



# MA19R01-E Appliance Recycling Report

FINAL

March 26, 2019

SUBMITTED TO:

Massachusetts Program Administrators  
Energy Efficiency Advisory Council Consultants

SUBMITTED BY:

NMR Group, Inc.

**NMR**  
Group, Inc.

# MA Appliance Recycling

Evaluating the Energy Savings from an Appliance Recycling Program

NMR conducted a follow-up study to the MA RLPNC 18-1 Appliance Recycling study to update gross, adjusted gross, and net energy savings for the MassSAVE Refrigerator and Freezer Recycling Initiative. The 2018 program year had higher savings than the prior year. The increased savings reflect the larger size of both refrigerators and freezers recycled by the program. For refrigerators, a greater proportion of primary use units and those with side-by-side doors also contributed to greater savings.

## Key Findings



REFRIGERATORS

Gross Energy Savings

**1,027 kWh**

Adjusted Gross Savings

**904 kWh**

Net Energy Savings

**398 kWh**



FREEZERS

Gross Energy Savings

**769 kWh**

Adjusted Gross Savings

**523 kWh**

Net Energy Savings

**295 kWh**

## Main Takeaways

### Recommendation

NMR recommends that the PAs adopt the energy savings estimates above for use in the 2018 annual report.

### Point of Guidance

Annual quick hit studies, like this one, will allow the PAs to update savings estimates for annual reports.

## Table of Contents

<b>EXECUTIVE SUMMARY</b> .....	<b>1</b>
STUDY TERMINOLOGY .....	1
STUDY APPROACH .....	2
KEY FINDINGS.....	3
Impact Factors .....	3
RECOMMENDATIONS AND GUIDANCE .....	4
Recommendation.....	4
Guidance .....	4
<b>SECTION 1    INTRODUCTION</b> .....	<b>5</b>
1.1    STUDY OBJECTIVES.....	5
1.2    STUDY TERMINOLOGY.....	5
1.3    DATA SOURCES.....	6
1.4    SPREADSHEET-BASED SAVINGS UPDATE .....	7
1.4.1    Revisions to 2017 Per-unit Gross Savings Estimates .....	8
<b>SECTION 2    ENERGY CONSUMPTION AND SAVINGS</b> .....	<b>10</b>
2.1    GROSS ENERGY CONSUMPTION (UEC) .....	10
2.2    ADJUSTED GROSS AND NET ENERGY SAVINGS.....	12
<b>SECTION 3    CONCLUSIONS AND RECOMMENDATIONS</b> .....	<b>13</b>
3.1    CONCLUSIONS.....	13
3.2    RECOMMENDATIONS .....	13
3.3    GUIDANCE.....	14
<b>APPENDIX A    ADDITIONAL FINDINGS</b> .....	<b>15</b>
<b>APPENDIX B    GROSS AND ADJUSTED GROSS ENERGY SAVINGS – 2017 REVISIONS</b> .....	<b>18</b>

### List of Acronyms

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

## Executive Summary

The Massachusetts Program Administrators (PAs) sponsored a refrigerator and freezer recycling program (the Program) in 2018 through the Residential Consumer Products Core Initiative. The program paid participants an incentive of \$50, or \$100 during special promotions, to recycle refrigerators and stand-alone freezers.<sup>1</sup> In 2018, the program provided 18,405 rebates: 15,717 for recycled refrigerators and 2,688 for recycled freezers.

In 2017, the PAs and Energy Efficiency Advisory Council Consultants (EEAC Consultants) completed an impact and process study to estimate per unit savings based on the characteristics and alternative outcomes for refrigerators and freezers recycled through the program.<sup>2</sup> This report updates the per unit savings estimates based on the characteristics of refrigerators and freezers recycled through the program in 2018. This update is necessary since expected savings change based on the characteristics of recycled appliances, which change over time. This report addresses the evaluated per unit impact factors for gross and adjusted gross savings estimates for 2018.

## STUDY TERMINOLOGY

Appliance recycling programs are designed to achieve energy savings by paying customers to remove less efficient, but operable, appliances from service. NMR created [Table 4](#) in the main body of the report to crosswalk the appliance recycling terminology with that more typically used by the PAs. This report strives to use the terminology that aligns with the MA Technical Resource Manual and reporting needs, but, at times we default to the common industry terminology for the sake of clarity and documentation should the PAs repeat this study in the future.

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<sup>1</sup> The Program's website indicates that the incentive is currently \$75 (as of February 12, 2019). <https://www.masssave.com/en/shop/recycling/refrigerator-and-freezer-recycling/>.

<sup>2</sup> NMR Group, Inc. 2018. *RLPNC 18-1 Appliance Recycling Report*. [http://ma-eeac.org/wordpress/wp-content/uploads/RLPNC\\_181\\_ApplianceRecycleReport\\_26SEP2018\\_FINAL.pdf](http://ma-eeac.org/wordpress/wp-content/uploads/RLPNC_181_ApplianceRecycleReport_26SEP2018_FINAL.pdf).

## STUDY APPROACH

In the prior RLPNC 18-1 study, NMR used the approach advocated in the Uniform Methods Project (UMP) to guide the estimation of per-unit gross energy savings.<sup>3</sup> In following the UMP approach, NMR relied on program tracking data provided by ARCA, the program implementer, for the necessary inputs to update the gross energy savings (summarized in Table 1). We estimated the gross energy savings using the regressions developed for the UMP. NMR multiplied the UMP-recommended regression coefficients by the average values of the units recycled through the Massachusetts program in 2018 and inputs estimated in the RLPNC 18-1 Appliance Recycling Report. We calculated adjusted gross and net savings by applying realization rates (part-use factors) and net-to-gross ratios drawn from the RLPNC 18-1 Appliance Recycling Report.

**Table 1: Data Sources and Approaches for Energy Savings<sup>1</sup>**

Algorithm Inputs	Savings Type	Data Source
<b>UMP Regression Inputs</b>		
Appliance Age	Gross	Program Tracking
Manufactured before 1990	Gross	Program Tracking
Appliance Size	Gross	Program Tracking
Door Configuration	Gross	Program Tracking
Primary / Secondary (Refrigerator Only)	Gross	Program Tracking
Unconditioned Space	Gross	RLPNC 18-1
<b>Post Adjustments Following UMP Guidance</b>		
Realization Rate (% of Year Plugged In)	Adjusted Gross	RLPNC 18-1
Net-to-Gross Ratio	Net	RLPNC 18-1

<sup>1</sup> RLPNC 18-1 Study is available at

[http://ma-eeac.org/wordpress/wp-content/uploads/RLPNC\\_181\\_ApplianceRecycleReport\\_26SEP2018\\_FINAL.pdf](http://ma-eeac.org/wordpress/wp-content/uploads/RLPNC_181_ApplianceRecycleReport_26SEP2018_FINAL.pdf).

<sup>3</sup> 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>.

## KEY FINDINGS

### Impact Factors

Table 2 presents the 2018 gross energy savings estimates derived from a spreadsheet-based approach. Applying the average values of units recycled through the Massachusetts program in 2018 to UMP-recommended coefficients and inputs presented in RLPNC 18-1 Appliance Recycling Report, the **2018 gross energy savings** was 1,027 kWh for refrigerators and 769 kWh for freezers. As described more in Section 2, gross savings increased in 2018 compared to 2017. This reflects the larger size of both refrigerators and freezers recycled by the program. For refrigerators, a greater proportion of primary use units and those with side-by-side doors also contributed to greater savings.

Table 3 presents the updated 2018 gross savings as well as adjusted gross savings and net savings after the application of the realization rates (part-use factors) and net-to-gross ratios (including free-ridership and transferred use) derived from the prior study.

**Table 2: Benefit-Cost Ratio Inputs for Appliance Recycling**

Measure	Free ridership Rate	Spillover (Participant) Rate	Spillover (Non-participant) Rate	Net to Gross	In-Service Rate	kWh Realization Rate	Non-Electric Realization Rate	2018 Gross Annual kWh Saved
Freezer Recycling	44%	0%	0%	56%	100%	68%	100%	769
Refrigerator Recycling	56%	0%	0%	44%	100%	88%	100%	1,027

**Table 3: Updated Impact Factors for 2018<sup>1</sup>**

	Refrigerators		Freezers	
	Factor	Savings	Factor	Savings
Per unit Gross Energy Savings (kWh)	n/a	1,027	n/a	769
Per Unit Adjusted Gross Savings (kWh)	88%	904	68%	523
Net Savings (kWh)	44%	398	56%	295

<sup>1</sup> Results subject to rounding error.

## RECOMMENDATIONS AND GUIDANCE

In this section, NMR offers a recommendation and guidance, and support rationales, for future study planning based on the findings discussed in this report.

### Recommendation

**Recommendation #1: NMR recommends that the PAs update the per unit energy savings estimates in Table 3 for use in the 2018 annual report.**

*Rationale: This study's scope did not include updates to realization rates and net-to-gross ratios, but it did conclude that the units recycled in 2018 used more energy than those recycled in 2017, mainly due to size, configuration, and primary use. As a result, the gross savings – and therefore the adjusted gross and net savings– increased in 2018.*

### Guidance

**Guidance #1: Biennial quick hits studies, like this one, will allow the PAs to provide updated savings estimates for annual reports.**

*Rationale: The difference in units recycled in 2011, 2017, and 2018 suggests that customers will continue to recycle larger refrigerators and freezers, and primary use and side-by-side door refrigerators. Yet, the proportion of units manufactured after 1990 under increased federal efficiency standards will continue to increase as well. At some point, the more stringent efficiency standards will likely cause savings to decrease. Biennial adjustments may be needed to accurately reflect the savings resulting from the program, given the uncertainty about when savings will begin to decrease.*

## Section 1 Introduction

The Massachusetts Program Administrators (PAs) sponsored a refrigerator and freezer recycling program (the Program) in 2018 through the Residential Consumer Products Core Initiative.<sup>4</sup> Marketed under the Mass Save<sup>®</sup> umbrella, the program collected unwanted refrigerators and freezers and, in 2018, paid an incentive of \$50, or \$100 during special promotions, to customers who recycle their appliances through the program.<sup>5</sup> In 2018, the program provided 18,405 rebates: 15,717 for recycled refrigerators and 2,688 for recycled freezers.

In 2017, the PAs and Energy Efficiency Advisory Council Consultants (EEAC Consultants) completed an impact and process study to estimate per unit savings based on the characteristics and alternative outcomes for refrigerators and freezers currently recycled through the program.<sup>6</sup> The scope of this study is limited to updating savings estimates based on the characteristics of refrigerators and freezers recycled through the program in 2018. This update is necessary since expected savings vary based on the characteristics of recycled appliances, which change over time. Moreover, the unexpected closure of a previous program implementer led to a program hiatus in 2016, which may have caused the units recycled in 2017 to differ from those recycled in 2018. Therefore, the PAs and EEAC consultants have asked NMR Group, Inc. to provide updates to per unit gross, adjusted gross, and net savings for filing in the 2018 Annual Report, and this report presents those updates. This report addresses the evaluated per unit impact factors for gross and adjusted gross savings estimates for 2018.

### 1.1 STUDY OBJECTIVES

The objectives of this research were as follows:

- Identify the current characteristics of refrigerators and freezers recycled through the program in 2018 and compare them to those recycled in 2017 as identified in the RLPNC 18-1 Appliance Recycling Study
- Calculate per-unit gross energy savings (measured as unit energy consumption or UEC), adjusted gross savings, and net savings for the 2018 program

### 1.2 STUDY TERMINOLOGY

Appliance recycling programs are designed to achieve energy savings by paying customers to remove less efficient, but operable, appliances from service. 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 set of

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<sup>4</sup> Under the Massachusetts Joint Statewide Electric and Gas Three-Year Energy Efficiency Plan, 2019 to 2021 Plan, the Program now resides within the Residential Retail Initiative. <http://ma-eeac.org/wordpress/wp-content/uploads/Exh.-1-Final-Plan-10-31-18-With-Appendices-no-bulk.pdf>.

<sup>5</sup> The Program's website indicates that the incentive is currently \$75 (as of March 22, 2019). <https://www.masssave.com/en/shop/recycling/refrigerator-and-freezer-recycling/>.

<sup>6</sup> NMR Group, Inc. 2018. *RLPNC 18-1 Appliance Recycling Report*. [http://ma-eeac.org/wordpress/wp-content/uploads/RLPNC\\_181\\_ApplianceRecycleReport\\_26SEP2018\\_FINAL.pdf](http://ma-eeac.org/wordpress/wp-content/uploads/RLPNC_181_ApplianceRecycleReport_26SEP2018_FINAL.pdf).

terminology and savings assumptions that diverge from standard practices in the industry. NMR created Table 4 to crosswalk the appliance recycling terminology with that more typically used by the PAs. This report strives to use the terminology that aligns with the MA Technical Resource Manual and reporting needs, but, at times we default to the common industry terminology for the sake of clarity and documentation should the PAs repeat this study in the future.

**Table 4: Key Terms Used in this Report**

Common Industry Recycling Program Terminology	Equivalent Terminology for MA TRM and Reporting	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)
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.
Net savings	Net savings	Savings achieved after applying realization rate and accounting for free ridership and likely appliance outcomes (including transferred use) in the absence of the program. Net savings for appliance programs does not consider spillover
Net-to-gross Ratio	Net-to-gross Ratio	Net savings / Adjusted Gross Savings

### 1.3 DATA SOURCES

The study relied primarily on 2018 program tracking data provided by ARCA, the program implementer. The dataset included records for 18,405 recycled appliances (15,717 refrigerators and 2,688 freezers – recycled by 17,095 unique customers). 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 appliance age to the calculation of gross energy savings (which contains inputs for both age and date of manufacture), we

compared the mean age of refrigerators with and without outliers (units 60 years or older<sup>7</sup>). We determined that including these older refrigerators had very little influence on the means, so we kept them in the savings estimation analysis. We also assessed the influence of very old freezers, again finding no strong influence on the important age variable. We did decide to exclude one freezer because its size was missing in the dataset, and we could not confirm the size through a model number search. The final estimation of gross energy savings relied on 15,717 refrigerators and 2,687 freezers. NMR then calculated the average values and proportions of units for the characteristics that serve as inputs into the regression model used to estimate savings (Section 2). Appendix A contains a data description for the most critical factors used to calculate gross energy savings.

## 1.4 SPREADSHEET-BASED SAVINGS UPDATE

We updated estimates of per-unit gross savings for both refrigerators and freezers using a spreadsheet approach. As in the prior study, we relied on regressions performed for and recommended in the UMP. As outlined in Table 5, NMR applied the coefficients of the UMP-recommended regressions to either the average or proportion of the units recycled through the Massachusetts program in 2018 or as identified in the RLPNC 18-1 Appliance Recycling Report. We applied the realization rates and net-to-gross ratios estimated in the same earlier study to the per unit gross savings to yield adjusted gross and net savings.

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<sup>7</sup> The sample had 58 refrigerators and 11 freezers that were 60 years or older.

**Table 5: Data Sources and Approaches for Energy Savings**

Algorithm Inputs	Savings Type	Data Source
<b>UMP Regression Inputs</b>		
Appliance Age	Gross	Program Tracking
Manufactured before 1990	Gross	Program Tracking
Appliance Size	Gross	Program Tracking
Door Configuration	Gross	Program Tracking
Primary / Secondary (Refrigerator Only)	Gross	Program Tracking
Unconditioned Space	Gross	RLPNC 18-1
<b>Post Adjustments Following UMP Guidance</b>		
Realization Rate (% of Year Plugged In)	Adjusted Gross	RLPNC 18-1
Net-to-Gross Ratio	Net	RLPNC 18-1

*Refrigerator UEC*

$$\begin{aligned}
 &= 365.25 * (0.582 + 0.027(\text{average appliance age}) \\
 &+ 1.055(\% \text{ manufactured before 1990}) + 0.067(\text{average size in cuft}) \\
 &+ -1.977(\% \text{ single - door}) + 1.017(\% \text{ side - by - side door}) \\
 &+ 0.605(\% \text{ primary use}) \\
 &+ .020(\text{interaction \% in unconditioned space and CDD}) \\
 &+ -0.045(\text{interaction \% in unconditioned space and HDD})
 \end{aligned}$$

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

**1.4.1 Revisions to 2017 Per-unit Gross Savings Estimates**

In developing the 2017 savings estimates, NMR used HDD and CDD provided by field technicians from REM/Rate™ models of energy use in Massachusetts homes. In preparing a

similar appliance recycling analysis for National Grid Rhode Island, we calculated HDD and CDD directly from the Typical Meteorological Year 3 (TMY3) data based on a 65° Fahrenheit break. As the UMP does not specify the base, we confirmed the 65° assumption with one of the UMP's authors. We compared the Rhode Island to the Massachusetts HDD and CDD and recognized that REM/Rate™ uses something other than a 65° base. Therefore, for 2018, NMR updated HDD and CDD for Massachusetts directly from TMY3 to match the 65° base assumed in the UMP. [Appendix B](#) provides a comparison of the original and revised savings estimates for 2017, with the overall impact suggesting greater savings using the revised HDD and CDD assumptions.

## Section 2 Energy Consumption and Savings

The primary objective of this study was to update gross, adjusted gross, and net energy savings for the 2018 Appliance Recycling Program, as discussed in [Section 1](#). We compare the 2018 estimates to those from 2017.

Key findings for the 2018 program include the following:

- Per-Unit Refrigerator impact factors:
  - Gross energy savings (UEC) = 1,027 kWh
  - Adjusted gross energy savings = 904 kWh
  - Net energy savings = 398 kWh
- Per-Unit Freezer impact factors:
  - Gross energy savings (UEC) = 769 kWh
  - Adjusted gross energy savings = 523 kWh
  - Net energy savings = 295 kWh

### 2.1 PER UNIT 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, while the fifth column lists the 2018 values. The fourth and sixth columns show the effect each input has on energy use. The daily use sums across the individual inputs, while the annual gross energy savings multiplies daily use by 365.25.<sup>8</sup>

The results in [Table 6](#) suggest that gross energy savings for refrigerators rose by less than one percent, from 1,018 kWh to 1,027 kWh. This slight increase reflects changes in the characteristics of units recycled through the program that result in greater energy use (and hence savings when the unit is removed from use). In particular, unit size, the prevalence of side-by-side door configuration, and primary usage increased between the 2017 and 2018 studies.

The gross energy savings for freezers increased by about four percent ([Table 7](#)), from 740 to 769 kWh. As with refrigerators, participants in 2018 recycled larger freezers in 2018 than in 2017, but unlike refrigerators, they also recycled slightly older freezers in 2018 than in 2017.

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<sup>8</sup> 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  $0.07 \times \text{size in cubic feet}$ . For 2018, this is  $0.07 \times 19.32 = 1.29$ .

**Table 6: Calculation of Per-Unit Gross Energy Savings for Refrigerators<sup>1</sup>**

Input	UMP	2017 Results		2018 Results	
	Coefficient	Value	UEC	Value	UEC
Intercept	0.58	1.00	0.58	1.00	0.58
Appliance Age (years)	0.03	19.22	0.52	19.19	0.52
Manufactured Pre-1990	1.06	0.19	0.20	0.17	0.18
Appliance Size (cubic feet)	0.07	19.15	1.28	19.32	1.29
Single-door Configuration	-1.98	0.03	-0.07	0.03	-0.06
Side-by-side Configuration	1.07	0.19	0.20	0.20	0.21
Primary Usage Type	0.61	0.48	0.29	0.52	0.31
Located in Unconditioned Space * CDDs	0.02	1.05	0.02	1.05	0.02
Located in Unconditioned Space * HDDs	-0.05	5.50	-0.25	5.50	-0.25
<b>Daily Use (kWh)</b>			<b>2.79</b>		<b>2.81</b>
<b>Annual Gross Energy Savings (kWh)</b>			<b>1,018</b>		<b>1,027</b>

<sup>1</sup> Results subject to rounding error.

**Table 7: Calculation of Per-Unit Gross Energy Savings for Freezers<sup>1</sup>**

Input	UMP	2017 Results		2018 Results	
	Coefficient	Value	UEC	Value	UEC
Intercept	-0.96	1.00	-0.96	1.00	-0.96
Appliance Age (years)	0.05	23.52	1.06	23.80	1.07
Dummy: Manufactured Pre-1990	0.54	0.39	0.21	0.36	0.19
Appliance Size (cubic feet)	0.12	15.27	1.83	15.96	1.92
Dummy: Chest Configuration	0.30	0.27	0.08	0.28	0.08
Located in Unconditioned Space * CDDs	0.08	1.35	0.11	1.35	0.11
Located in Unconditioned Space * HDDs	-0.03	10.11	-0.31	10.11	-0.31
<b>Daily Use (kWh)</b>			<b>2.03</b>		<b>2.11</b>
<b>Annual Gross Energy Savings (kWh)</b>			<b>740</b>		<b>769</b>

<sup>1</sup> Results subject to rounding error.

## 2.2 PER-UNIT ADJUSTED GROSS AND NET ENERGY SAVINGS

As explained in the RLPNC 18-1 Appliance Recycling Report, 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, 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 net-to-gross ratios to be 44% for refrigerators and 56% for freezers.

Table 8 reports the adjusted gross and net savings for the 2018 program. NMR applied the 2017 realization rates to the gross energy savings for 2018 reported above in Section 2.1, yielding adjusted gross energy savings of 903 kWh for refrigerators and 523 kWh for freezers in 2018. NMR applied the 2017 net-to-gross ratios to the adjusted gross savings to calculate net savings of 398 and 295, respectively. This table also compares the results to the revised values derived from the 2017 study (with adjustments for the HDD and CDD calculations).

**Table 8: Calculation of Per-Unit Adjusted Gross and Net Energy Savings<sup>1</sup>**

	Refrigerators			Freezers		
	Factor	2017	2018	Factor	2017	2018
Gross Energy Savings (kWh)	n/a	1,018	<b>1,027</b>	n/a	740	<b>769</b>
<b>Adjusted Gross Savings (kWh)</b>	88%	896	<b>903</b>	68%	503	<b>523</b>
<b>Net Savings (kWh)</b>	44%	394	<b>398</b>	56%	282	<b>295</b>

<sup>1</sup> Results subject to rounding error.

## Section 3 Conclusions and Recommendations

### 3.1 CONCLUSIONS

The Refrigerator and Freezer Recycling Program saw increased per unit gross savings between 2017 and 2018. Refrigerator savings rose by about one percent, from 1,018 kWh to 1,027 kWh, while those for freezers rose by about four percent, from 740 kWh to 769 kWh. For refrigerators, these increases were driven by larger size and the greater prevalence of side-by-side door configurations and primary use units. For freezers, the increases reflected larger size and a slight uptick in the age of units recycled.

### 3.2 RECOMMENDATIONS

The study makes a single recommendation.

**Recommendation #1: NMR recommends that the PAs adopt the per unit energy savings estimates in Table 9 for use in the 2018 annual report.**

**Table 9: Recommended Updates to Impact Factors for 2018<sup>1</sup>**

	Refrigerators		Freezers	
	Factor	Savings	Factor	Savings
Per unit Gross Energy Savings (kWh)	n/a	1,027	n/a	769
Per Unit Adjusted Gross Savings (kWh)	88%	904	68%	523
Net Savings (kWh)	44%	398	56%	295

<sup>1</sup> Results subject to rounding error.

*Rationale: This study's scope did not include updates to realization rates and net-to-gross ratios, but it did conclude that the units recycled in 2018 used more energy than those recycled in 2017, mainly due to size, configuration, and primary use. As a result, per unit gross savings – and therefore the adjusted gross and net savings too – increased in 2018.*

### 3.3 GUIDANCE

The study offers the following guidance for future research.

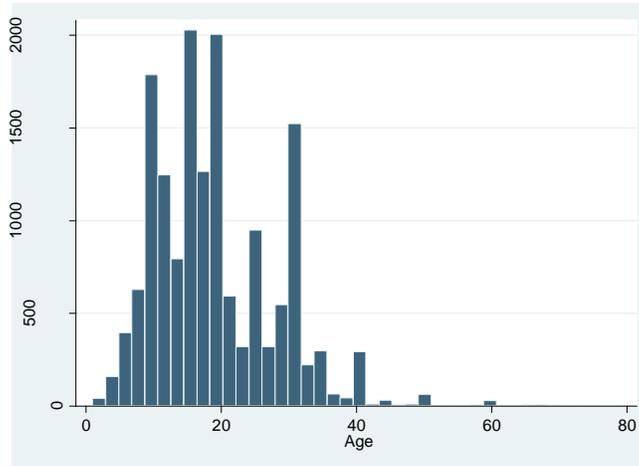
**Guidance #1: Biennial *quick hits* studies, like this one, will allow the PAs to provide updated per unit savings estimates for annual reports.**

*Rationale: The difference in units recycled in 2011, 2017, and 2018 suggests that customers will continue to recycle larger refrigerators and freezers, and primary use and side-by-side door refrigerators. Yet, the proportion of units manufactured after 1990 under increased federal efficiency standards will continue to increase as well. At some point, the greater efficiency standards will likely cause savings to decrease. Biennial adjustments may be needed to accurately reflect the savings resulting from the program, given the uncertainty about when savings will begin to decrease.*

## Appendix A Additional Findings

The following tables and graphs describe the inputs in the calculation of 2018 gross energy savings (UEC). Note that the sample sizes change due to missing data for some inputs.

**Figure 1. Distribution of Recycled Refrigerator Age (Count = 15,717)**



**Figure 2. Distribution of Recycled Freezer Age (Count = 2,688)**

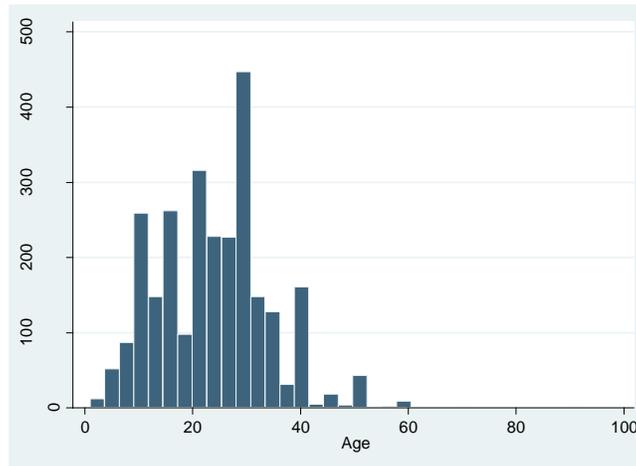


Figure 3. Distribution of Recycled Refrigerator Size (Count = 15,631)

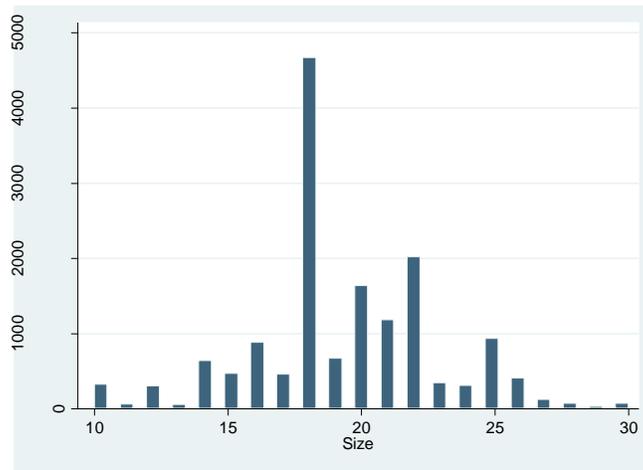


Figure 4. Distribution of Recycled Freezer Size (Count = 2,652)

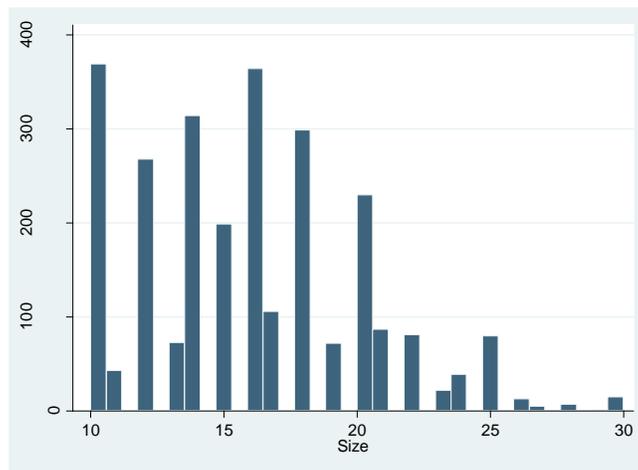


Table 10. Recycled Unit Year of Manufacture

Year of Manufacture	Refrigerators	Percentage	Freezers	Percentage
Pre-1990	2,641	17%	955	36%
1990 and later	13,076	83%	1,733	64%
<b>Total</b>	<b>15,717</b>		<b>2,688</b>	

**Table 11. Recycled Unit Configuration**

Unit Type	Door Configuration	Count	Percentage
Refrigerators	Bottom Freezer	1,464	9%
	Side-by-side	3,125	20%
	Single Door	481	3%
	Top Freezer	10,647	68%
	<b>Total Refrigerator</b>	<b>15,717</b>	
Freezers	Chest	762	28%
	Upright	1,926	72%
	<b>Total Freezer</b>	<b>2,688</b>	<b>9%</b>

**Table 12. Recycled Unit Use**

Unit Use	Refrigerators	Percentage	Freezers	Percentage
Primary	8,155	52%	458	17%
Secondary	7,562	48%	2,230	83%
<b>Total</b>	<b>15,717</b>		<b>2,688</b>	

## Appendix B Gross and adjusted gross energy savings – 2017 revisions

Table 13 compares the original 2017 gross and adjusted gross savings with the revised 2017 estimates after adjusting the HDD and CDD base to 65 degrees. On the one hand, the revised gross and adjusted gross energy savings for refrigerators remained largely unchanged. On the other hand, gross energy savings for freezers increased from 718 kWh to 740 kWh. The greater change for freezers is due to the fact that more freezers than refrigerators are located in unconditioned space, making their energy use more susceptible to changes in the weather, particularly warmer days.

**Table 13: Calculation of Per Unit Adjusted Gross Energy Savings<sup>1</sup> – 2017**

	Refrigerators		Freezers	
	Original	Revised	Original	Revised
Gross Energy Savings (kWh)	1,019	1,018	718	740

<sup>1</sup> Results subject to rounding error.