Appliance Recycling Impact Factor Update

FINAL

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SUBMITTED TO:
National Grid Rhode Island

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RI Appliance Recycling

Evaluating the Energy Savings from an Appliance Recycling Program

NMR conducted a study to estimate gross, adjusted gross, and net energy savings for a NGRID sponsored refrigerator and freezer recycling program in Rhode Island. In comparison to 2011 program estimates, the current program resulted in lower savings, driven down by younger and more efficient units recycled through the program. Efficiency gains for refrigerators were somewhat offset by the prevalence of side-by-side door configuration, primary usage, and larger size. Results will be used to inform energy efficiency planning for 2020.

Main Takeaways

Implications

Year over year savings will decline due to the diminishing supply of older and less efficient units that get recycled through the program.

Recommendation

NMR recommends that National Grid adopt the savings for use in program planning.

Point of Guidance

Biennial (every other year) *quick hits* studies similar to this one will allow National Grid to provide more accurate savings estimates in program planning.

Key Findings

Comparison of Savings

The per-unit savings for refrigerators and freezers decreased between 2011 and 2017/2018 by 19% and 36%, respectively. The current program recycles younger units that were manufactured under increased federal efficiency standards, and therefore use less energy than those recycled in 2011.

Rhode Island and Massachusetts exhibited similar refrigerators savings in 2018, but Rhode Island's freezers savings fell below those of Massachusetts, largely reflecting the younger age of freezers in Rhode Island.

2017/2018 Impact Factors

REFRIGERATORS

Gross Energy Savings	1,004 kWh
Adjusted Gross Savings	883 kWh
Net Energy Savings	389 kWh

FREEZERS

Gross Energy Savings	724 kWh
Adjusted Gross Savings	492 kWh
Net Energy Savings	278 kWh

Appliance Characteristics

REFRIGERATORS

18 yrs Average Age	19 cu.ft Average Size
52% Primary Units	69% Top Freezer Units

FREEZERS

22 yrs Average Age	16 cu.ft Average Size
88% Secondary Units	76% Upright Units

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Executive Summary

National Grid currently sponsors a refrigerator and freezer recycling program in Rhode Island. The program collects unwanted refrigerators and freezers and pays an incentive to customers who surrender the appliances to the program. Incentives amounts varied, $25, $50, or $100, in 2017 and 2018, depending on the specific promotion National Grid offered at the time. The program makes it possible for households to avoid paying another hauler to remove an unwanted appliance, reduces the energy-use for participants, diverts units from the secondary appliance market, and ensures that units are disposed in an environmentally sound manner. Appliance Recycling Center of America (ARCA) currently serves as the implementation contractor. In 2017, 5,157 National Grid Rhode Island customers recycled 4,960 refrigerators and 626 freezers, and in 2018, 3,544 customers recycled 3,460 refrigerators and 333 freezers.

National Grid asked NMR Group, Inc. (NMR) to estimate gross, adjusted gross, and net energy savings (and a net-to-gross ratio (NTG)) based on the characteristics and alternative outcomes for refrigerators and freezers currently recycled through the program. NMR calculated these estimates by applying the characteristics of appliances recycled in Rhode Island in 2017 and 2018 to a regression equation developed for the Uniform Methods Project (UMP), supplemented with findings from a 2017 study conducted for the Massachusetts Program Administrators, as described more in the Study Approach below and in Section 1. The study also compares the current savings estimates to those derived from a 2011 study, as discussed in the main body of the report. Results will be used to inform the Rhode Island Annual Energy Efficiency Plan for 2020.

Study Terminology and Acronyms

Appliance recycling programs pay customers to get rid of products that waste energy. This logic stands in contrast to more typical energy efficiency programs that pay incentives to increase adoption of an efficient product or behavior. Likewise, appliance recycling programs come with their own terminology and savings assumptions that diverge from other efficiency programs. NMR created Table 1 to crosswalk the appliance recycling terminology with that more typically used for energy-efficiency programs. We also list the acronyms used in this report (Table 2).

The terms *primary* and *secondary* also have unique – and in the case of *secondary*, dual – meanings in the appliance market. Usually located in the kitchen, *primary refrigerators* refer to the units that households use the most. *Secondary refrigerators* tend to handle the overflow, such as extra food for holiday meals and beverage cooling. They are usually located outside of the kitchen. The primary and secondary appliance distinctions do not apply to freezers, although the term *stand-alone* may be used to distinguish the freezer integrated with a refrigerator from one devoted solely to freezing.

Confusingly, recycling programs also use *secondary* to refer to the *used appliance market*. One objective of appliance recycling programs is to prevent units from being transferred to another user, either directly (when the previous owner gives or sells the appliance to another user) or

indirectly (when the previous owner disposes of the unit in such a way that it ends up in the used appliance market). Stores that sell previously owned appliances prefer the term *secondary* to reduce potential negative connotations associated with the term *used*.

Table 1: Key Terms Used in this Report

Common Industry Recycling Program Terminology	Equivalent Energy-Efficiency Program Terminology	Definition
Unit Energy Consumption (UEC)	Gross savings	How much energy the unit used based on its age, size, configuration, and other characteristics
Part-use Adjustment	Realization Rate	Adjustment for the portion of the year the unit was plugged in
Part-use Adjusted Savings	Adjusted Gross Savings	Savings after application of the realization rate
Free Ridership	Free Ridership	The free ridership rate for appliance recycling programs accounts for units that would have been taken out of service without the program (by recycling or disposal, or because they are older than 10 years)[1]
Transferred Units	Component of Free Ridership	Considers the likely actual outcome of all units whose ownership would have transferred to a stranger or retailer without the program.[1]
Net savings	Net savings	Savings achieved after applying realization rate and accounting for free ridership and likely appliance outcomes in the absence of the program. Net savings for appliance recycling programs does not consider spillover
Net-to-gross Ratio	Net-to-gross Ratio	Net savings / Adjusted Gross Savings

[1] We use the Massachusetts values for Rhode Island because the savings algorithms depend on survey responses, which we did not conduct as part of this research.

Table 2: List of Acronyms

Acronym	Meaning
ARCA	Appliance Recycling Center of America
CDD	Cooling Degree Days
HDD	Heating Degree Days
NMR	NMR Group, Inc.
RLPNC	Residential Lighting Products and New Construction
TMY	Typical Meteorological Year
UEC	Unit Energy Consumption
UMP	Uniform Methods Project

STUDY APPROACH

As described in more detail in Section 1.3, NMR used the approach advocated in the Uniform Methods Project (UMP) to guide the estimation of gross and net energy savings.[1][2] The estimation process relied on regression equations developed for and recommended by the UMP. Program tracking data provided by ARCA, the program implementer, supplied most of the necessary inputs to estimate gross energy savings (summarized in Table 5, in the main body of the report). Lacking recent data from Rhode Island, NMR used a proxy value for the percentage of units located in unconditioned space in the summer and winter drawn from a recent Massachusetts study.[3] NMR multiplied the UMP-recommended coefficients by the average values of the units recycled through the Rhode Island program in 2017 and 2018 or the proxies drawn from the Massachusetts study to estimate per-unit gross energy savings.

We estimated adjusted gross and net energy savings through the application of realization rates and NTG ratios, also drawn from the Massachusetts study. The realization rate accounts for partial use (the percentage of the year the unit was plugged in), while the NTG ratio considers the likely dispositions of units in the absence of the program based on a combination of survey responses, unit age, and assumptions outlined in the UMP. The adjusted gross and net savings presented in this report all rely solely on Massachusetts research, so the report does not go into their calculation in detail.[4]

1[1] 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-7A40-68563. http://www.nrel.gov/docs/fy17osti/68563.pdf.

[2] The UMP was developed for the U.S. Department of Energy. As the preface explains, "The UMP provides model protocols for determining energy and demand savings that result from specific energy-efficiency measures implemented through state and utility programs…. The UMP protocols can be used by utilities, program administrators, public utility commissions, evaluators, and other stakeholders for both program planning and evaluation." *Ibid* page iv. Keeling and Bruchs developed the recycling regression equations based on the results of multiple metering studies, as discussed more in Chapter 7, *ibid*.

[3] NMR Group. 2018. *RLPNC 18-1 Appliance Recycling Report*. http://ma-eeac.org/wordpress/wp-content/uploads/RLPNC_181_ApplianceRecycleReport_26SEP2018_FINAL.pdf.

[4] The Massachusetts study describes the estimation of realization rates and NTG ratios in detail. NMR Group. 2018 *ibid.* While the *age of unit* is available for Rhode Island, NMR did not adjust free ridership, as the application of that characteristics occurs *after* determining alternative unit disposal methods as stated by survey respondents. We did not feel it was appropriate to change one parameter in a complicated algorithm that incorporates numerous pieces of information.

KEY FINDINGS

Impact Factors

Table 3 and Table 4 present the energy savings estimates for refrigerators and freezers recycled in 2017 and 2018 in Rhode Island and compare them to the results of the most recently completed impact evaluation of the Rhode Island program (2011).[5] We report results for 2017 and 2018 separately and then combined.

As the tables show, adjusted gross and net savings decreased compared to the 2011 study. The decrease in adjusted gross savings is driven almost entirely by the greater proportion of units recycled in 2017 and 2018 that were manufactured under federal efficiency standards implemented in 1987 (subsequently revised). These standards made units more efficient, which reduced gross savings. Yet, the realization rates (the impact factors for adjusted gross savings) actually *increased* from 2011 to 2017/2018 because recent participants had refrigerators and freezers plugged in for a greater part of the year prior to recycling.

Methodological differences between the 2011 and current study make it more difficult to determine what drove decreases in NTG ratios. However, the expanded availability of municipal and other recycling alternatives, and the recycling of units that were too old for resale (so they are considered free riders), play a role.

The small increase in energy use for both refrigerators and freezers between 2017 and 2018 reflects the complex interplay of efficiency, configurations, and use. At this time, preference for larger units and side-by-side or chest configurations causes savings to nudge up each year. However, NMR believes that at some point the proportion of units recycled through the program will have been manufactured under the even more stringent federal standards put in place in the later 1990s and 2000s, leading to future decreases in savings.

Table 3: Refrigerator Savings for 2017 and 2018

	Prior Study		Current Study			
	Factor	2011	Factor	2017	2018	Combined
Gross Energy Savings (kWh)	n/a	1,242	n/a	991	1,022	1,004
Adjusted Gross Energy Savings (kWh)	58%	716	88%	872	900	883
Net Savings (kWh)	69%	492	44%	384	396	389

[5] For more information on the 2011 study, see NMR Group. 2011. *Rhode Island Appliance Turn-in Program Impact Evaluation.* http://rieermc.ri.gov/wp-content/uploads/2018/03/ri-appliance-turn-in-program-impact-evaluation-report-final.pdf.

Table 4: Freezer Savings for 2017 and 2018

	Prior Study		Current Study			
	Factor	2011	Factor	2017	2018	Combined
Gross Energy Savings (kWh)	n/a	1,139	n/a	721	731	724
Adjusted Gross Energy Savings (kWh)	58%	660	68%	490	497	492
Net Savings (kWh)	59%	390	56%	274	280	278

RECOMMENDATION AND GUIDANCE

In this section, NMR offers a recommendation and a point of guidance on the findings discussed in this report.

Recommendations

Recommendation #1: NMR recommends that National Grid adopt the combined 2017/2018 annual energy savings estimates in Table 3 and Table 4 for use in planning and reporting savings for 2020.

Rationale: While the 2018 estimates suggest increased savings between 2017 and 2018, we recommend using the combined 2017/2018 number for program planning. This more conservative approach reflects the fact that the percentage of units manufactured after 1990 will continue to increase, and, all things being equal, these units use less energy. This means that, at some point, per-unit savings will likely begin to decrease.

Guidance for Future Evaluations

Guidance #1: National Grid should consider one of two approaches for updating savings for the appliance recycling program moving forward. 1) Biennial (every other year) *quick hits* studies like this one will help National Grid accurately track and update per-unit savings over time. 2) Update the Rhode Island Technical Reference Manual (TRM) to require unit-specific savings based on the methods outlined in this report.

Rationale: Savings from appliance recycling programs reflect a combination of the unit's efficiency, configurations, and use. These characteristics caused recycling energy savings to decrease between 2011 and 2017 but increase between 2017 and 2018. At some point it is likely that the proportion of units recycled will reflect more stringent federal standards put in place in the 1990s and 2000s, which will cause savings to decrease again. This suggests that regular quick hits *studies such as this one will allow for more accurate estimation of savings based on the units recycled in a given time period. Because the movement in savings was rather small between 2017 and 2018, NMR believes biennial studies would be sufficient. However, given the logistics of how the TRM is updated and applied prospectively in Rhode Island, any change in savings will necessarily lag changes in the marketplace by two to three years given a biennial* quick hit *schedule. To minimize the impact of this lag, National Grid may choose to update the TRM to require unit-specific savings based on appliance type, age, size, and configuration. Other factors, including: conditioned space, part-use, and NTG would not vary by unit but instead be set by prior program-wide evaluations. If the second option is chosen, this would require a unit-by-unit analysis on an ongoing or annual basis, this analysis could be conducted by National Grid, the implementer, or a third-party evaluator. The analysis could be completed based on the data provided by the implementer as part of this evaluation.*

Section 1 Introduction

National Grid currently sponsors a refrigerator and freezer recycling program in Rhode Island. The program collects unwanted refrigerators and freezers and pays customers an incentive of $25, $50, or $100, depending on the promotion National Grid is offering, to surrender the appliances to the program. The program makes it possible for households to avoid paying another hauler to remove an unwanted appliance, reduces the energy-use for participants, diverts units from the secondary appliance market, and ensures the environmentally sound disposal of the units. Appliance Recycling Center of America (ARCA) currently serves as the implementation contractor.

The last impact evaluation for this program was completed in 2011.[6] However, National Grid Rhode Island updated savings assumptions for the 2019 plan based on an impact evaluation of appliances recycled in 2017 in a similar program offered in Massachusetts (the Massachusetts study).[7] Like National Grid Rhode Island, the Massachusetts program administrators (PAs) had last examined their recycling program in 2011. The more recent Massachusetts study found that the savings estimates had changed between 2011 and 2017 due to differences in the characteristics of units recycled and what participants think would have happened to their units in the absence of the program.

National Grid Rhode Island asked NMR to update savings resulting from their appliance recycling program in 2017 and 2018 by drawing on the characteristics of recycled units as reported in the Rhode Island program tracking data and leveraging the results of the recent Massachusetts study for additional savings parameters not included in the tracking data. This report presents updated gross, adjusted gross, and net energy savings for use in planning and reporting.

1.1 Study Objectives

The objectives of this research were as follows:

- Identify the current characteristics of refrigerators and freezers being recycled through the program in 2017 and 2018 and compare them to those identified in the 2011 study[8].
- Calculate per-unit gross energy savings (measured as unit energy consumption or UEC, adjusted gross savings, and net savings for the 2018 program.

[6] NMR Group. 2011. *Rhode Island Appliance Turn-in Program Impact Evaluation.* http://rieermc.ri.gov/wp-content/uploads/2018/03/ri-appliance-turn-in-program-impact-evaluation-report-final.pdf

[7] NMR Group, Inc. 2018. *RLPNC 18-1 Appliance Recycling Report.* http://ma-eeac.org/wordpress/wp-content/uploads/RLPNC_181_ApplianceRecycleReport_26SEP2018_FINAL.pdf

[8] Including both the impact evaluation linked above as well as the related process evaluation. NMR Group, Inc. 2011. *Rhode Island Appliance Turn-in Program Evaluation.* http://rieermc.ri.gov/wp-content/uploads/2018/03/ri-appliance-turnin-prog-eval-rept-final-03-04-11.pdf,

1.2 DATA SOURCES

The study relied primarily on 2017 and 2018 program tracking data provided by ARCA, the program implementer. The 2017 dataset included records for 5,586 recycled appliances (4,960 refrigerators and 626 freezers – recycled by 5,157 unique customers). The 2018 dataset included records for 3,793 recycled appliances (3,460 refrigerators and 333 freezers – recycled by 3,544 unique customers).[9] Prior to calculating the program averages and proportions for estimating gross energy savings, NMR reviewed the data, plotting distributions and identifying outliers. Given the importance of age to the calculation of gross energy savings (which contains inputs for both age and date of manufacture), we compared the average age of refrigerators and freezers with and without units 60 years or older (which we identified as outliers)[10]. We determined that including these older units had very little impact on the averages, so we retained them in the savings estimation analysis. In the 2017 data, we excluded one refrigerator because its model type was missing in the data set, and we could not confirm the model type though a model number search.[11] NMR then calculated the average values and proportions of units for the necessary regression model inputs (Section 2). Appendix A contains a data description for the most critical factors used to calculate gross energy savings.

1.3 SPREADSHEET-BASED SAVINGS UPDATE

We updated estimates of per-unit gross savings for both refrigerators and freezers for 2017, 2018, and the two years combined using regressions performed for and recommended in the Uniform Methods Project (UMP)[12,13] and inputs derived from Rhode Island program tracking data, the Massachusetts study, and weather data. The UMP derived the recommended regression equations based on the results of numerous metering studies, as described more in the chapter.[14] NMR performed spreadsheet-based calculations that applied UMP-recommended coefficients to the average values of the units recycled through the Rhode Island program in 2017 and 2018 and inputs identified in the Massachusetts study, including the percentage of units located in unconditioned space in the summer and winter, realization rates, and net-to-gross ratios (NTG). We also used Typical Meteorological Year 3 (TMY3) data for Rhode Island, which the UMP regression uses in an interactive effect with unconditioned space in the gross savings calculation.

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[9] The program experienced a one-year hiatus in 2016 due to the unexpected closure of the previous implementation contractor. The hiatus likely explains the greater number of appliances recycled in 2017 compared to 2018, as the 2017 program recycled two years' worth of refrigerators and freezers.

[10] The 2017 sample had 21 refrigerators and 2 freezers that were 60 years or older. The 2018 sample had 1 refrigerator and 14 freezers that were 60 years or older.

[11] The final estimation of 2017 gross energy savings relied on 4,959 refrigerators and 626 freezers whereas the 2018 gross energy savings utilized the full sample.

[12] 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-7A40-68563. http://www.nrel.gov/docs/fy17osti/68563.pdf.

[13] The UMP was developed for the U.S. Department of Energy. As the preface explains, "The UMP provides model protocols for determining energy and demand savings that result from specific energy-efficiency measures implemented through state and utility programs…. The UMP protocols can be used by utilities, program administrators, public utility commissions, evaluators, and other stakeholders for both program planning and evaluation." *Ibid.,* page iv.

[14] *Ibid.*

The realization rate accounts for partial use (the percentage of the year the unit was plugged in), while the NTG ratio considers the likely dispositions of units in the absence of the program based on a combination of survey responses, unit age, and assumptions outlined in the UMP.[15] Table 5 summarizes the inputs and their sources, and the UMP regression equations appear below the table.

Table 5: Data Sources and Approaches for Energy Savings

Algorithm Inputs	Savings Type	Data Source
UMP Regression Inputs		
Appliance Age	Gross	Program Tracking
Manufactured before 1990[1]	Gross	Program Tracking
Appliance Size	Gross	Program Tracking
Door Configuration	Gross	Program Tracking
Primary / Secondary (Refrigerator Only)	Gross	Program Tracking
Unconditioned Space	Gross	Massachusetts Study
Cooling and Heating Degree Days	Gross	TMY3
Post Adjustments Following UMP Guidance		
Realization Rate (% of Year Plugged In)	Adjusted Gross	Massachusetts Study
Net-to-Gross Ratio	Net	Massachusetts Study

[1] Increased federal efficiency standards (since 1987), introduction of the ENERGY STAR label (1992), and reduced performance due to age caused both *age of unit* and *date of manufacturer* to have net effects on appliance use in the UMP regression model.

$$
\begin{aligned}
&Refrigerator\ UEC \\
&\quad = 365.25 * (0.582 + \ 0.027(average\ appliance\ age)) \\
&\quad + 1.055(\%\ manufactured\ before\ 1990) + 0.067(average\ size\ in\ cuft) \\
&\quad + \ -1.977(\%\ single - door) + 1.071(\%\ side - by - side\ door) \\
&\quad + 0.605(\%\ primary\ use) \\
&\quad + \ .020(interaction\ \%\ in\ unconditioned\ space\ and\ CDD) \\
&\quad + \ -0.045(interaction\ \%\ in\ unconditioned\ space\ and\ HDD)
\end{aligned}
$$

[15] The Massachusetts study describes the estimation of realization rates and NTG ratios in detail. NMR Group. 2018 *ibid.*

$$Freezer\ UEC = 365.25 * (-0.955 + 0.045(average\ appliance\ age) + 0.543(\%\ manufactured\ before\ 1990) + 0.12(average\ size\ in\ cuft) + 0.298(\%\ chest\ configuration) + .082(interaction\ \%\ in\ unconditioned\ space\ and\ CDD) + -0.031(interaction\ \%\ in\ unconditioned\ space\ and\ HDD)$$

Section 2 Energy Consumption and Savings

The primary objectives of this study involved updating gross energy savings and net energy savings for the Appliance Recycling Program, as discussed in this section of the report. We compare these estimates to current TRM values. This section also provides a deeper look at the role the program plays in the decision to recycle the unit, the range of alternative appliance outcomes, and the degree to which financial and physical considerations may limit alternative ways of removing the appliance.

Key findings include the following:

- As expected, the per-unit savings for refrigerators and freezers decreased between 2011 and 2017/2018. The current program recycles younger units that were manufactured under increased federal efficiency standards, and therefore use less energy than those recycled in 2011.
- Per-unit refrigerator impact factors in 2017 and 2018 were approximately as follows:
  - Gross energy savings ≈ 1,000 kWh
  - Adjusted gross energy savings ≈ 900 kWh
  - Net energy savings ≈ 400 kWh
- Per-unit freezer impact factors in 2017 and 2018 were approximately as follows:
  - Gross energy savings (UEC) ≈ 725 kWh
  - Adjusted gross energy savings ≈ 500 kWh
  - Net energy savings ≈ 300 kWh
- Both refrigerator and freezer savings went up between 2017 and 2018, driven largely by the greater size of units recycled and, for refrigerators, the increased prevalence of side-by-side door configurations and primary units.
- Rhode Island and Massachusetts exhibited similar refrigerators savings in 2018, but Rhode Island's freezers savings fell below those of Massachusetts, largely reflecting the younger age of freezers in Rhode Island.

2.1 Gross Energy Consumption (UEC)

Table 6 and Table 7 summarize the calculation of gross energy savings for refrigerators and freezers, respectively. The first column shows the UMP-recommended regression inputs and the second shows the regression coefficients. The third column lists the 2017 values for those inputs, the fifth column lists the 2018 values, and the seventh column lists the combined 2017 and 2018 values. The fourth, sixth, and eighth columns show the effect each input has on energy use. The results in the fourth, sixth, and eighth columns are equal to the first column multiplied by the third,

fifth, and seventh columns, respectively (with some rounding error). The daily use sums across the individual inputs, while the annual gross energy savings multiplies daily use by 365.25.[16]

The results in Table 6 suggest that gross energy savings for refrigerators rose by three percent, from 991 kWh to 1,022 kWh. This increase reflects changes in the characteristics of units recycled through the program that result in greater energy use (and thus higher savings when the unit is removed from service). In particular, unit size and the prevalence of side-by-side door configuration and primary usage increased between the 2017 and 2018 programs. Unit size increased from 19.09 cubic feet to 19.35 cubic feet, side-by-side door configuration from 18% of units to 23% of units, and primary use from 49% of units to 57% of units.

Table 6: Calculation of Gross Energy Savings (UEC) for Refrigerators[1]

	UMP	2017 Results		2018 Results		Combined Results	
Input	Coefficient	Value	UEC	Value	UEC	Value	UEC
Intercept	0.582	1.000	0.582	1.000	0.582	1.000	0.582
Appliance Age (years)	0.027	18.390	0.497	17.820	0.481	18.150	0.490
Manufactured Pre-1990	1.055	0.132	0.139	0.127	0.134	0.130	0.137
Appliance Size (cubic feet)	0.067	19.090	1.279	19.350	1.296	19.200	1.286
Single-door Configuration	-1.977	0.033	-0.065	0.031	-0.061	0.032	-0.064
Side-by-side Configuration	1.071	0.185	0.198	0.215	0.231	0.197	0.211
Primary Usage Type	0.605	0.488	0.296	0.573	0.347	0.523	0.317
Located in Unconditioned Space * CDDs[2]	0.020	1.204	0.024	1.204	0.024	1.204	0.024
Located in Unconditioned Space * HDDs[3]	-0.045	5.233	-0.235	5.233	-0.235	5.233	-0.235
Daily Use (kWh)			**2.714**		**2.799**		**2.749**
Annual Gross Energy Savings (kWh)			**991**		**1,022**		**1,004**

[1] Results subject to rounding error.
[2] 71% located in space not cooled in the summer, 619.5 CDD divided by 365.25 to yield average daily CDD.
[3] 31% located in space not heated in the winter, 6165.25 HDD divided by 365.25 to yield average daily HDD.

[16] The model is a linear regression, so to figure out the effect of any single input, one multiplies the coefficient by the value. For example, the impact of appliance size on daily energy use is *0.07 x size in cubic feet*. For 2018, this is 0.07x19.35=1.30.

The gross energy savings for freezers increased by about two percent (Table 7), from 721 to 731 kWh. Participants in 2018 recycled slightly larger freezers in 2018, and the units were also more likely to have a chest configuration, which also uses more energy.

Table 7: Calculation of Gross Energy Savings (UEC) for Freezers[1]

	UMP	2017 Results		2018 Results		Combined Results	
Input	Coefficient	Value	UEC	Value	UEC	Value	UEC
Intercept	-0.955	1.000	-0.955	1.000	-0.955	1.000	-0.955
Appliance Age (years)	0.045	22.340	1.005	22.200	0.999	22.290	1.003
Dummy: Manufactured Pre-1990	0.543	0.270	0.147	0.288	0.16	0.276	0.150
Appliance Size (cubic feet)	0.120	15.630	1.876	15.780	1.89	15.680	1.882
Dummy: Chest Configuration	0.298	0.243	0.072	0.267	0.08	0.251	0.075
Located in Unconditioned Space * CDDs[2]	0.082	1.543	0.127	1.543	0.127	1.543	0.127
Located in Unconditioned Space * HDDs[3]	-0.031	9.621	-0.298	9.621	-0.298	9.621	-0.298
Daily Use (kWh)			**1.973**		**2.002**		**1.983**
Annual Gross Energy Savings (kWh)			**721**		**731**		**724**

[1] Results subject to rounding error.
[2] 91% located in space not cooled in the summer, 619.5 CDD divided by 365.25 to yield average daily CDD.
[3] 57% located in space not heated in the winter, 6165.25 HDD divided by 365.25 to yield average daily HDD.

For both refrigerators and freezers, it is important to note that characteristics related to size, configuration, and manner of use offset efficiency gains associated with the recycling of younger units. The dynamic between age and other characteristics suggests the need for regular spreadsheet-based updates to savings.

2.2 Adjusted Gross and Net Energy Savings

As explained in the RLPNC 18-1 Appliance Recycling Report for Massachusetts, NMR estimated realization rates based on partial use – the portion of the year survey respondents had appliances plugged in the year prior to participation. On average, Massachusetts respondents used refrigerators 88% of the year and freezers 68% of the year in 2017. Likewise, based on a combination of survey responses and UMP-derived assumptions about alternative appliance outcomes if not recycled through the program, the RLPNC 18-1 Appliance Recycling Report found

the NTG ratios to be 44% for refrigerators and 56% for freezers. This study conducted no primary research on realization rates or NTG.

NMR applied the 2017 realization rates and NTG from the recent Massachusetts study to the gross energy savings for 2017 and 2018 (Table 8 and Table 9). These calculations yielded 2017 adjusted gross energy savings of 872 kWh for refrigerators and 490 kWh for freezers. Net savings were 384 kWh and 274 kWh respectively. For 2018, adjusted gross energy savings were 900 kwh for refrigerators and 497 kWh for freezers. Net savings were 396 kWh and 280 kWh, respectively. These tables also present results of the 2017 and 2018 combined values.

Table 8: Calculation of Refrigerator Adjusted Gross Energy Savings[1]

	Factor	2017	2018	Combined
Gross Energy Savings (kWh)	n/a	991	1,022	1,004
Adjusted Gross Energy Savings (kWh)	88%	872	900	**883**
Net Savings (kWh)	44%	384	396	**389**

[1] Results subject to rounding error.

Table 9: Calculation of Freezer Adjusted Gross Energy Savings[1]

	Factor	2017	2018	Combined
Gross Energy Savings (kWh)	n/a	721	731	724
Adjusted Gross Energy Savings (kWh)	68%	490	497	**492**
Net Savings (kWh)	56%	274	280	**278**

[1] Results subject to rounding error.

2.3 COMPARISONS TO THE 2011 RHODE ISLAND STUDY

Table 10 summarizes the gross savings estimates for refrigerators and freezers recycled in 2011 and 2017/2018. The first and third columns show the estimated savings (the averages of two estimation methods reported in Table ES-1 in the 2011 study).[17] The second and fourth columns show the 2017 and 2018 combined energy savings for the current program. The 2018 Rhode Island TRM assumptions align closely with the results of the 2011 study.[18]

The gross savings estimates suggest that refrigerator savings decreased by 19%, from 1,242 kWh to 1,004 kWh. Similarly, for freezers, gross savings estimates decreased by 36 percent, from 1,139 kWh to 724 kWh. These decreases for both appliances reflect the fact that the program currently recycles younger units that were manufactured under increased federal efficiency standards, and therefore use less energy than those recycled in 2011. Refrigerator savings,

[17] NMR Group. 2011. *Rhode Island Appliance Turn-in Program Impact Evaluation.* http://rieermc.ri.gov/wp-content/uploads/2018/03/ri-appliance-turn-in-program-impact-evaluation-report-final.pdf ;
NMR Group, Inc. 2011. *Rhode Island Appliance Turn-in Program Evaluation.* http://rieermc.ri.gov/wp-content/uploads/2018/03/ri-appliance-turnin-prog-eval-rept-final-03-04-11.pdf,
[18] National Grid. 2018. *Rhode Island Technical Reference Manual For Estimating Savings from Energy Efficiency Measures 2018 Program Year* http://www.ripuc.org/eventsactions/docket/4755-NGrid-2018-TRM-RI.pdf.

however, were offset by the increased prevalence in 2017/2018 of characteristics associated with higher energy use – primary usage, side-by-side door configuration, and larger size.

This study did not conduct primary research on the realization rates and NTG ratios used to estimate adjusted gross and net savings, but we instead relied on the Massachusetts study results. The results in Massachusetts suggested that realization rates increased for both appliances due to their being plugged in for a greater proportion of the year prior to recycling than in 2011 (especially for primary refrigerators). The NTG rates remained stable for freezers in both the 2011 Massachusetts and the 2011 Rhode Island studies. However, NTG decreased for refrigerators. Methodological differences make it difficult to pinpoint the reasons for the decrease, but two contributors included the greater prevalence of municipal and other recycling alternatives, and the assumption that secondary appliance dealers would not accept/sell units that were more than ten years old. Both of these factors increase free-ridership, which reduced NTG ratios.

Table 10: Comparison of Refrigerator Impact Factors[1]

	2011 Study		Current Study	
	Factor	Savings	Factor	Savings
Gross Energy Savings (kWh)	n/a	1,242	n/a	1,004
Adjusted Gross Energy Savings (kWh)[2]	58%	716	88%	883
Net Savings (kWh)[2]	69%	492	44%	389

[1] Results subject to rounding error.
[2] Adjusted gross and net savings came directly from the 2011 report; 2017/2018 adjusted gross and net savings based on the application of realization rates and NTG ratios, respectively, as described in Table 8 and Table 9 above.

Table 11: Comparison of Freezer Impact Factors[1]

	2011 Study		Current Study	
	Factor	Savings	Factor	Savings
Gross Energy Savings (kWh)	n/a	1,139	n/a	724
Adjusted Gross Energy Savings (kWh)[2]	58%	660	68%	492
Net Savings (kWh)[2]	59%	390	56%	278

[1] Results subject to rounding error.
[2] Adjusted gross and net savings came directly from the 2011 report; 2017/2018 adjusted gross and net savings based on the application of realization rates and NTG ratios, respectively, as described in Table 8 and Table 9 above.

2.4 Comparisons to the Recent Massachusetts Study

Table 12 and Table 13 compare the input values used to estimate 2018 gross energy savings for refrigerators and freezers in Rhode Island and Massachusetts, respectively. Table 14 shows adjusted gross and net savings after the application of the same impact factors to gross savings for both states.

Rhode Island and Massachusetts exhibited similar energy savings for refrigerators in 2018 (Table 12). Participants in Massachusetts recycled older refrigerators whereas Rhode Island participants recycled slightly larger units and had slightly higher prevalence of side-by-side units and primary

usage units. Overall, the slight differences balanced out, so that per-unit refrigerator savings in both states were virtually the same (1,022 kWh in Rhode Island and 1,027 in Massachusetts).

The gross energy savings for freezers recycled in Rhode Island is 5% lower than freezer units recycled in Massachusetts, 731 kWh compared to 769 kWh (Table 13). Participants in Rhode Island recycled slightly younger and smaller freezers than participants in Massachusetts, resulting in smaller savings when the units are removed from use.

The adjusted gross and net savings reflect the application of the same realization rates and NTG ratios to each state.

Table 12: Comparison of Gross Energy Savings (UEC) for Refrigerators[1]

	UMP	Rhode Island		Massachusetts	
Input	Coefficient	Value	UEC	Value	UEC
Intercept	0.58	1.00	0.58	1.00	0.58
Appliance Age (years)	0.03	17.82	0.48	19.19	0.52
Manufactured Pre-1990	1.06	0.13	0.13	0.17	0.18
Appliance Size (cubic feet)	0.07	19.35	1.30	19.32	1.29
Single-door Configuration	-1.98	0.03	-0.06	0.03	-0.06
Side-by-side Configuration	1.07	0.22	0.23	0.20	0.21
Primary Usage Type	0.61	0.57	0.35	0.52	0.31
Located in Unconditioned Space * CDDs	0.02	1.20	0.02	1.05	0.02
Located in Unconditioned Space * HDDs	-0.05	5.23	-0.24	5.50	-0.25
Daily Use (kWh)			**2.80**		**2.81**
Annual Gross Energy Savings (kWh)			**1,022**		**1,027**

[1] Results subject to rounding error.

Table 13: Comparison of Gross Energy Savings (UEC) for Freezers[1]

Input	UMP Coefficient	Rhode Island Value	Rhode Island UEC	Massachusetts Value	Massachusetts UEC
Intercept	-0.96	1.00	-0.96	1.00	-0.96
Appliance Age (years)	0.05	22.20	1.00	23.80	1.07
Dummy: Manufactured Pre-1990	0.54	0.29	0.16	0.36	0.19
Appliance Size (cubic feet)	0.12	15.78	1.89	15.96	1.92
Dummy: Chest Configuration	0.30	0.27	0.08	0.28	0.08
Located in Unconditioned Space * CDDs	0.08	1.54	0.13	1.35	0.11
Located in Unconditioned Space * HDDs	-0.03	9.62	-0.30	10.11	-0.31
Daily Use (kWh)			**2.00**		**2.11**
Annual Gross Energy Savings (kWh)			**731**		**769**

[1] Results subject to rounding error.

Table 14: Comparison of 2018 RI and MA Impact Factors[1]

	Refrigerator			Freezer		
	Factors	RI	MA	Factors	RI	MA
Gross Energy Savings (kWh)	n/a	1,022	1,027	n/a	731	769
Adjusted Gross Energy Savings (kWh)	88%	900	903	68%	497	523
Net Savings (kWh)	44%	396	398	56%	280	295

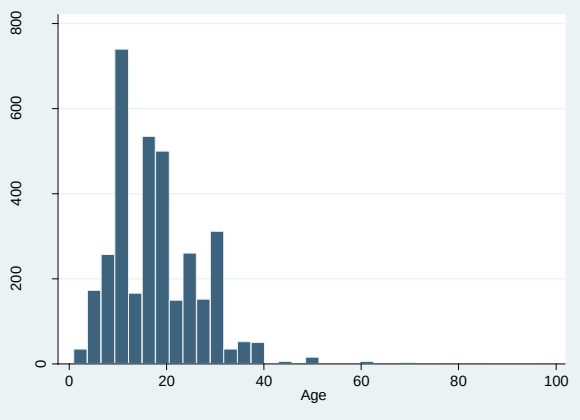
[1] Results subject to rounding error.
[2] Adjusted gross and net savings in both states based on the application of realization rates and NTG ratios, respectively, presented in Table 8 and Table 9 above.

Appendix A Additional Findings

The following tables and graphs describe the inputs in the calculation of gross energy savings (UEC). Note that the sample sizes change due to missing data for some inputs.

Figure 1. Distribution of Recycled Refrigerator Age

A. 2017 (n=4,960)



B. 2018 (n=3,460)

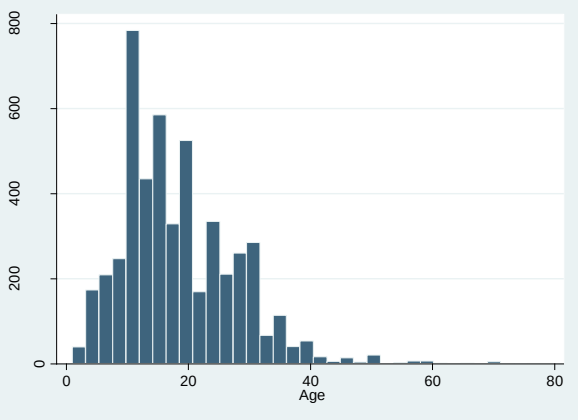
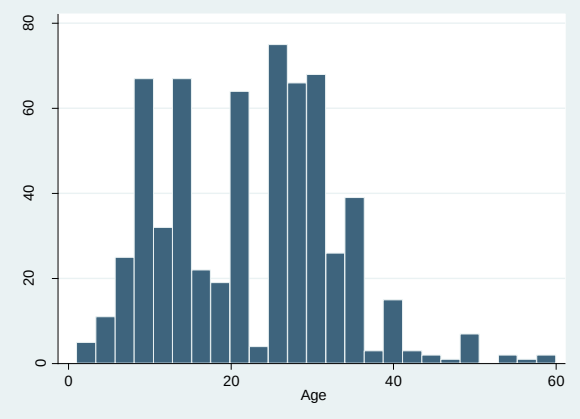


Figure 2. Distribution of Recycled Freezer Age

A. 2017 (n=626)



B. 2018 (n=333)

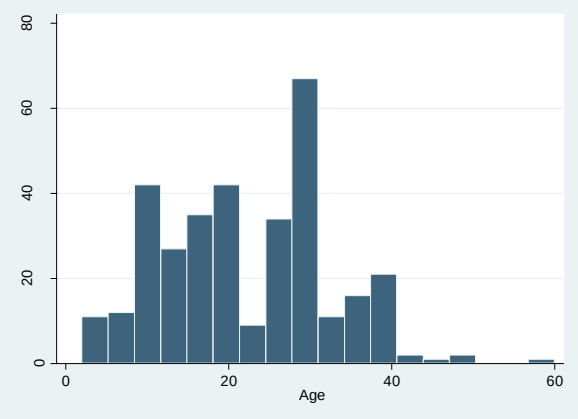
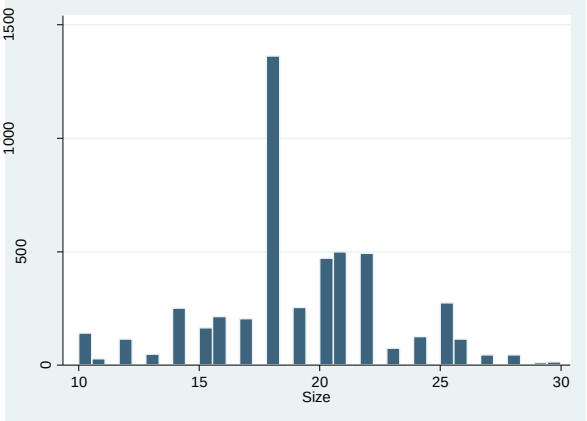


Figure 3. Distribution of Recycled Refrigerator Size

A. 2017 (n=4,960)



B. 2018 (n=3,460)

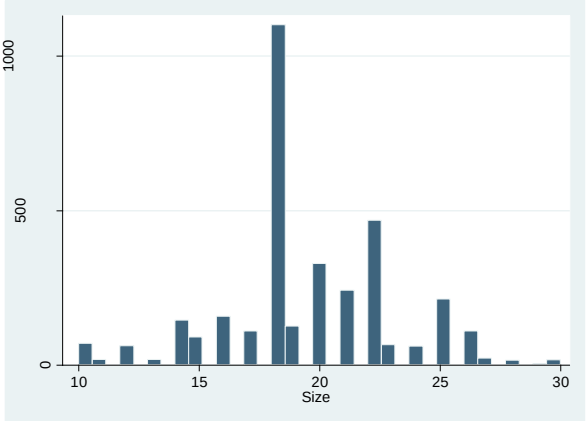
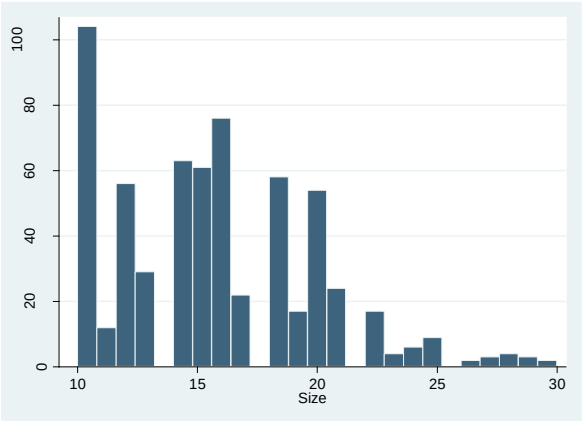


Figure 4. Distribution of Recycled Freezer Size

A. 2017 (n=626)



B. 2018 (n=333)

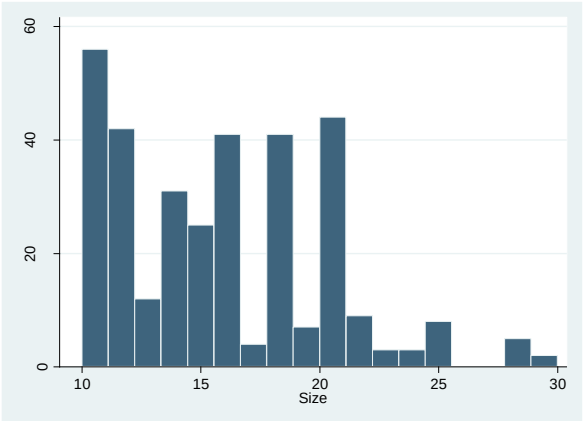


Table 15. Recycled Unit Year of Manufacture

Unit Type	Unit Use	2017		2018	
		Count	Percentage	Count	Percentage
Refrigerators	Pre-1990	655	13%	439	13%
	1990 and later	4,305	87%	3,021	87%
	Total Refrigerator	**4,960**		**3,460**	
Freezers	Pre-1990	169	27%	96	29%
	1990 and later	457	73%	237	71%
	Total Freezer	**626**		**333**	

Table 16. Recycled Unit Configuration

Unit Type	Door Configuration	2017		2018	
		Count	Percentage	Count	Percentage
Refrigerators	Bottom Freezer	337	7%	317	9%
	Side-by-side	916	18%	745	22%
	Single Door	164	3%	107	3%
	Top Freezer	3,542	71%	2,291	66%
	Total Refrigerator	**4,959**		**3,460**	
Freezers	Chest	152	24%	89	27%
	Upright	474	76%	244	73%
	Total Freezer	**626**		**333**	

Table 17. Recycled Unit Use

Unit Type	Unit Use	2017		2018	
		Count	Percentage	Count	Percentage
Refrigerators	Primary	2,422	49%	1,984	57%
	Secondary	2,538	51%	1,476	43%
	Total Refrigerator	**4,960**		**3,460**	
Freezers	Primary	78	12%	36	11%
	Secondary	548	88%	297	89%
	Total Freezer	**626**		**333**	