Appliance Recycling 2019 Impact Evaluation

MA21R33-E-ARI

Prepared for:

The Electric Program Administrators of Massachusetts

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Executive Summary

The Massachusetts Program Administrators (PAs), including Cape Light Compact (CLC), Eversource, National Grid, and Until, sponsored an Appliance Recycling Program (the Program) in 2019. The Program's goal is to reduce energy use by taking old and inefficient appliances off the electric grid and recycling them in an environmentally safe manner. This is accomplished by providing customer incentives and offering a convenient way for customers to remove unwanted appliances from their homes. The Program recycles old refrigerators, freezers, and dehumidifiers.

Guidehouse Inc., and ILLUME Advising, LLC (the evaluation team) developed this report for the PAs and the Energy Efficiency Advisory Council Consultants (EEAC Consultants). This evaluation assesses the gross impacts achieved by the Program during 2019 and includes a limited process review. The following sections briefly describe the study's approach to accomplish these objectives, along with key findings and recommendations.

Study Approach

The evaluation team followed Chapter 7 of the Uniform Methods Project (UMP) to calculate gross savings for recycled refrigerators and freezers. To create Program-specific inputs, the team collected and analyzed survey and tracking data. Combined with the algorithm specified in the Comprehensive Technical Reference Manual (TRM) Review (MA19R17-B-TRM), the team used this data to estimate gross impacts for recycled dehumidifiers and to aid in understanding the influence of specific characteristics on average unit energy consumption (UEC) estimates for recycled dehumidifiers.

The team conducted interviews with the PA sponsors of the Program and the Program implementers, Appliance Recycling Centers of America (ARCA) and TRC, to provide a limited process evaluation. These interviews explored the participation process and experience for customers, program eligibility and data tracking, areas of success and opportunities for the future, and how the COVID-19 pandemic has affected program delivery.

Key Findings and Recommendations

This section provides the evaluation team's key findings and related recommendations.

Findings	Recommendations
Evaluated 2019 values for refrigerators and freezers are very similar to 2018 results at 1,005 kWh and 753 kWh, respectively. This is driven, in part, by the consistency in key recycled refrigerator and freezer characteristics, such as age, size, configuration, and primary and secondary units across program years.	**The model presented in the UMP likely remains a sufficiently reliable method for estimating impacts.** If key appliance characteristics change or more recently metered data becomes available, the PAs may consider using newer data to re-estimate impacts for the appliances recycled through this program.
Survey results from 2019 participants show a 22% increase in the part-use factor for freezers over the previous year. Reasons for the change in freezer part-use were not determined through this study. The refrigerator part-use factor is very similar between 2018 and 2019.	**The PAs should request that evaluators attempt to measure part-use factors during the next impact evaluation of the Program.** This will help the PAs to understand if there are any significant shifts from 2019 values.
The overall UEC value for recycled dehumidifiers in 2019 is 1,050 kWh. When calculated separately, the appliance pick-up UEC is about 12% higher than the turn-in event UEC. The appliance pick-up track allowed any size dehumidifier to be picked up in 2019, resulting in a higher number of smaller and less efficient units. Going forward, values between program tracks should more closely align as all units must meet the size eligibility of 20-70 pints.	**The PAs should adopt a different prospective savings value for dehumidifiers that reflects the new size eligibility requirements.** The evaluation team calculated an overall prospective UEC value of 1,020 kWh. The two program tracks should also ensure that they coordinate on any future eligibility changes to build in consistency where possible.
The PA sponsors are very satisfied with the delivery of the Program. The PA sponsors note that the Program has received positive feedback from customers and runs very smoothly with minimal issues.	**The PAs should consider ways to leverage positive Program feedback by determining how to use the Program as an entry point for new or harder-to-reach customers.** The Program should review findings from the Limited English Proficiency Customer Journey Mapping Study, when available, to determine how it might inform the appliance recycling journey for non-English speaking customers. The Program could consider distributing literature about other programs or no-cost measures and kits to participants as well.

Findings	Recommendations
Program staff successfully adjusted for the COVID-19 pandemic.	**Certain COVID-19-related adjustments should remain an option for customers post-pandemic.**
The Program was still offered for customers' benefit—staff were able to navigate new requirements and adjustments as needed.	The Program is valued by customers for its convenience, and ARCA notes that many customers prefer the contactless pick-up option because it does not require them to wait at home while the pick-up occurs.
Appliance pick-up tracking data was straightforward to obtain, but dehumidifier turn-in event tracking data required additional iterations to receive information for the impact evaluation.	**The database administrator should ensure that dehumidifier turn-in event equipment information is included with future data downloads from EFI.**
Some appliance pick-up dehumidifiers appeared to have capacities listed in pints or liters, and about one-third of dehumidifier turn-in records were missing capacity information. Neither dataset included dehumidifier unit nameplate efficiency, which resulted in the use of an assumed efficiency rating to estimate gross impacts.	In addition to collecting dehumidifier capacity information consistently in pints, both Program tracks should consider their ability to collect dehumidifier unit nameplate efficiency factor. This data would enhance future evaluations and the ability to estimate gross impacts more directly.
The drain configuration and control type of dehumidifiers does impact the UEC value.	**The PAs should consider having a future evaluation collect the drain configuration and control type of recycled dehumidifiers.**
The assortment of these characteristics within 2019 survey respondents was different than the metering sample included in the Baseline Study, resulting in a different average UEC.	This information will allow the PAs to determine whether an update should be made to the dehumidification load included in the Technical Reference Manual (TRM).

1. Introduction

This section discusses this study's objectives, provides an overview of the Program, and describes the study methodology that was followed.

1.1 Study Description and Objectives

This study assessed the gross savings impacts of the Program during 2019.[1] The study was designed to achieve the following goals:

- Verify savings for each measure group (refrigerators, freezers, dehumidifiers)
- Describe the drivers of deviations from the 2018 evaluation results and considerations for future program planning
- Conduct additional analysis to understand the influence of control types and drain configurations on average UEC estimates for recycled dehumidifiers
- Provide limited process evaluation results through staff and stakeholder interviews

1.2 Program Overview

The PAs sponsor a two-track appliance recycling program via the Mass Save® Residential Consumer Products Core Initiative. The first track is implemented by ARCA and includes the pick-up of unwanted refrigerators and freezers. ARCA also picks up used dehumidifiers if they are already at the residence to retrieve a refrigerator or freezer. TRC implements the second track, which includes dehumidifier turn-in events that are held throughout the state.

Appliances recycled must be in working condition and meet the following requirements, shown in Table 1-1.

Table 1-1. Program Eligibility in 2019

Eligibility Factor	Appliance Pick-up	Dehumidifier Turn-in Events
Service account type	Residential electric account holder of CLC, Eversource, National Grid, or Unitil	
Refrigerator and Freezer Size	10 to 30 cubic feet	NA
Dehumidifier Size	No size limitations*	20 to 70 pints
Number of Units	Max of two units per calendar year, plus dehumidifiers	Max of two units per calendar year
Condition	Must be in working condition	

*In March 2021, the PAs reported that size limitations now match Turn-in Events at 20-70 pints.

[1] Net impacts are assessed via the *Appliance Recycling Net Savings Update Report (MA20X03-E-ARNTG)*, delivered by NMR.

Customers in the appliance pick-up track apply to the Program by completing an online application form accessible via the Mass Save® website or call the customer service phone line. Customers who participate in a dehumidifier turn-in event bring their old dehumidifier to an open event, drop off the appliance with Program staff and receive a rebate form to complete and submit. Refrigerators and freezers are provided rebates of $75 per unit, while both tracks offer a rebate of $30 per unit for dehumidifiers.

1.3 Methodology Overview

The evaluation team completed the following research tasks to meet the study objectives:

1. Staff and stakeholder interviews
2. Tracking data review
3. Participant surveys
4. Impact analysis of recycled appliances
5. Additional analysis of dehumidifier configuration

The approach to each task is further described in the following sub-sections.

1.3.1 Staff and Stakeholder Interviews

The evaluation team completed interviews in March and April 2021 with the following individuals:

- PA representatives from the following sponsors – Eversource, National Grid, Unitil, and CLC
- Account Manager, ARCA
- Dehumidifier Turn-in Events Manager, TRC

The team's interviews with staff and stakeholders explored offering eligibility, how the participation process works, the history of the offerings, outreach and marketing strategies, program goals and objectives, and prospects and barriers for meeting those goals. Finally, the team sought to understand whether COVID-19 affected the delivery of the Program, if at all, and whether any new considerations exist.

1.3.2 Tracking Data Review

The evaluation team received ARCA program tracking data from DNV in January and TRC turn-in event data in May of 2021. The tracking data was reviewed to understand whether the following key evaluation inputs were readily available:

- Age of appliance (in years or year manufactured)
- Size of appliance (in cubic feet)
- Configuration of appliance (e.g., top freezer, side-by-side)
- Use of appliance (for refrigerators, primary or secondary, for dehumidifiers, used humidity controls or operated continuously)

- Date the appliance was removed

The tracking data was also reviewed to identify and remove, as appropriate, any outliers, ineligible units, and duplicate records.

1.3.3 Participant Surveys

The evaluation team used participant survey data collected by NMR for the net savings analysis of this program to inform the impact and high-level process analyses.[2] NMR prepared the sample by randomly selecting participants from the program tracking data. A check was also performed to ensure that the proportion of sample for each service territory reflected the Program population. This survey effort included 345 completed surveys across the three appliance types: 174 dehumidifiers, 75 freezers, and 96 refrigerators.

The participant survey provided critical inputs used to calculate the UEC for refrigerators and freezers. Specifically, the survey collected data on appliance use (to calculate part-use factors), and location (to determine percentage of appliances in unconditioned space). For dehumidifiers, the survey collected data on the appliance configuration (control and drain types) to help inform the additional analysis described in Section 1.3.5.

1.3.4 Impact Analysis

This section describes the methodologies used to calculate savings for recycled refrigerators, freezers, and dehumidifiers.

1.3.4.1 Gross Savings – Refrigerators and Freezers

Chapter 7 of the UMP[3] directs evaluators on approaches for calculating savings resulting from refrigerator and freezer recycling programs. The UMP provides evaluators with three impact evaluation options: (1) conduct in-situ metering from the program; (2) use meter data or a model derived from meter data collected from another evaluation deemed representative, or (3) apply inputs gathered through primary and secondary sources to the prescribed UMP regression equation to calculate UEC.

The evaluation team determined the third option—updating and applying inputs to a regression model derived from meter data collected across a sample of customers—was the optimal and most cost-efficient approach. Given the high cost of metering, the UMP recommends this approach where reliable and territory specific data exist.

According to the UMP, total gross savings (kilowatt hours [kWh] per year) from recycling inefficient but still working refrigerators and freezers is calculated using the following algorithm:

Gross_kWh = ***N * Existing_UEC * Part_use***

Where:

Gross_kWh = *Annual electricity savings*

[2] Additional survey details can be found in the *Appliance Recycling Net Savings Update Report (MA20X03-E-ARNTG)* conducted by NMR.

[3] Chapter 7, Uniform Methods Project, assessed here.

N = *Number of appliances recycled*
Existing_UEC = *Average Annual Energy Consumption of participating appliances*
Part_use = *Portion of year the average appliance would likely be plugged in and operating*

The evaluation team used inputs from the 2019 program tracking data and the participant survey to calculate the parameters included in both the Gross_kWh and Existing_UEC algorithms. Specific data inputs and sources are shown in Table 1-2. Data Inputs and Sources to Calculate Gross Impacts for Refrigerators and Freezers

Table 1-2. Data Inputs and Sources to Calculate Gross Impacts for Refrigerators and Freezers

Input for Model	Data Source
Age (in years or year manufactured)	Tracking data
Size (in cubic feet)	Tracking data
Configuration (e.g., top freezer, side-by-side)	Tracking data
Use of appliance (primary or secondary)	Tracking data
Location of appliance (conditioned or unconditioned space)	Self-report survey data
Appliance use (percentage of year it was plugged in)	Self-report survey data

1.3.4.2 Gross Savings – Dehumidifiers

The evaluation team verified gross savings for recycled dehumidifiers primarily by using guidance from the Comprehensive TRM Review MA19R17-B-TRM[4]. This document provides the following updated algorithm and assumptions for calculating dehumidifier UEC for recycled units.

$$\Delta kWh_{RETIRE} = Dehumidification\_Load * \left(\frac{1}{Eff_{Retire}}\right)$$

Where:

Dehumidification_Load = Typical annual moisture removal (Liters/year)
Eff ***RETIRE*** = Average efficiency of model being recycled, in Liters/kWh

The evaluation team used 2019 program tracking data to calculate parameters included in the above algorithm. Table 1-3 presents the full list of data sources the evaluation team used to calculate gross impacts for dehumidifiers.

[4] The final report can be accessed here.

Table 1-3. Data Inputs and Sources to Calculate Gross Impacts for Dehumidifiers

Input for Model	Data Source
Dehumidification Load (Liters/year)	1,520 Liters/year*
Eff $_{RETIRE}$ (Liters/kWh)	Federal efficiency standard, effective October 1, 2012; Capacity from 2019 tracking data

**This value is derived from data collected during the RES 1 baseline study.*

1.3.4.3 Adjusted Gross Savings

The evaluation team applied part-use factors to estimate adjusted gross savings for refrigerators and freezers. This adjustment is necessary to calculate a more accurate estimate of gross savings, as appliances that are recycled through the Program may not have been plugged in year-round prior to being recycled. Part-use factors are assigned as follows:

- Plugged in and running all the time: Part-use = 1.0
- Plugged in and running none of the time: Part-use = 0
- Plugged in and running some of the time: Part-use = Months Used / 12

Adjusted gross savings are calculated by applying the part-use factors to the calculated gross savings. A part-use factor is not applied to dehumidifiers, as the dehumidification load already accounts for hours of use during the year.

1.3.5 Additional Analysis

Early findings from the MA Residential Building Use and Equipment Characterization Study (formerly known as the Residential Baseline Study) suggest that UEC may vary for dehumidifiers depending on control type and drain configuration. The evaluation team conducted an additional analysis to aid in understanding the influence of these two characteristics on average UEC estimates for recycled dehumidifiers. Specifically, the team performed the following:

- Characterized the assortment of control types and drain configurations for 2019 Program participants using the following four categories:
  - Batch drainage, no humidistat control
  - Batch drainage, with humidistat control
  - Continuous drainage, no humidistat control
  - Continuous drainage, with humidistat control
- Leveraged the evaluation team's ongoing research on dehumidifiers to provide insight into whether the assortment of participating dehumidifiers might create variance from the average UEC value for 2019 program participants when adjusting for controls and drain configuration.

Data inputs and sources appear in Table 1-4.

Table 1-4. Data Inputs and Sources to Estimate Impact of Device Characteristics on UEC

Input for Model	Data Source
Used humidity controls or operated continuously	Self-report survey data
Drained via hose or bucket	Self-report survey data

2. Key Findings

This section provides a summary of findings from interviews with the PA sponsors and implementation staff, a review of the Program's 2019 tracking data, an assessment of 2019 gross and adjusted gross savings levels, and the additional dehumidifier analysis performed.

2.1 Program Staff and Stakeholder Interviews

The PA sponsors are very satisfied with the delivery of the appliance recycling offerings and receive positive feedback from customers. Program operations and outreach are largely unchanged since 2019, and Program staff were able to effectively make changes to delivery methods to adjust to the COVID-19 pandemic in 2020.

This section presents key findings from interviews conducted with the PA sponsors and Program staff from ARCA and TRC.

2.1.1 Program Operations and Feedback

Both Program staff and the PA sponsors note that the appliance recycling design and delivery to the market – except for adjustments made due to COVID-19 – have remained largely the same since 2019. The PA sponsors report satisfaction with the current program delivery provided by ARCA and TRC, and generally receive very positive feedback from customers about the Program. The PAs note that customers like that it is a free service and that they are paid to have their old appliance hauled away.

During the COVID-19 pandemic, the Program was on hold from March to June of 2020 while it determined the appropriate safety protocols. Once program activities reconvened, Program staff wore personal protective equipment (PPE) such as face masks and gloves and practiced social distancing. ARCA also added a contactless pick-up option to the refrigerator and freezer pick-ups. The PA sponsors and ARCA note that this option may remain post-COVID to accommodate customers who do not want to be at home when the pick-up takes place. TRC stated that dehumidifier turn-in events did not start up again until November of 2020. Program staff planned events to encourage customers to remain in their cars while two staff people removed the old dehumidifiers from the vehicles, whereas before COVID-19, staff limited the handling of units.

2.1.2 Marketing and Outreach

In general, Program marketing and outreach efforts have been consistent since 2019. Program staff report that the Program is promoted primarily through social media, bill inserts, and newsletters. Other marketing strategies have included email blasts, paid online advertising, and radio spots. The PA sponsors note that marketing is generally not targeted to any specific segment of the population, and messaging revolves around the convenience of the offering, recycling responsibly, doing something good for the environment, and being paid for your old appliance.

In addition to general marketing, the Program will also occasionally increase incentive levels for refrigerators and freezers for a limited period during the year to increase uptake. The following subsections describe additional promotional activities specific to each Program track.

2.1.2.1 Track 1 Appliance Pick-up – Partnerships with Retailers

ARCA staff report that they partner with Home Depot to promote the Program in approximately 120 of its stores across Massachusetts. Program staff note that Home Depot sees the Program as a sales tool to sell new appliances and as way to increase their customers' satisfaction levels. Program staff conduct training sessions with Home Depot staff to explain how the Program works, the value proposition for customers, and how to walk through the application process with the customer while they are still in the store. To facilitate this, Program staff add the Mass Save® Program webpage to the favorites list on each computer's web browser. Program staff report that approximately 7%-9% of pick-up orders come from Home Depot on an annual basis[5].

Program staff report that they are also in discussions with other retailers like Lowes to create a similar arrangement as they have with Home Depot. However, some retailers still collect used appliances and sell them on the secondary market, which can be a barrier to creating a such a partnership.

2.1.2.2 Track 2 Dehumidifier Turn-in Events – Event Promotion

Dehumidifier turn-in events are offered across the state, with the goal of achieving good geographical representation. Program staff reach out to local municipal offices to receive permission to hold the event and coordinate on a specific location. TRC reports that events are typically held at retail stores like a Home Depot or Lowes that typically have larger parking lots, lumber yards, or municipal building parking lots like a police station. Once an event is confirmed, Program staff distribute flyers about a week ahead of time to local community gathering places, such as libraries, town halls, or grocery stores.

Program staff note that occasional barriers include: (1) municipalities who perceive the events as competition to local appliance removal services and may reduce fee revenue received; and (2) a lack of space to hold the events, as they reduce the number parking spaces available for customers going into stores. TRC states that this is more often an issue in larger cities, where building density is higher.

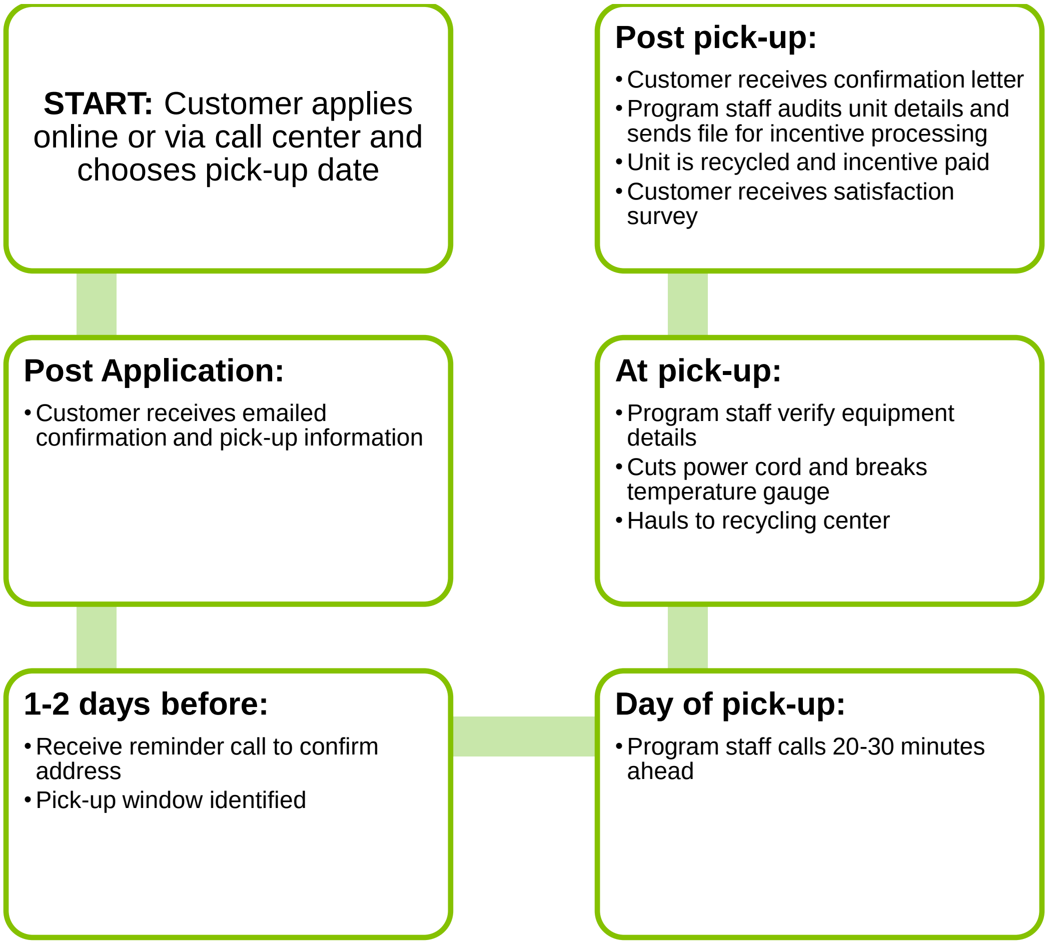
2.1.3 Participation Process

This section walks through the participation process for each Program track.

Figure 2-1 shows the customer participation process for refrigerator and freezer pick-ups. The customer applies to the Program and then receives an email confirmation with additional details on what the pick-up will entail. One to two days prior to pick-up, the customer will receive a reminder call and the pick-up window is identified. On the day of the pick-up, the customer received a call approximately 20-30 minutes before arrival. Program staff will confirm equipment details and when onsite, cut the power cord and break the temperature gauge so that the unit can no longer be used, and haul the equipment away. The unit is then recycled, and the incentive is processed.

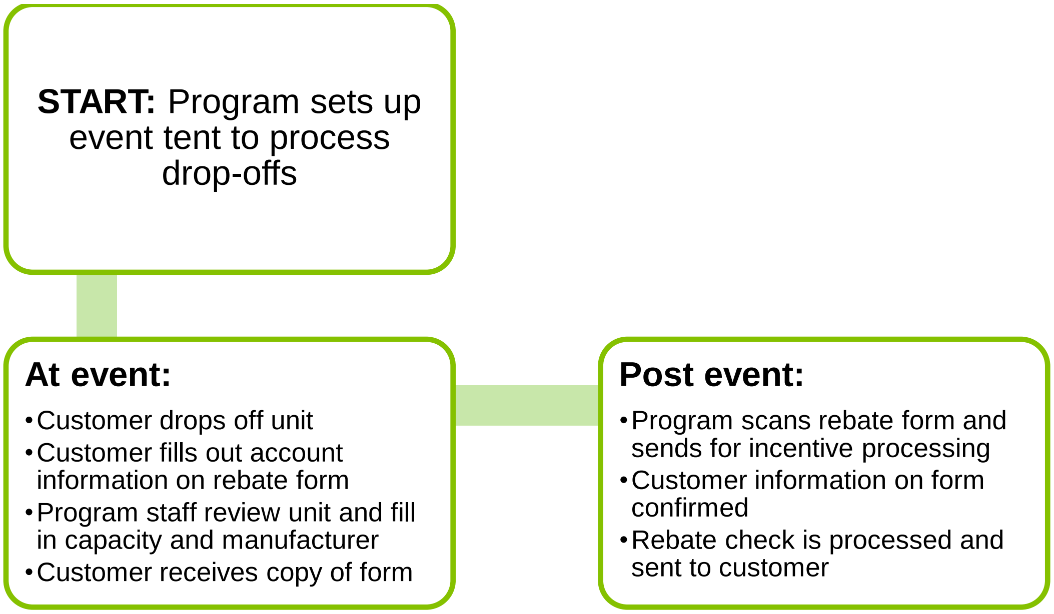
[5] The Evaluation Team does not have data to confirm this. Program staff report that these numbers are derived from the online application form, which includes a question about how the customer heard about the Program.

Figure 2-1. Track 1 – Appliance Pick-up Participation Process



In Figure 2-2 we walk through the participation process for dehumidifier turn-in events. Once an event is open, customers drop off their old dehumidifiers and receive a rebate form to fill in personal information while Program staff review the unit and then provide unit capacity and manufacturer information on the form. The customer then receives a copy of the rebate form for their records. After the event, Program staff scan all rebate forms for incentive processing. Customer information on the forms is confirmed and checks are mailed.

Figure 2-2. Track 2 – Dehumidifier Turn-in Event Participation Process



2.1.4 Future Considerations

The evaluation team identified the following future opportunities during stakeholder interviews.

2.1.4.1 Promotion of Other Programs

Program staff noted that due to the delivery model of the Program, they are in various locations across the state on a regular basis. This gives them access to local communities and customers' homes that other programs may not always have. Program staff suggest that the Program could act as an extension of the larger Mass Save® portfolio to promote other programs, provide relevant literature, or offer free measures and kits to customers.

2.1.4.2 Serving Non-English Speakers

The PA sponsors noted that information about the Program is being translated into Spanish on the Mass Save® website, and customer service representatives are also available to speak to customers Spanish. It is worth noting that the evaluation team is currently launching a study to explore the customer journey for limited English proficiency customers. When completed, this study may include additional insights into how the Program can continue to engage diverse language populations going forward.

2.2 Tracking Data Review

Overall, 2019 program tracking data included the inputs necessary to conduct the impact evaluation. Tracking data was reviewed thoroughly to identify any outliers, duplicate records, and ineligible units like appliances tied to business accounts.

Histograms showing the post-data cleaning distribution of appliance sizes, ages, and configurations are provided in the Appendices. The following sub-sections discuss the data processing steps taken and the final number of records included in the gross impact analysis.

2.2.1 Refrigerators and Freezers

The raw program tracking data included 19,844 refrigerators and 3,332 freezers, as shown in Table 2-1 and Table 2-2. Non-residential units were removed as they are not eligible for the Program. The evaluation team also identified several duplicated records, which exactly matched other records (including the same unit manufacturer, size, age, etc.) within the same order number. We also removed units that did not meet size qualifications (10-30 cubic feet).

Table 2-1. Refrigerator Data Cleaning Steps

Raw Data	19,844	18,243	17,968
Data Cleaning Step	**Records**	**Order Numbers**	**Guidehouse IDs**
Removed Non-Residential Units	310	165	157
Removed Duplicated Records	1,162	0	0
Removed Non-Qualifying Sizes	39	36	35
Cleaned Data	**18,333**	**18,042**	**17,776**

Source: ARCA 2019 Program Tracking Data provided by DNV on January 19, 2021.

Table 2-2. Freezer Data Cleaning Steps

Raw Data	3,332	3,139	3,131
Data Cleaning Step	**Records**	**Order Numbers**	**Guidehouse IDs**
Removed Non-Residential Units	23	20	19
Removed Duplicated Records	48	26	26
Removed Non-Qualifying Sizes	140	0	0
Cleaned Data	**3,121**	**3,093**	**3,086**

Source: ARCA 2019 Program Tracking Data provided by DNV on January 19, 2021.

2.2.2 Dehumidifiers

The raw program tracking data included 3,677 dehumidifiers (1,080 in the appliance pick-up track, and 2,597 in the turn-in event track). The evaluation team took the following data cleaning steps for each dataset are shown in Table 2-3 and Table 2-4.

Table 2-3. Dehumidifier Pick-up Data Cleaning Steps

Raw Data	1,080	977	976
Data Cleaning Step	**Records**	**Order Numbers**	**Guidehouse IDs**
Removed Duplicated Records	30	0	0
Cleaned Data	**1,050**	**977**	**976**

Source: ARCA 2019 Program Tracking Data provided by DNV on January 19, 2021.

Table 2-4. Dehumidifier Turn-in Data Cleaning Steps

Raw Data	2,597	NA	NA
Data Cleaning Step	**Records**	**Order Numbers**	**Guidehouse IDs**
Filtered to records in 2019	1,184	NA	NA
Filtered to events in MA	26		
Removed records where bucket capacity was null	346		
Removed non-qualifying sizes	15		
Cleaned Data	**1,026**		

Source: TRC 2019 Program Tracking Data provided by DNV on May 26, 2021.

2.3 Gross Impacts

The evaluation team found adjusted gross savings of refrigerators in 2019 to be very similar to the previous year's evaluation at 884 kWh per unit. Freezer adjusted gross savings are 19% higher than the previous evaluation at 622 kWh per unit, influenced primarily by an increase in the part-use factor. Dehumidifier adjusted gross savings are 1,050 kWh per unit.

The following sections outline the steps the evaluation team took to update 2019 gross and adjusted gross energy savings for recycled refrigerators, freezers, and dehumidifiers.

2.3.1 Gross Savings

Consistent with the 2018 analysis conducted by NMR, the evaluation team calculated the UECs of retired refrigerators and freezers for 2019 using the UMP regression model, which is based on an aggregated in-situ data set of 472 metered refrigerators and 57 metered freezers.[6] With the wide distribution of appliance ages, sizes, configurations, usage scenarios (primary or secondary), and climate conditions, the UMP data set is an ideal data source for determining the energy savings of appliance recycling.

The evaluation team calculated dehumidifier UEC by primarily using guidance from the Comprehensive TRM Review (MA19R17-B-TRM).

2.3.1.1 Refrigerators

The evaluation team calculated the refrigerator UEC using the UMP regression model as shown below, as well as 2019 tracking data and survey information. This approach ensured that the resulting UEC was based on specific units recycled though the program in 2019.

*Refrigerator UEC = 365.25 * [0.582 + (0.027 * average appliance age)*
*+ (1.055 * percent manufactured before 1990)*
*+ (0.067 * average size in cubic feet)*
*- (1.977 * percent single-door units)*
*+ (1.071 * percent side-by-side units)*
*+ (0.605 * percent primary use)*

[6] Keeling, J.; Bruchs, D. (2017). Chapter 7: Refrigerator Recycling Evaluation Protocol. The Uniform Methods Project: Methods for Determining Energy-Efficiency Savings for Specific Measures. Golden, CO; National Renewable Energy Laboratory. NREL/SR-7A40-6-8563. Accessed here.

*+ (0.02 * interaction percent in unconditioned space and CDDs)*
*+ (0.045 * interaction percent in unconditioned space and HDDs)]*

Data sources for the regression model inputs are shown in Table 2-5.

Table 2-5. Refrigerator UMP Regression Model Data Sources

Regression Model Input	Data Source
Appliance Age	2019 Tracking Data
Manufactured Before 1990	2019 Tracking Data
Appliance Size	2019 Tracking Data
Door Configuration	2019 Tracking Data
Primary / Secondary	2019 Participant Survey
Unconditioned Space	2019 Participant Survey
HDD / CDD	MA19R01-E*

Source: NMR (2019)

In preparing the analysis, the evaluation team compared cooling degree days (CDD) and heating degree days (HDD) from the 2018 evaluation report, which were calculated from the Typical Meteorological Year 3 (TMY3) data and based on 65 °F, to CDD and HDD data from the National Oceanic and Atmospheric Administration's National Weather Service Forecast Office, also based on 65 °F. The team elected to use the 2018 CDD and HDD values to provide year-to-year consistence, given that there was less than a 3% difference for both CDD and HDD between the two approaches.[7,8]

Table 2-6 summarizes the UMP model specifications used to estimate a refrigerator's gross annual energy consumption. The second column presents the UMP regression model coefficients, which indicate the impact of the independent variable on the UEC. The third and fifth columns (Value) show the average of corresponding characteristics (i.e., the independent variables) for participants during the relevant program year. The fourth and sixth columns (UEC) indicate the influence of the independent variable on daily consumption.

Table 2-6. Refrigerator UEC Regression Model

Independent Variable	UMP Coefficient	PY 2018		PY2019	
		Value	UEC	Value	UEC
Intercept	0.58	1.00	0.58	1.00	0.58
Appliance Age (years)	0.03	19.19	0.52	18.90	0.51
Manufactured Pre-1990	1.06	0.17	0.18	0.16	0.17
Appliance Size (cubic feet)	0.07	19.32	1.29	19.41	1.30
Single-Door Configuration	-1.98	0.03	-0.06	0.03	-0.06

[7] NMR Group, Inc. (2019). MA19R01-E Appliance Recycling Report
[8] Source link accessible here.

Independent Variable	UMP Coefficient	PY 2018		PY2019	
		Value	UEC	Value	UEC
Side-by-Side Configuration	1.07	0.20	0.21	0.21	0.22
Primary Usage Type	0.61	0.52	0.31	0.54	0.33
Located in Unconditioned Space * CDD	0.02	1.05	0.02	1.07	0.02
Located in Unconditioned Space * HDD	-0.05	5.50	-0.25	6.74	-0.30
Daily Use (kWh)			2.81		2.75
Annual Gross Energy Savings (kWh)			**1,027**		**1,005**

In 2019, the UEC decreased by 22 kWh, or approximately 2%. The increase in the average number of refrigerators located in an unconditioned space during the heating season is the primary driver for this decrease in gross energy savings, compared to 2018 when fewer refrigerators were in conditioned spaces during the heating season. The 2% decrease in the average age of recycled units and 1% increase in average appliance size have minimal impact on the UEC.

The distribution of characteristics for recycled refrigerators is presented in Appendix A and the sensitivity analysis for the savings calculation is presented in Appendix B.

2.3.1.2 Freezers

Consistent with the approach for calculating the UEC for refrigerators, the evaluation team calculated the freezer UEC using the UMP regression model, as shown below. This approach ensures that the resulting UEC is based on characteristics specific to units recycled though the program in 2019.

*Freezer UEC = 365.25 * **[**-0.955 + (0.045 * average appliance age)*
*+ (0.543 * percent manufactured before 1990)*
*+ (0.12 * average size in cubic feet)*
*+ (0.298 * percent chest configuration)*
*+ (0.082 * interaction percent in unconditioned space and CDD)*
*- (0.031 * interaction percent in unconditioned space and HDD)**]***

Data sources for each equation input are shown in Table 2-7.

Table 2-7. Freezer UMP Regression Model Data Sources

Regression Model Input	Data Source
Appliance Age	PY 2019 Tracking Data
Manufactured Before 1990	PY 2019 Tracking Data
Appliance Size	PY 2019 Tracking Data
Chest Configuration	PY 2019 Tracking Data
Unconditioned Space	PY2019 Participant Survey
HDD / CDD	MA19R01-E*

Source: NMR (2019)

Table 2-8 details the UMP model specifications used to estimate a freezer's gross annual energy consumption. The second column in this table presents the UMP regression model coefficients, which indicate the impact of the independent variables on the UEC. The third and fifth columns (Value) show the corresponding characteristics on average (i.e., the independent variables) for participants during the relevant Program Year. The fourth and sixth columns (UEC) indicate the influence of the independent variable on daily consumption.

Table 2-8. Freezer UEC Regression Model

Independent Variable	UMP Coefficient	PY 2018		PY2019	
		Value	UEC	Value	UEC
Intercept	-0.96	1.00	-0.96	1.00	-0.96
Appliance Age (years)	0.05	23.80	1.07	22.43	1.01
Manufactured Pre-1990	0.54	0.36	0.20	0.31	0.17
Appliance Size (cubic feet)	0.12	15.96	1.92	16.18	1.94
Chest Configuration	0.30	0.28	0.08	0.23	0.07
Located in Unconditioned Space * CDD	0.08	1.35	0.11	1.32	0.11
Located in Unconditioned Space * HDD	-0.03	10.11	-0.31	9.05	-0.28
Daily Use (kWh)			2.11		2.06
Annual Gross Energy Savings (kWh)			**769**		**753**

The team found that annual gross energy savings in 2019 decreased from 2018 by 16 kWh, or approximately 4%. This is primarily driven by a reduction in the average appliance age by approximately 1.4 years.

The distribution of characteristics for recycled freezers is provided in Appendix C and the sensitivity analysis for the UEC calculation is presented in Appendix D.

2.3.1.3 Dehumidifiers

The evaluation team calculated gross energy savings for recycled dehumidifiers based on the algorithm specified in the Comprehensive TRM Review (MA19R17-B-TRM) with input values from the pick-up and turn-in events tracking data.

$$kWh_{Recycling} = Dehumidification\_Load * \left(\frac{1}{Eff_{Retire}}\right)$$

Where:

Dehumidification_Load = Average capacity of dehumidifier in Pints/24 Hours
Eff_{Retire} = Average efficiency of model being recycled, in Liters/kWh

The 2019 tracking data did not include efficiency ratings for the recycled dehumidifiers, so the team referred to the Massachusetts eTRM[9] for the accepted definition of efficiency for a recycled unit:

> *"The baseline efficiency for recycling is a unit that is approximately **8 years old**, meeting the standard that was in place at the time (1.6 Liters/kWh)," where1.6 Liters/kWh is based on the 2012 Federal standard."* [10]

With this definition, and because the tracking data included capacity information for each recycled unit, the evaluation team referenced the 2012 Federal standard and assigned efficiency factors for each recycled dehumidifier based on actual capacity.

Table 2-9 lists the energy savings algorithm variable values, sources for the values, and the average energy savings for the pick-up dehumidifiers, the turn-in dehumidifiers, and the overall 2019 value for recycled dehumidifiers ($kWh_{Recycling}$).

Table 2-9. Dehumidifiers Assumptions and Average Energy Consumption

Variable	Value	Source
Dehumidification Load (Liters/year)	1,520	Comprehensive TRM Review
Eff_{Retire} (Liters/kWh)	Up to 35.00 pints/day: 1.35 35.01 – 45.00 pints/day: 1.50 45.01 – 54.00 pints/day: 1.60 54.01 – 75.00 pints/day: 1.70 75 or more pints/day: 2.50	Federal efficiency standard effective October 1, 2012
$kWh_{Pick\ Up}$ (kWh)	1,109	
$kWh_{Turn\ In}$ (kWh)	989	
$kWh_{Recycling}$ (kWh)	**1,050**	

[9] Massachusetts eTRM (2021). Accessed here.
[10] Electronic Code of Federal Regulations (2012). Accessed here.

Appendix E contains a comparison of unit savings based on assigning efficiency factors using actual capacity versus the Comprehensive TRM Review, which suggests assigning a single, deemed efficiency factor across all units. as well as the Appendix also contains the distribution of capacities for recycled units for both program tracks.

Prospective Dehumidifier Savings

As previously noted, dehumidifier unit size eligibility via the pick-up track was revised mid-2021. Dehumidifiers recycled through this track must now be between 20 to 70 pints, matching the turn-in event track requirements. This change affects the overall unit energy savings going forward; therefore, the evaluation team recommends a different prospective value for 2022 planning.

To calculate a prospective energy savings value, the evaluation team removed pick-up units from the analysis that are now ineligible based on size. Turn-in units included in the analysis remain the same. The evaluation team took the same steps as applied above to calculate 2019 evaluated savings. This resulted in an overall average UEC value of 1,020 kWh, or approximately 3% lower than the 2019 evaluated result as shown in Table 2-10. Slightly lower savings are expected, as just over half of the pick-up units in 2019 were below the new size eligibility requirements and thus less efficient.

Table 2-10. Retrospective vs. Prospective Dehumidifier Savings (kWh)

Track	2019 Evaluated UEC	Prospective UEC
Pick-up track	1,109	1,088
Turn-in track	989	989
Overall Value	**1,050**	**1,020**

2.3.2 Adjusted Gross Savings

The evaluation team estimated adjusted gross savings for refrigerators and freezers by applying a part-use factor. Part-use is an adjustment factor specific to appliance recycling, that is used to convert the UEC into an average per-unit adjusted gross savings value based on the portion of the year 2019 survey[11] respondents said they had the appliance plugged in. Note that dehumidifier savings were not adjusted as the savings algorithm already includes a dehumidification load which accounts for hours operated during the year.

As in previous evaluations, the part-use methodology relies on information from surveyed customers regarding pre-program use patterns. Specifically, part-use is calculated using a weighted average of the following three part-use categories and factors:

[11] NMR noted that a higher rate of return letters (about one half of the 161 returned out of 1,625 sent) were from the Cape Light Compact service territory, which has a larger number of vacation properties. Properties may have been sold, and summer residents may not have forwarded their Cape mail to their winter addresses. This may have caused an overstatement of the portion of the year that appliances were used, assuming seasonal residents unplug their appliances when their homes are vacant.

1. Appliances that ran all the time throughout the year (part-use = 1.0)
2. Appliances that did not run at all (part-use = 0.0)

1) Appliances that operated a portion of the year (part-use is between 0.0 and 1.0). More specifically, we completed the following steps for these units:

    - If participants said their refrigerator or freezer operated for only a portion of the year, we asked the total number of months that the appliance was plugged in

    - We divided each value by 12 to calculate the annual part-use factor for all refrigerators and freezers operated for only a portion of the year

The following sub-sections discuss part-use factors and the resulting adjusted gross savings for refrigerators and freezers.

2.3.2.1 Refrigerators

Survey results indicate that for the 92 respondents who remembered, on average refrigerators were plugged in for 88% of the year prior to recycling. Table 2-11 lists the resulting part-use factor by category.

Table 2-11. Refrigerator Part-Use Factor

Part-Use Category	Recycled Units n=92 (%)	Part-Use Factor
Not in Use	4	0.00
Used Part Time	16	0.53
Used Full Time	79	1.00
Weighted Average	**100***	**0.88**

*Results subject to rounding

Table 2-12 applies the part-use factor to gross energy savings, resulting in an adjusted gross savings of 884 kWh. Program years 2018 and 2019 showed the same part-use factors, but as mentioned above in Section 2.3.1.1, the reduction in PY2019 energy savings is driven by a higher percentage of refrigerators located in an unconditioned space for units recycled in the 2019 program.

Table 2-12. Refrigerator Adjusted Gross Savings

Savings	PY 2018		PY2019	
	Factor	Value (kWh)	Factor	Value (kWh)
Gross Energy Savings	n/a	1,027	n/a	1,005
Adjusted Gross Savings	**0.88**	**903**	**0.88**	**884**

2.3.2.2 Freezers

Seventy-five customers who recycled freezers in 2019 were surveyed, and on average, freezers were plugged in 83% of the year prior to recycling. Table 2-13 lists the resulting part-use factor by category.

Table 2-13. Freezer Part-Use Factor

Part-Use Category	Recycled Units n=75 (%)	Part-Use Factor
Not in Use	13	0.00
Used Part Time	9	0.57
Used Full Time	77	1.00
Weighted Average	100*	**0.83**

*Subject to rounding

Using the same approach for calculating adjusted gross energy savings for refrigerators, we applied the part-use factor to the UEC calculated energy consumption to calculate average per-unit adjusted gross energy savings for the 2019 program. Table 2-14 shows the PY2019 adjusted gross savings are 622 kWh, approximately 16% greater than PY2018 and driven by the larger part-use factor.

Table 2-14. Freezer Adjusted Gross Savings

Savings	PY 2018		PY2019	
	Factor	Value (kWh)	Factor	Value (kWh)
Gross Energy Savings	n/a	769	n/a	753
Adjusted Gross Savings	**0.68**	**523**	**0.83**	**622**

An increase in the freezer part-use factor could be for several reasons. It could indicate a maturing market if more infrequently used freezers were already picked up in previous years. Recall bias may also come into play, as 2019 participants were not surveyed until early 2021. Finally, the COVID-19 pandemic may have influenced survey participation in ways that we are not able to pinpoint at this time.

2.4 Additional Dehumidifier Analysis

The Residential Building Use and Equipment Characterization study's early findings suggested that a recycled dehumidifier's gross energy savings may vary depending on the unit control type and drain configuration. As the sample of dehumidifiers currently included in the Baseline Study was not designed to be representative of the Program population, the evaluation team included questions in the customer survey designed to collect the control type and drain configuration of recycled units to aid in understanding the assortment of dehumidifiers recycled through the Program.

The following sections walk through the analysis and our findings. Note that this analysis is intended to be directional in nature, to provide the PAs with an understanding of whether data derived from the Baseline Study may be representative of recycled dehumidifiers.

2.4.1 Characterization of Control Types and Drain Configurations

Table 2-15 presents the prevalence of respective configurations and control types of the dehumidifiers metered in the Baseline Study. To create a comparison, the evaluation team collected and reviewed the assortment of control types and drain configurations through the 2019 survey efforts. The survey findings indicate that almost two-thirds (63%) of the recycled units are batch dehumidifiers, where the homeowner must manually drain the collection bucket. Fewer units (57%) are continuous with a hose to drain the unit. More than half of the units (58%) are controlled by a humidistat, turning on or off based on a user-set humidity level.

Table 2-15. Dehumidifier Distribution

Configuration and Control Type	PY2019 (percent)	Metering Study (percent)
Batch - Humidistat	52%	22%
Batch – No Humidistat	11%	35%
Total Batch	**63%**	**57%**
Continuous - Humidistat	31%	28%
Continuous – No Humidistat	6%	15%
Total Continuous	**37%**	**43%**
Total with Humidistat (Batch + Continuous)	*83%*	*50%*
Total without Humidistat (Batch + Continuous)	*17%*	*50%*

2.4.2 Dehumidification Load Analysis

The evaluation team estimated dehumidification load using the following algorithm and input parameters.

$$Dehumidification\_Load = kWh_{Baseline\ Study} * Eff_{TRM}$$

Where:

- $kWh_{BaselineStudy}$ = Median energy consumption of metered units by configuration and drain type as recorded in the Baseline Study
- Eff_{TRM} = 1.6 Liters/kWh, from the Massachusetts eTRM

Input values for $kWh_{BaselineStudy}$ and Eff_{TRM} and the estimated dehumidification load are shown in Table 2-16.

Table 2-16. Dehumidification Load by Type

	Batch Humidistat	Batch No Humidistat	Continuous Humidistat	Continuous – No Humidistat
$kWh_{BaselineStudy}$	473	694	960	1,123
Eff_{TRM} (Liters/kWh)	1.6	1.6	1.6	1.6
Dehumidification load by type (Liters)	756	1,110	1,536	1,798

Next, the evaluation team determined the overall average dehumidification load across the 2019 survey respondents by calculating the weighted average of load based on the distributions shown in Table 2-15. We then compared the overall weighted average to both the overall average and median loads estimated in the Baseline Study.

Table 2-17 includes the results of this analysis and shows that the average Baseline Study load is almost 40% greater than the average of units participating in 2019, while the median Baseline load is 5% lower than the 2019 average. These results suggest that drain configurations and control types do affect energy consumption.

Table 2-17. Dehumidification Load

	Load (Liters)	Difference from 2019 (Liters)	Difference from 2019 (Percent)
2019 Units - Average	1,096	-	-
Baseline Study – Average	1,520	417	39%
Baseline Study – Median	1,047	(56)	-5%

Appendix A. 2019 Refrigerator Unit Distribution for Key Characteristics

Distributions for refrigerator size, age, and configuration are shown in the following figures.

Figure A-1. Refrigerator Size Distribution (cubic feet)

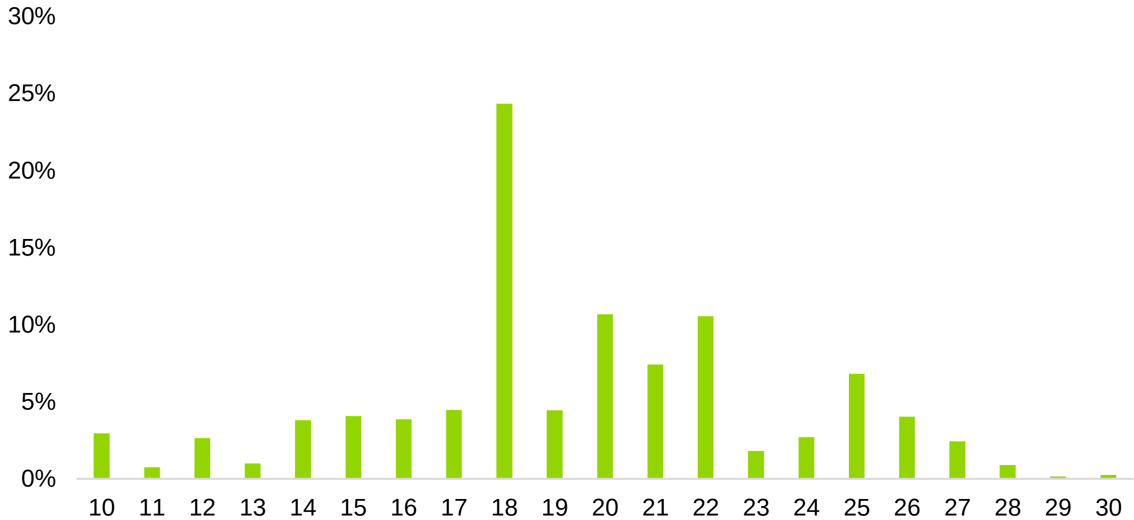


Figure A-2. Refrigerator Age Distribution (years)

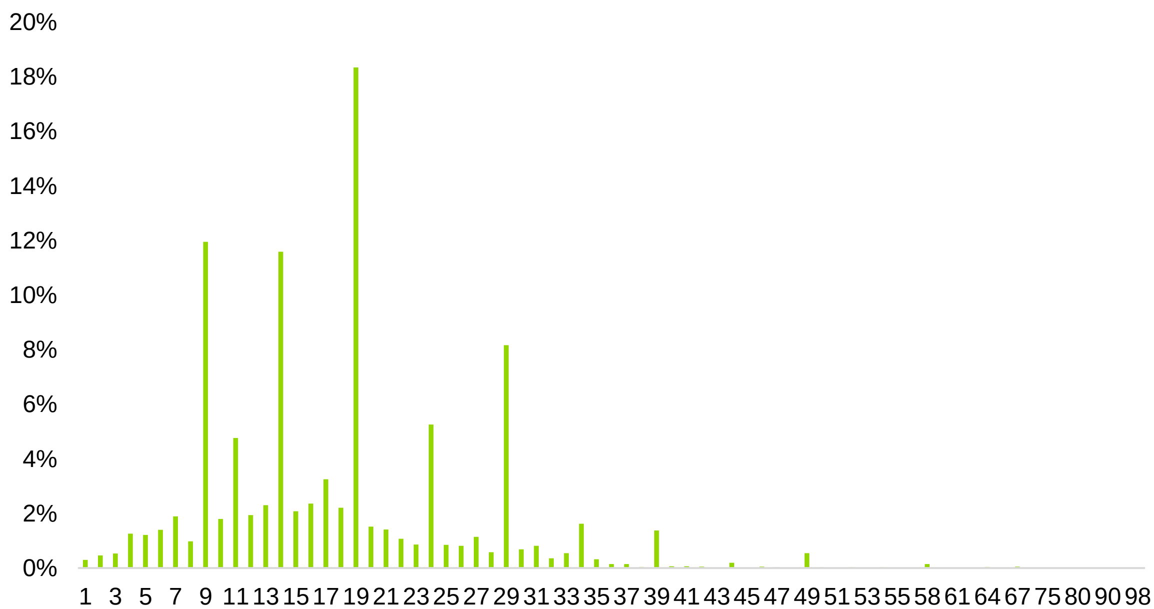
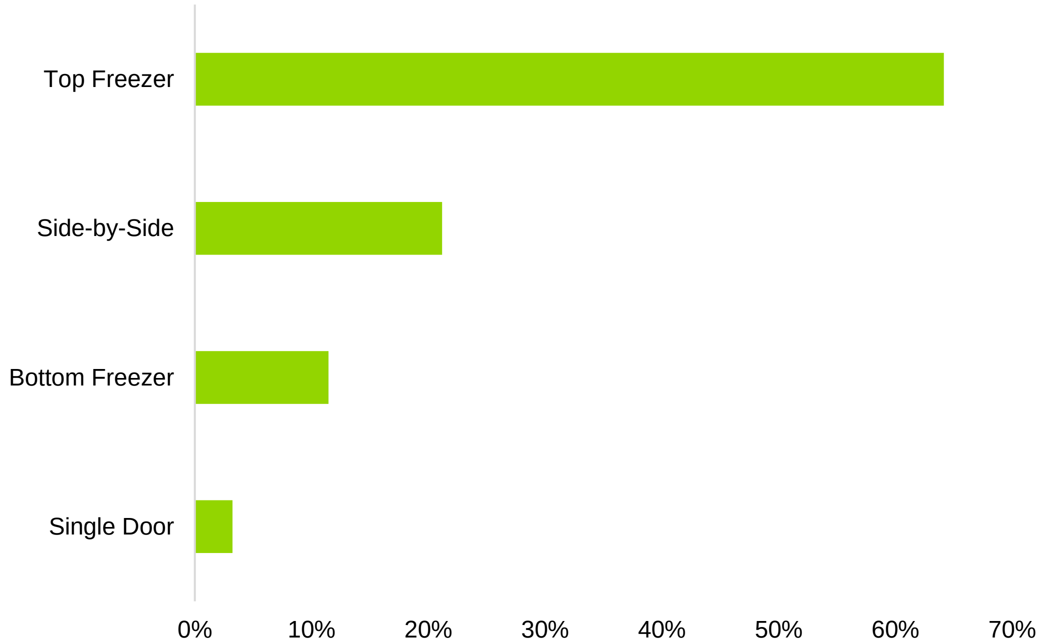


Figure A-3. Refrigeration Configuration



Appendix B. Refrigerator Sensitivity Analysis

The evaluation team compared how the 2019 UEC would change if values for unconditioned space, age, and size were the same as values in 2018. Unconditioned space causes the largest change.

Table B-1. Refrigerator Sensitivity Analysis

Independent Variable	PY2019		PY 2019 w/ PY2018 Uncond Space		PY 2019 w/ PY2018 Age		PY2019 w/ PY2018 Size	
	Value	UEC	Value	UEC		UEC	Value	UEC
Intercept	1.00	0.58	1.00	0.58	1.00	0.58	1.00	0.58
Appliance Age (years)	18.90	0.51	18.90	0.51	**19.19**	**0.52**	18.90	0.51
Manufactured Pre-1990	0.16	0.17	0.16	0.17	0.16	0.17	0.16	0.17
Appliance Size (cubic feet)	19.41	1.30	19.41	1.30	19.41	1.30	**19.32**	**1.29**
Single-Door Configuration	0.03	-0.06	0.03	-0.06	0.03	-0.06	0.03	-0.06
Side-by-Side Configuration	0.21	0.22	0.21	0.22	0.21	0.22	0.21	0.22
Primary Usage Type	0.54	0.33	0.54	0.33	0.54	0.33	0.54	0.33
Located in Unconditioned Space * CDD	1.07	0.02	**1.05**	**0.02**	1.07	0.02	1.07	0.02
Located in Unconditioned Space * HDD	6.74	-0.30	**5.50**	**-0.25**	6.74	-0.30	6.74	-0.30
Annual Gross Energy Savings (kWh)		1,005		1,026		1,008		1,005
Percent Increase (Decrease) from PY2019		NA		(2.1%)		0.3%		0.5%

Appendix C. 2019 Freezer Distribution for Key Characteristics

The following figures show freezer size, age, and configuration.

Figure C-1. Freezer Size (cubic feet)

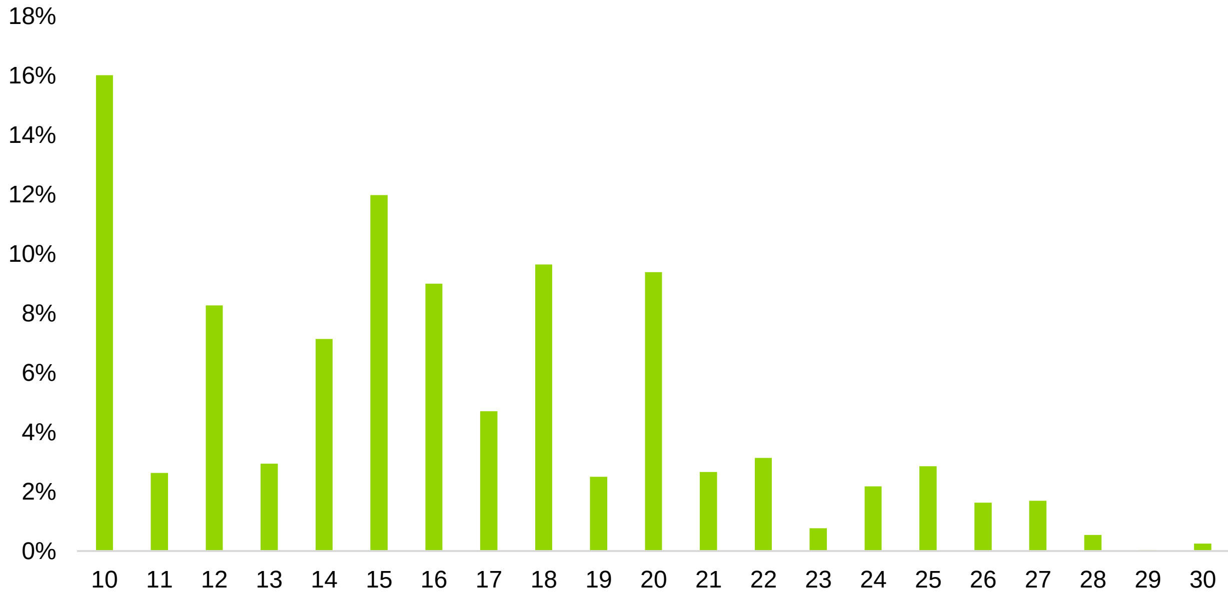


Figure C-2. Freezer Age (years)

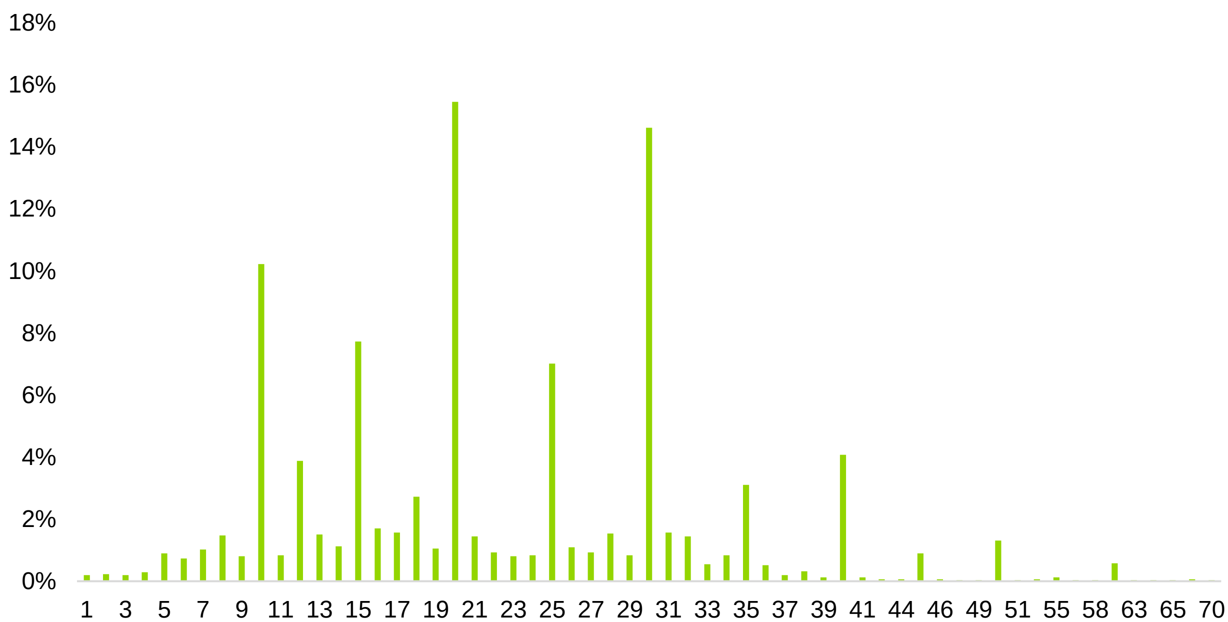
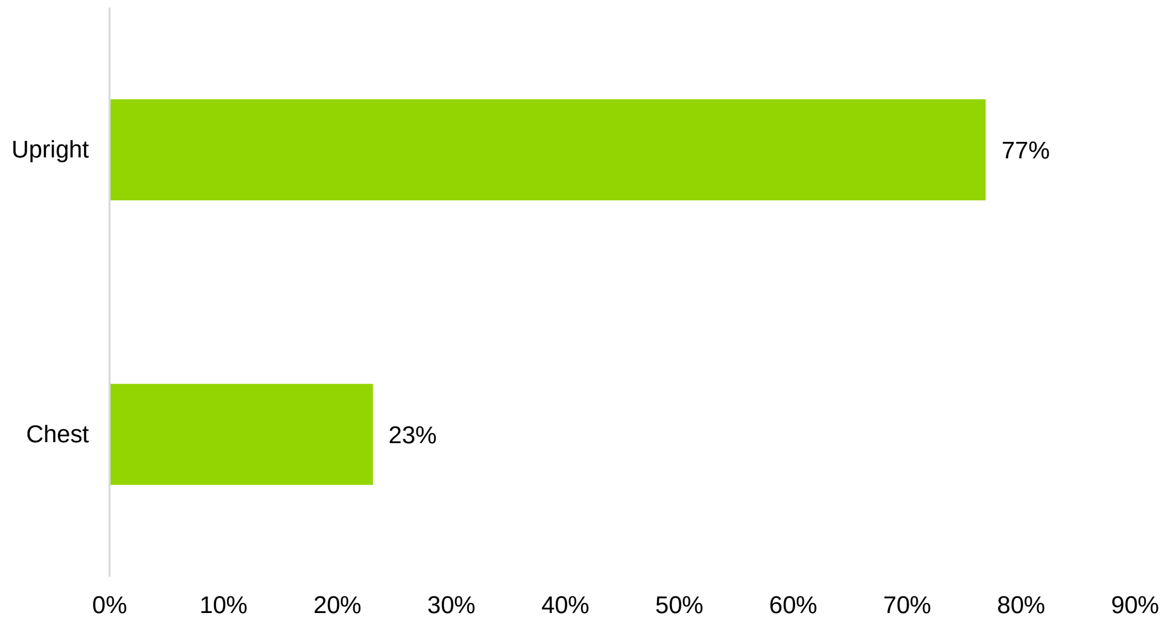


Figure C-3. Freezer Configuration



Appendix D. Freezer Sensitivity Analysis

The evaluation team explored how the 2019 freezer UEC would change if values for unconditioned space, age, and configuration were equal to 2018 values. Age had the largest effect.

Table D-1. Refrigerator Sensitivity Analysis

Independent Variable	PY2019		PY 2019 w/ PY2018 Uncond Space		PY 2019 w/ PY2018 Age		PY2019 w/ PY2018 Configuration	
	Value	UEC	Value	UEC		UEC	Value	UEC
Intercept	1.00	-0.96	1.00	-0.96	1.00	-0.96	1.00	-0.96
Appliance Age (years)	22.43	1.01	22.43	1.01	**23.80**	**1.07**	22.43	1.01
Manufactured Pre-1990	0.31	0.17	0.31	0.17	0.31	0.17	0.36	0.20
Appliance Size (cubic feet)	16.18	1.94	16.18	1.94	16.18	1.94	16.18	1.94
Chest Configuration	0.23	0.07	0.23	0.07	0.23	0.07	**0.23**	**0.07**
Located in Unconditioned Space * CDD	1.23	0.11	**1.35**	**0.15**	1.32	0.11	1.32	0.11
Located in Unconditioned Space * HDD	9.05	-0.28	**10.11**	**-0.31**	9.05	-0.28	9.05	-0.28
Annual Gross Energy Savings (kWh)		752		754		775		763
Percent Increase (Decrease) from PY2019		NA		(0.2%)		3%		1%

Appendix E. Dehumidifier Efficiency Factor and Recycled Unit Distribution Information

As discussed in Section 2.3.1.3, the evaluation team applied a baseline efficiency factor to each recycled unit based on capacity. Table E-1 shows the energy savings calculated using the 2012 Federal standard efficiency factors based on capacity compared to the energy savings calculated using the 2021 Massachusetts eTRM deemed efficiency factor of 1.6 Liters/kWh. The resulting energy savings based on applying an efficiency factor to the recycled units by capacity results in a 10% greater savings compared to using a single deemed value across all units.

$$kWh_{Recycling} = Dehumidification\_Load * \left(\frac{1}{Eff_{Retire}}\right)$$

Table E-1. Dehumidifier Efficiency Factors

Approach	Efficiency Factor Liters/kWh	Average Energy Use (kWh)	Difference (kWh)	Difference (%)
2021 Massachusetts eTRM	1.6	950	-	
2012 Federal Standard	Up to 35.00 pints/day: 1.35 35.01 – 45.00 pints/day: 1.50 45.01 – 54.00 pints/day: 1.60 54.01 – 75.00 pints/day: 1.70 75 or more pints/day: 2.50	1,050	100	10

The figures below show the size distribution of units recycled in 2019 through both the appliance pick-up track and the turn-in track. The most common capacity for the pick-up track was 25 pints, whereas the most common size recycled through the turn-in track was larger, at 50 pints.

Figure E-1. Pick-up Track: Dehumidifier Size Distribution (pints)

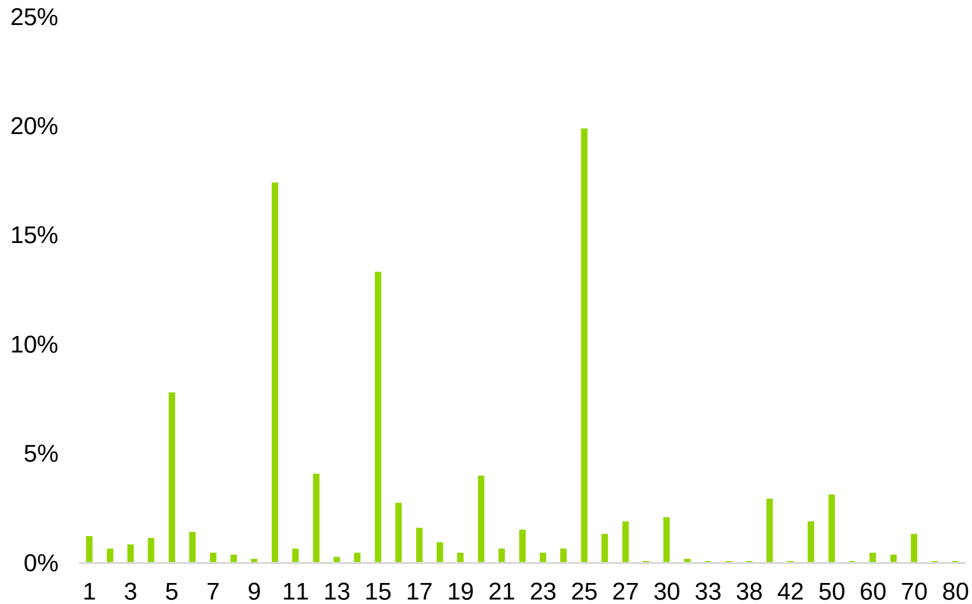


Figure E-2. Turn-in Track: Dehumidifier Size (pints)