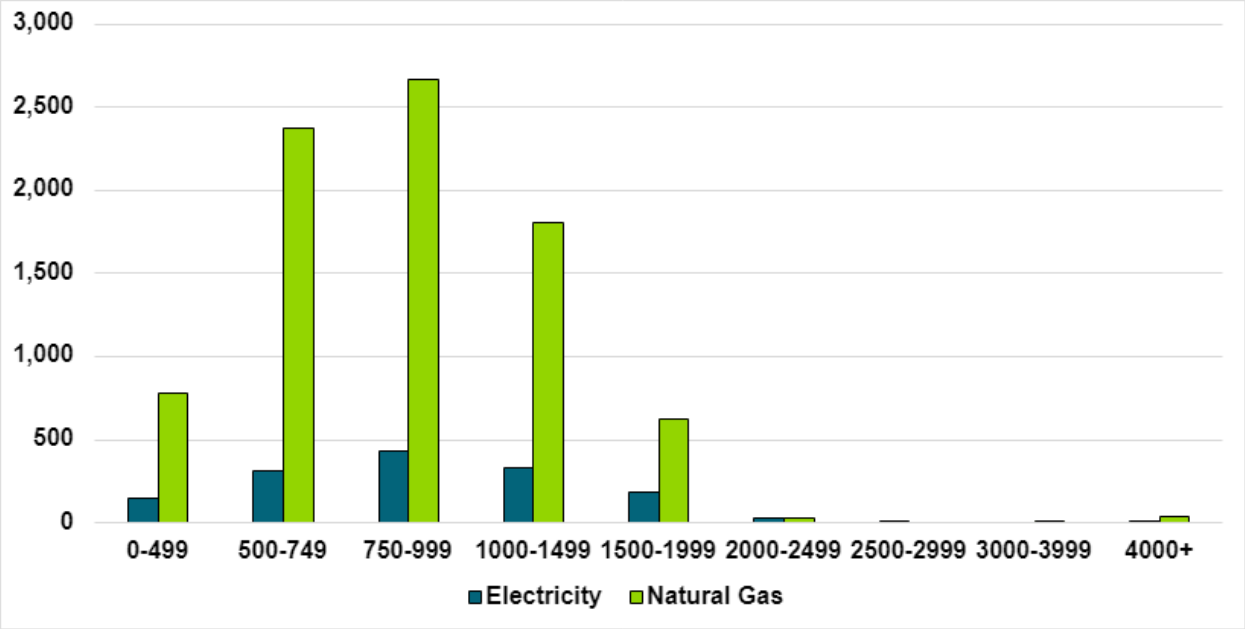
The building simulation process matched participant accounts (billing data) to dwelling unit models. Dwelling unit models vintages ranged from pre-WWII to 2010s and ranged from less than 450 sq. ft. to over 4,000 sq. ft. Figure 10 and Figure 12 show the distribution of RCD and IE, respectively, dwelling unit model vintages for participants with electric or natural gas heating. Figure 11 and Figure 13 show the distribution of RCD and IE, respectively, dwelling unit model sizes for participants with electric or natural gas heating.

Figure 10. RCD MF Modeled Dwelling Unit Count by Unit Heating Fuel and Vintage



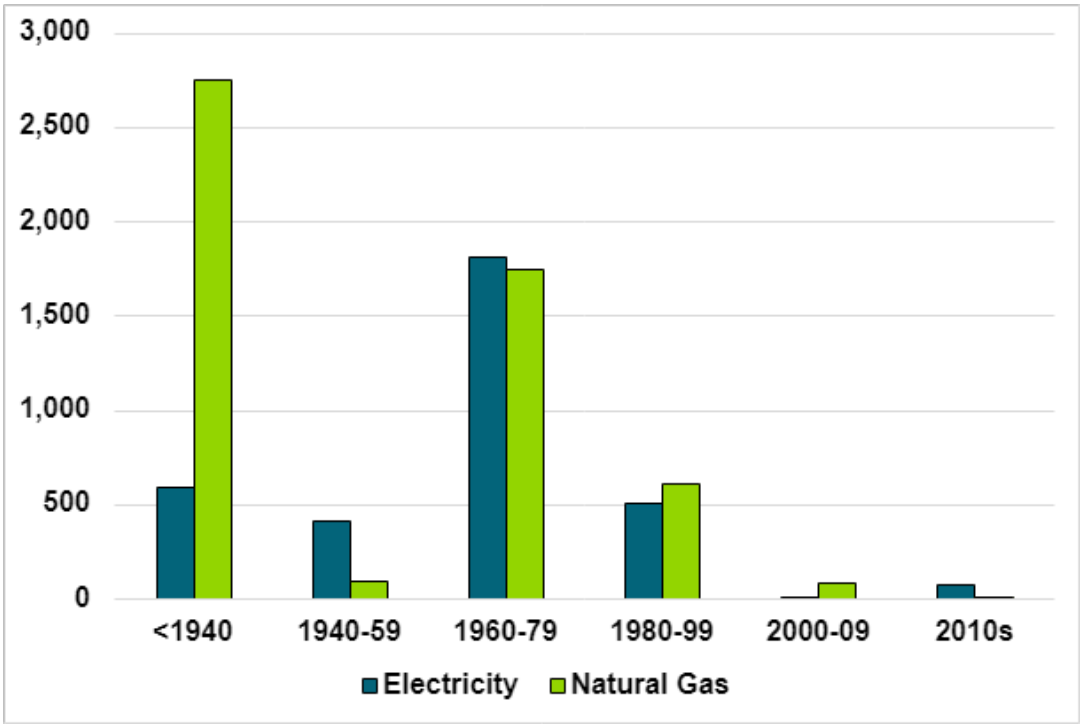
Source: Cadeo analysis

Figure 11. RCD MF Modeled Dwelling Unit Count by Unit Heating Fuel and Size



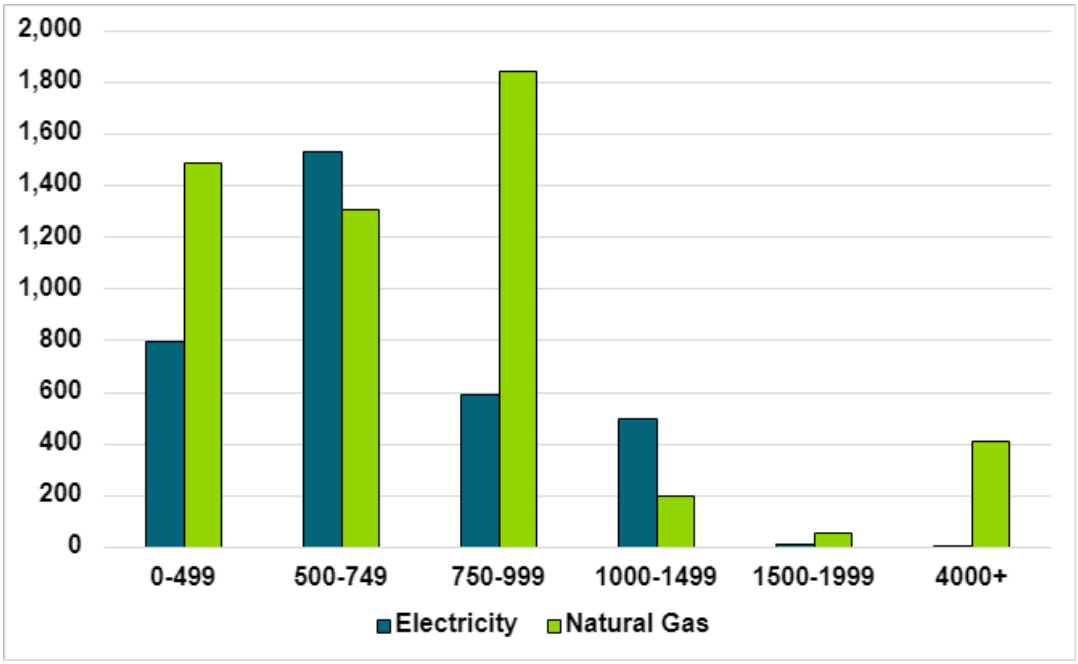
Source: Cadeo analysis

Figure 12. IE MF Modeled Dwelling Unit Count by Unit Heating Fuel and Vintage



Source: Cadeo analysis

Figure 13. IE MF Modeled Dwelling Unit Count by Unit Heating Fuel and Size



Source: Cadeo analysis

Appendix C. Gross Realization Rates

The following tables summarize evaluated and reported savings by initiative and PA.

In general, we found that all our evaluated savings were typically greater than the PA provided reported savings. However, the team is concerned that the comparison of evaluated savings to reported savings may not be an apples-to-apples comparison in all cases. Specifically, there is also some uncertainty that reported quantities do not consistently represent dwelling units serviced. There are also notable differences in average reported savings across PAs and across initiatives which are difficult to explain. The evaluation team and PAs met to discuss these issues and were unable to generate and/or identify alternative reported values for calculating reliable gross realization rates.

For these reasons, we do not recommend PAs use these values and have provided them for reference only. As noted previously in the report, the team recommends the PAs continue to use the existing gross energy savings and gross realization rates for both initiatives.

Table 50. Statewide and PA Specific Comparison of RCD MF Evaluated and Vendor Estimated Weatherization Savings – Natural Gas

Measure	Statewide			National Grid			Eversource			EGMA		
	Evaluated	Reported	GRR	Evaluated	Reported	GRR	Evaluated	Reported	GRR	Evaluated	Reported	GRR
Air Sealing	61	19	3.26	84	18	4.77	88	35	2.55	49	22	2.22
Insulation	50	12	4.01	55	10	5.30	51	33	1.56	21	19	1.13

Source: Cadeo analysis

Table 51. Statewide and PA Specific Comparison of IE MF Evaluated and Vendor Estimated Weatherization Savings – Natural Gas

Measure	Statewide			National Grid			Eversource			EGMA		
	Evaluated	Reported	GRR	Evaluated	Reported	GRR	Evaluated	Reported	GRR	Evaluated	Reported	GRR
Air Sealing	62	42	1.48	66	46	1.44	71	27	2.63	60	77	0.78
Insulation	42	42	1.01	43	48	0.90	49	27	1.84	40	87	0.46

Source: Cadeo analysis

Table 52. Statewide and PA Specific Comparison of RCD MF Evaluated and Vendor Estimated Weatherization Savings – Electric

Measure	Statewide			National Grid			Eversource		
	Evaluated	Reported	GRR	Evaluated	Reported	GRR	Evaluated	Reported	GRR
Air Sealing	1,277	155	8.22	1,297	105	12.32	1,224	233	5.26
Insulation	1,464	341	4.30	1,616	275	5.88	1,337	1,436	0.93

Source: Cadeo analysis

Table 53. Statewide and PA Specific Comparison of IE MF Evaluated and Vendor Estimated Weatherization Savings – Electric

Measure	Statewide			National Grid			Eversource		
	Evaluated	Reported	GRR	Evaluated	Reported	GRR	Evaluated	Reported	GRR
Air Sealing	1,676	392	4.28	1,930	385	5.01	1,930	445	4.33
Insulation	1,415	372	3.80	920	469	1.96	920	196	4.70

Source: Cadeo analysis

Table 54. Statewide Comparison of RCD MF Evaluated and Vendor Estimated Weatherization Savings – Delivered Fuels

Measure	Statewide – Fuel Oil			Statewide - Propane		
	Evaluated	Reported	GRR	Evaluated	Reported	GRR
Air Sealing	4.10	3.16	1.30	7.40	20.26	0.37
Insulation	3.40	0.95	3.58	6.10	19.76	0.31

Source: Cadeo analysis

Table 55. Statewide Comparison of IE MF Evaluated and Vendor Estimated Weatherization Savings – Delivered Fuels

Measure	Statewide – Fuel Oil			Statewide - Propane		
	Evaluated	Reported	GRR	Evaluated	Reported	GRR
Air Sealing	7.10	3.37	2.11	6.20	4.66	1.33
Insulation	4.80	4.08	1.18	4.20	4.33	0.97

Source: Cadeo analysis

Appendix D. Copy of the Massachusetts and Connecticut Heat Pump Metering Study (MA22R51-B-HPMS/CT R2246)

Embedded below is a copy of the Massachusetts and Connecticut Heat Pump Metering Study used to evaluate savings for various heat pump technologies installed through the IE MF initiative. The report includes significant details about the metering and analysis process that yielded the IE MF savings reported in this impact evaluation.

MA HPMS CT R2246
- Heat Pump Meterinç