Massachusetts Appliance Turn-in Program Impact Evaluation

FINAL

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Submitted to:

National Grid, NSTAR Electric, Cape Light Compact, Western Massachusetts Electric Company

Submitted by:

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Executive Summary

This report presents estimates of the gross and net impacts of the Massachusetts Appliance Turn-in Program (the "Program") for 2009 and 2010, sponsored by NSTAR Electric, National Grid, Cape Light Compact, and Western Massachusetts Electric Company ("WMECo") (the "Sponsors"). Other evaluation activities for this project consisted of participant telephone survey, in-depth interviews with program staff and implementation contractors, and an exploration of the secondary appliance market. Reports for those activities are provided under separate cover, but Section 7 of this report presents overall findings and recommendations from the impact study, the participant telephone survey and an exploration of the secondary appliance market.

Findings

All per-unit impact calculations are based on program appliances from June 2009 through August 2010; NMR has applied these findings to reflect the savings from all program appliances retired through November 2010.

Table ES-1 shows a summary of results for each of the methodologies presented in this report[1]. Net savings results were considerably higher using the NMR Association of Home Appliance Manufacturers (AHAM) methodology as opposed to the NMR DOE testing methodology. In fact, the AHAM methodology results in a net savings estimate that is 27% higher for refrigerators 24% higher for freezers relative to the DOE method.

Table ES-1: Summary of Results (kWh/year)

Savings	NMR AHAM		NMR DOE Testing		Average	
	Refrigerators	Freezers	Refrigerators	Freezers	Refrigerators	Freezers
UEC	1,410	1,200	1,168	1,010	1289	1105
Adjusted gross savings	835	722	675	594	755	658
Net savings	585	432	459	349	522	391

Averaging the savings from each of the methodologies presented in this report, we derive a per-unit net savings estimate of 522 kWh for refrigerators and 391 kWh for freezers (Table ES-2). It is important to note that these are average savings values, and the impacts for the program were calculated on a participant by participant basis. Each participant had a unique savings value that was dependent on a variety of inputs.[2] The Massachusetts Appliance Turn-in Program requires that removed refrigerators be secondary, not primary, refrigerators. Nevertheless, about one in

[1] The data used in this study come from a variety of sources, including the participant survey, AHAM, and the DOE-based model utilized by Cadmus in their 2010 evaluation of the California Appliance Recycling Program (ARP). The participant survey achieved a margin of error of 4.8% for refrigerators and 5.1% for freezers and an overall margin of error of 3.6% at a 90% confidence level.

five (19%) of the respondents in the refrigerator group reported that they had used the removed appliance as the primary fridge in their home. We present categorical net savings based on whether the appliance was a secondary unit that was replaced, a secondary unit that was not replaced, or a primary unit. The categorical distribution of participants by type of unit recycled and replacement status is found in Table 3-1 of this report.

Table ES-2: Net Savings (kWh/year)—Average of Two Methods

Savings	Refrigerators	Freezers
Average net savings-Overall	522	391
Secondary replaced	506	432
Secondary no replacement	593	381
Primary	293	n/a

Table ES-3 shows the range of net-to-gross (NTG) estimates for the secondary and primary appliances that were recycled through the program. The NTG reflects the net effect of the program on a customer's decision to recycle an appliance, versus keeping that same appliance in use. The NTG is calculated as the ratio of net savings to adjusted gross savings.

Table ES-3: Net Savings Estimates

Savings	Refrigerators				Freezers		
	Secondary replaced	Secondary, no replacement	Primary	Overall	Secondary replaced	Secondary, no replacement	Overall
Ex ante savings	724	724	724	724	724	724	724
Adjusted gross savings	694	836	531	755	596	672	658
Net savings	506	593	293	522	432	381	391
Net-to-gross ratio (based on adjusted gross)	0.73	0.71	0.55	0.69	0.73	0.57	0.59

[2] Inputs include the following: Type of appliance retired, age of equipment, household size, reported plug in times, replacement equipment, and free ridership.

In order to identify the per-unit gross savings attributable to the Massachusetts Program Administrators' (PAs') programs, NMR used two methodologies to develop annual unit energy consumption (UEC) estimates.

1) We used UECs from the Association of Home Appliance Manufacturers (AHAM) to develop UECs for program-supported appliances—referred to throughout this report as NMR AHAM methodology[3] [4][5]

2) We applied Massachusetts refrigerator characteristics to the DOE-based model utilized by Cadmus in their 2010 evaluation of the California Appliance Recycling Program (ARP)—referred to throughout this report as NMR DOE testing methodology[6]

Manufacturers estimate the annual energy consumption of refrigerators and freezers based on the DOE lab testing procedures.[7] AHAM uses these estimates, along with annual shipment data, to develop shipment-weighted UECs for refrigerators and freezers based on model year.

In their 2010 evaluation of the California ARP, Cadmus used lab metering results, based on the DOE lab testing procedures, to develop a multiple regression model and estimate an average refrigerator UEC. The model assessed the impacts of various refrigerator characteristics (e.g. configuration, size, and age) on the metered energy consumption of refrigerators. The regression results were then used to scale up the metered results to the program's overall refrigerator population.

The NMR team used the AHAM data and California model to develop initial consumption estimates for the Massachusetts Program's refrigerators and freezers. A lab-to-on-site factor was applied to these estimates to account for *in situ* factors (e.g. climate and household size) that are not captured through lab-based metering results. We applied the following adjustments to the NMR initial estimates to develop final adjusted UEC estimates:

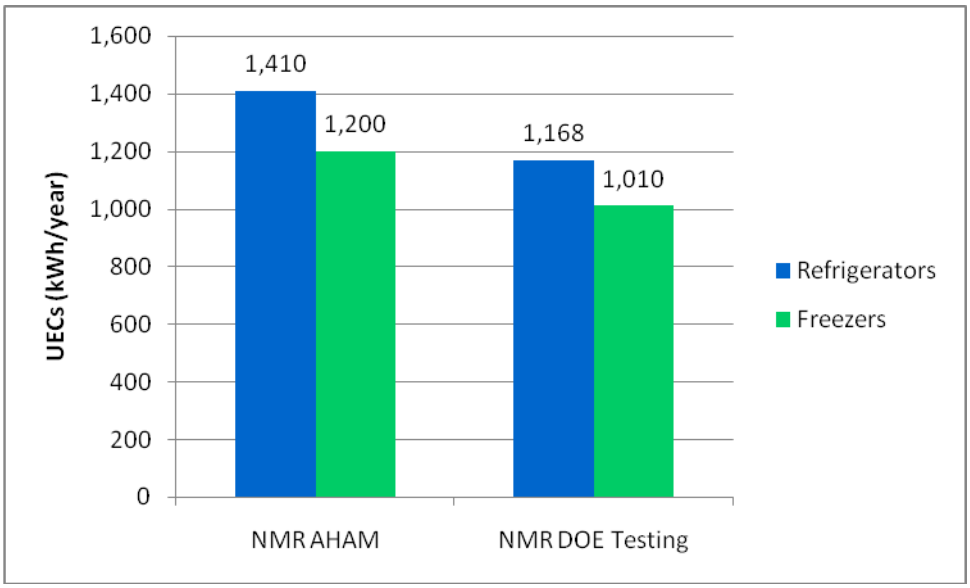
- We applied a degradation factor to NMR AHAM estimates to account for the deterioration of appliance performance over time.[8]
- The California model was developed based on refrigerators only. To account for this, NMR applied a refrigerator-to-freezer factor to the NMR DOE testing methodology to develop a freezer UEC.[9]

Using AHAM data, NMR initially estimated UECs of 1,410 kWh per year for refrigerators and 1,200 kWh per year for freezers. Applying Massachusetts program characteristics to the

[3] AHAM (2010). *Trends in Energy Efficiency 2009.* July 6th, 2010.
[4] AHAM (2003). *Refrigerators Energy Efficiency and Consumption Trends.* May 23rd, 2003.
[5] http://www.nwcouncil.org/energy/rtf/meetings/2010/0629/ResFrigRecycle_FY10v2_1.zip
[6] Cadmus et al. (2010). *Residential Retrofit High Impact Measure Evaluation Report.* February 8th, 2010.
[7] http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&tpl=/ecfrbrowse/Title10/10cfr430_main_02.tpl
[8] The California model accounts for degradation through the independent variables. Unit age is likely the most significant with regards to degradation.
[9] A refrigerator-to-freezer factor was not applied to the NMR AHAM methodology as AHAM publishes data on freezers.

California model, NMR developed UECs of 1,168 kWh per year for refrigerators and 1,010 kWh per year for freezers (Figure ES-1).

Figure ES-1: UEC Estimates (kWh/year)[10]



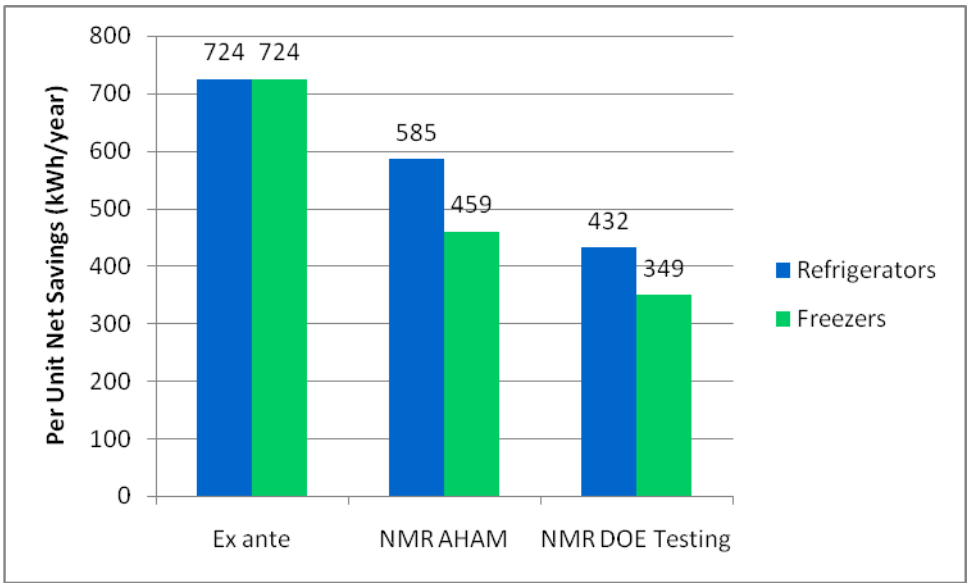
Under each of the NMR methodologies, we adjusted UECs to account for numerous factors in order to estimate per-unit net savings attributable to program sponsors. The following factors were considered when calculating net savings:

- Partial use—adjusted savings to account for the varying plug-in times of appliances retired by the program[11]
- Replacement equipment—adjusted savings to account for appliances that were retired by the program, but ultimately were replaced[12]
- Free ridership—adjusted savings to account for program free ridership[13]

[10] UECs were calculated for the following participant categories: primary appliance—replaced, secondary appliance—replaced, and secondary appliance—not replaced. This figure presents a weighted average of these UECs based on program proportions.
[11] Source: Participant survey conducted in August of 2010 by NMR.
[12] Sources: Participant survey; AHAM data.
[13] Source: Participant survey

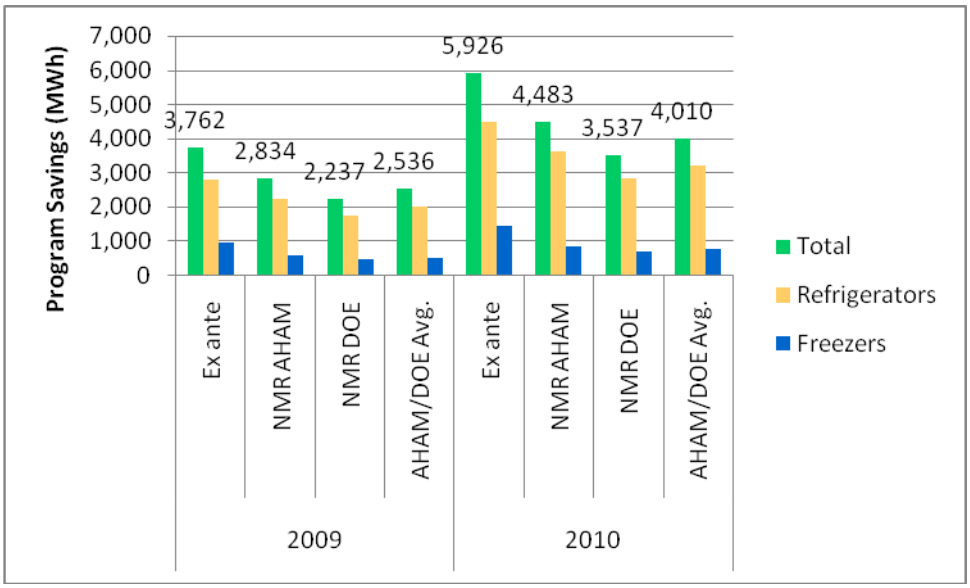
The sponsors of the Massachusetts Appliance Turn-in Program currently estimate that per-unit net savings for the refrigerators and freezers recycled through the Program are 724 kWh per year. Program sponsors currently use a per-unit net savings value of 724 kWh per year for both refrigerators and freezers. Beginning with the two different UECs described above, NMR developed two estimates of program net impacts, by applying results from a participant telephone survey conducted by NMR in August 2010 and results from existing studies from outside the state. Our estimates yield per-unit net program savings of 585 kWh per year and 432 kWh per year for refrigerators (using NMR AHAM and NMR DOE UEC estimates, respectively) and 459 kWh per year and 349 kWh per year for freezers. Figure ES-2 compares the per-unit net savings calculated by NMR to the *ex ante* values used by program sponsors. The per-unit savings currently used by sponsors is substantially higher than those calculated using the NMR AHAM and NMR DOE testing methodologies. This is likely due to the fact that these methodologies account for the various factors mentioned above, while the *ex ante* estimates account for free ridership and partial year use, and are not adjusted to reflect *in situ* factors. The free ridership estimates developed by NMR also contribute to the savings differences, as they differ from the free ridership estimates currently used by program sponsors.

Figure ES-2: Per-Unit Net Savings (kWh/year)



From June 2009 through November 2010 the program retired 13,381 appliances; specifically, the program retired 10,040 refrigerators and 3,341 freezers over that time. Figure ES-3 displays the total savings attributable to program sponsors from June 2009 through November 2010. Over that time period, NMR estimates program savings of 7,317MWh using the NMR AHAM methodology, and 5,774 MWh using the NMR DOE testing methodology. Averaging the two methodologies results in savings of 6,546 MWh.

Figure ES-3: Program Savings (MWh)—June, 2009 through November, 2010



1 Program Overview

The goal of the program is to reduce energy use and power demand through the early retirement of secondary refrigerators and freezers. The program provides free collection and recycling services and a $50 incentive as a means of encouraging customers to recycle their inefficient secondary refrigerators and freezers.

The program is sponsored by National Grid, NSTAR, Western Massachusetts Electric Company (WMECo) and the Cape Light Compact (CLC). Between June 2009 and November 2010, 13,381 refrigerators and freezers were recycled through the program. Refrigerators comprised the majority (75%) of the appliances recycled through the program.

Table 1-1shows the distribution of appliances by sponsor territory recycled through the program.

Table 1-1: Retired Refrigerators and Freezers—June, 2009 through November, 2010[14]

Sponsor	2009			2010		
	Refrigerators	Freezers	Total	Refrigerators	Freezers	Total
National Grid	3,852	1,344	5,196	3,808	1,201	5,009
NSTAR	--	--	--	2,004	697	2,701
CLC	--	--	--	189	67	256
WMECo	--	--	--	187	32	219
Total	**3,852**	**1,344**	**5,196**	**6,188**	**1,997**	**8,185**

[14] Based on the program tracking data National Grid was the first sponsor to retire appliances through the program (June, 2009). NSTAR (April, 2010), CLC (April, 2010), and WMECo (May, 2010) all began retiring appliances through the program at a much later date.

The deemed savings values used by sponsors are based on ADM's 2008 evaluation of the Residential Appliance Recycling Program (RARP) in California.[15] In order to calculate program savings the sponsors have adjusted the deemed savings values to account for program free ridership, and currently assume a per-unit net savings value of 724 kWh per year for both refrigerators and freezers that are recycled through the program.[16] Using the sponsors' savings assumptions, the program has generated 9,688 MWh of savings since implementation began (Table 1-2).

Table 1-2: Program Savings (MWh)—June, 2009 through November, 2010

Sponsor	2009			2010		
	Refrigerators	Freezers	Total	Refrigerators	Freezers	Total
National Grid	2,789	973	3,762	2,757	870	3,627
NSTAR	--	--	--	1,451	505	1,956
CLC	--	--	--	137	49	185
WMECo	--	--	--	135	23	159
Total	**2,789**	**973**	**3,762**	**4,480**	**1,446**	**5,926**

1.1 Tracking Database

The program implementation contractor, JACO Environmental, Inc., tracks all of the refrigerators and freezers that are recycled through the program. Some of the information included in the tracking database includes the following:

- Pickup Date
- Type of appliance picked up (i.e. refrigerator or freezer)
- Configuration (e.g. top freezer or side-by-side)
- Size (cu. ft.)
- Year manufactured[17]
- Manufacturer and model number
- Location prior to pickup
- Use prior to pick up (i.e. primary, secondary, or not in use)
- Estimated annual kWh consumption

[15] ADM et al. (2008). *Evaluation Study of the 2004-05 Statewide Residential Appliance Recycling Program.* April, 2008.

[16] KEMA-Xenergy "Measurement and Evaluation Study of 2002 Statewide Residential Appliance Recycling Program".

[17] Based on an email exchange with Dick Bacon of JACO on December 3rd, 2010, JACO estimates the model year of program appliances when such information is unknown. These estimates are based on appliance characteristics such as configuration and shelf layouts that are common to certain vintages.

The tracking database provides information about the types of appliances that are being recycled through the program, and in some cases the participant survey conducted by NMR collected parallel information. For the purposes of the impact evaluation, NMR used information from the participant survey to identify characteristics about appliance use and replacement rather than relying on similar data collected at the time of pick-up.

JACO provides annual kWh consumption estimates for a portion of the appliances that are recycled through the program. The consumption estimates are based on nameplate information such as manufacturer and model number, but these data are not listed in the JACO database for all units.[18] A large portion of the units recycled through the program are older and the nameplate information is either unavailable or difficult to look up. JACO provided consumption estimates for about one-half of the refrigerators (49%) and fewer than one-fifth of the freezers (16%) recycled through the program from June 2009 through August 2010.

2 Methodology

The NMR evaluation team used two methodologies to develop gross impact estimates for the program.

1) We adjusted AHAM UECs for program refrigerators and freezers based on the methodology utilized by the Northwest Power and Conservation Council's Regional Technical Forum
2) We applied Massachusetts refrigerator characteristics to the DOE-based model utilized by Cadmus in their 2010 evaluation of the California ARP

NMR considered a third methodology using an ENERGY STAR® database of appliance energy consumption values to estimate annual energy consumption based on appliance size, configuration, and model year.[19] The UECs developed from the database were substantially higher than those developed from the other two methodologies, but we could not confirm the assumptions used to develop the database and do not include that source in this analysis.

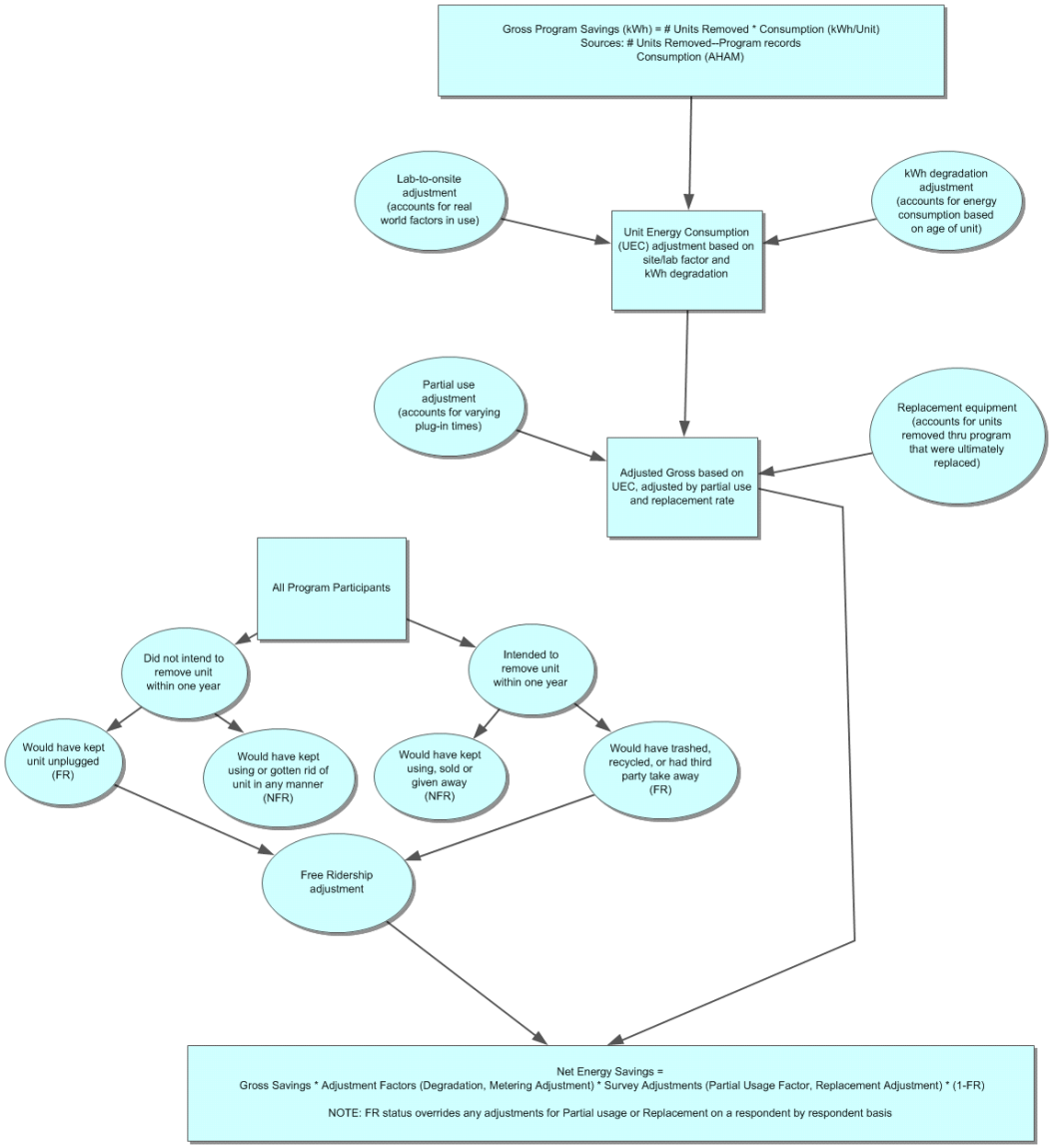
After developing UECs for program-supported refrigerators and freezers, we calculated adjusted gross savings values to reflect the partial use and replacement of program appliances. Finally, per-unit net savings were estimated by applying free ridership estimates to the adjusted gross savings estimates.

[18] Based on an email exchange with Phil Sission of Sission & Associates on November 16th, 2010, JACO uses the homeenergy.org database to estimate annual energy consumption for refrigerators and freezers based on manufacturer and model number.

[19] http://www.energystar.gov/index.cfm?fuseaction=refrig.calculator&screen=1

Figure 2-1shows the pathways we used to calculate the net impact savings from the program.

Figure 2-1: Appliance Gross to Net Impact Measurement Diagram



2.1 AHAM Adjusted Methodology

AHAM provides shipment-weighted data that specifies the average UEC for refrigerators and freezers based on model year. AHAM's energy consumption estimates are available for model years 1972, 1978, and 1980 through 2009.

2.1.1 RTF Methodology

The Northwest Power and Conservation Council's Regional Technical Forum (RTF) recently developed a methodology to calculate the gross and net impacts of appliance recycling programs for seven different utilities in the Pacific Northwest.[20] The RTF methodology uses AHAM data, adjusted for appliance degradation over time, to estimate the UEC of refrigerators and freezers retired through these programs. The following equations lay out the RTF's methodology for developing net savings estimates:

$$Energy\ Savings = (kWh_{old}) \times (F_{partuse}) \times (Baseline_{adjustment})$$

$$kWh_{old} = \left(\frac{\textbf{Site}}{\textbf{Lab}}\textbf{Factor}\right) \times \frac{\sum_{i=1}^{n}[(kWh\ at\ manufactuer_i) + (kWh\ degradation_i)]}{n} \times C$$

Where:

- Site/Lab Factor: Adjustment for DOE to *in situ* performance[21]
- kWh at manufacture: Per-unit AHAM data based on model year, extrapolated and interpolated for missing model years
- $kWh\ degradation_i = Unit\ age_i \times Performance\ degradation\ factor$ kWh degradation: Increased energy use per year due to degradation of appliances over time
- n: Number of units recycled in 2009
- C: Correction factor to adjust for increased efficiency of recycled appliances in future program years

- $F_{partuse}$: Adjustment factor accounting for the partial use of recycled appliances
- $Baseline_{adjustment}$: Adjustment factor accounting for units that would have been taken out of service without the program

The RTF used a variety of secondary sources to determine the values that were used for the adjustment factors listed above. Ideally, results from *in situ* metering, specific to the programs being studied, would be used for the site/lab factor and the kWh degradation adjustments. Similarly, participant and non-participant surveys would be used to determine the $F_{partuse}$ and

[20] Regional Technical Forum, "Refrigerator and Freezer Decommissioning: Deemed Measure Review and Update". June 29th, 2010.
[21] Based on the 2010 Cadmus results for "cool" California climate zones.

Baseline$_{adjustment}$values. The RTF did not have *in situ* metering or survey results, and instead used secondary research to determine the adjustment factor values.

2.1.2 NMR AHAM Methodology

The NMR team relied on the work done by the RTF as a foundation for developing a methodology to adjust AHAM model year UECs and develop UECs for the Massachusetts Program's refrigerators and freezers. We developed a unique UEC, for both refrigerators and freezers, for each respondent who participated in the NMR telephone survey. The UEC varied from participant to participant depending on the age and type of appliance retired through the program. After determining the UECs for refrigerators and freezers, NMR adjusted the values to develop per unit net savings attributable to program sponsors. The calculations used to develop UECs, per unit adjusted gross savings based on usage and replacements for the each of three disposal scenarios, and per unit net savings are presented below:

$$UEC_i = [(AHAM_i) + (kWh\ degradation_i)] \times \left(\frac{\text{Site}}{\text{Lab}}\text{Factor}\right)$$

Where:

- $AHAM_i$: Per unit AHAM annual energy consumption
- $kWh\ degradation_i = Unit\ age_i \times Performance\ degradation\ factor$ [22]
- Site/Lab Factor: Adjustment for DOE to *in situ* performance[23]

Adjusted Gross Savings by Disposal Scenario

Secondary replace

$$\begin{aligned} Adjusted_{gross} &= \left[\left(UEC \times F_{partuse}\right) \times \left(1 - Replacement_{rate}\right)\right] \\ &+ \left[\left(\left(UEC \times F_{partuse}\right) - New_{kWh}\right) \times \left(New_{pct} \times Replacement_{rate}\right)\right] \\ &+ \left[\left(\left(UEC \times F_{partuse}\right) - Old_{kWh}\right) \times \left(Old_{pct} \times Replacement_{rate}\right)\right] \end{aligned}$$

Primary

$$\begin{aligned} Adjusted_{gross} &= \left[UEC \times \left(1 - Replacement_{rate}\right)\right] \\ &+ \left[\left(UEC - New_{kWh}\right) \times \left(New_{pct} \times Replacement_{rate}\right)\right] \\ &+ \left[\left(UEC - Old_{kWh}\right) \times \left(Old_{pct} \times Replacement_{rate}\right)\right] \end{aligned}$$

[22] Source: 1998 Miller and Pratt study
[23] Source: 2010 Cadmus evaluation of the California ARP

Secondary no replace

$$Adjusted_{gross} = [(UEC \times F_{partuse})]$$

$$Net_{savings} = Adjusted_{gross} \times (1 - FR)$$

Where:

- $F_{partuse}$: Adjustment factor accounting for the partial use of recycled appliances*
- $Replacement_{rate}$: Percent of participants who reported replacing equipment*
- New_{kWh}: 2009 AHAM annual kWh consumption per unit
- New_{pct}: Portion of $Replacement_{rate}$ that is new appliances*
- Old_{kWh}: 2000 AHAM annual kWh consumption per unit
- Old_{pct}: Portion of $Replacement_{rate}$ that is used appliances*

$$Net_{savings} = Adjusted_{gross} \times (1 - FR)$$

Where:

- FR: Free ridership rate*

*Source: Participant survey

Some of the adjustments used to develop gross and net impacts through NMR's AHAM methodology required metered data that were not available for this analysis. NMR used secondary sources to determine the appropriate adjustment values for these variables. We used data from the participant survey for all other adjustment values. Details on the adjustment values selected and the assumptions made can be found in the *Assumptions* section.

2.2 DOE Testing Methodology

2.2.1 California ARP Methodology

As part of their 2010 evaluation of the California ARP, Cadmus developed a multiple regression model using results of a dual metering study conducted both on-site and using the DOE lab-testing methodology. The model was used to identify the impacts of various appliance characteristics (e.g. top freezer and automatic defrost) on the annual energy consumption of refrigerators. Ultimately, the California model included only characteristics that were significant at the 0.05 level in the model. The final coefficients from the model were used to scale the metered results up to the total program refrigerator population and develop a UEC for refrigerators recycled through the program.

Prior to being metered in a lab using the DOE testing methodology, California appliances were metered *in situ* in order to compare lab-based results to results "in the field." Metering appliances *in situ* takes into account real world factors that affect energy consumption and are not captured using the DOE testing methodology. Examples of these factors include climate impacts, refrigerator door openings, household size, and appliance location.

In total, 321 refrigerators were metered in the lab and *in situ*, and it was found that *in situ* results were, on average, 11% lower than DOE results.

2.2.2 NMR DOE Testing Methodology

The NMR team used the DOE-based multiple regression model developed in California to estimate a second UEC for program refrigerators in Massachusetts. NMR multiplied the average Massachusetts Program's characteristics by the associated California model coefficients to develop model factors unique to the Massachusetts Program. We then summed these factors to develop a DOE based UEC. This is consistent with the methodology used in the California study. Each survey respondent had an average UEC value applied under the DOE methodology. Two UECs, one for refrigerators and one for freezers, were applied to all respondents based on the average characteristics of program participants. This differs from the AHAM methodology in which we applied a unique UEC for each survey respondent.[24]

In California, it was found that *in situ* metering results more accurately reflect the true energy consumption of refrigerators retired through the California ARP than do DOE testing results. A second California model was developed based on *in situ* metering, but NMR determined that the model was not applicable in Massachusetts due to the program-specific nature of the independent variables. The *in situ* model included two dummy variables, one for warmer climate zones and another for primary appliances, both of which are unique to the California program. In California, it was found that primary appliances actually use less energy than secondary appliances due to their locations. Secondary appliances are often located in unconditioned space; in California unconditioned space is often warmer than conditioned space, and appliances must consume more energy to maintain a desired temperature. In Massachusetts the situation is often reversed as secondary appliances are located in cooler unconditioned space and require less energy to maintain a desired temperature than primary appliances. Because of these differences, NMR determined that the lab-based metering results were more applicable to Massachusetts appliances, and used California DOE-based regression model to develop UECs for the program.

While the DOE-based regression model was used to develop program UECs, *in situ* factors still needed to be accounted for. Using information from the participant survey, NMR adjusted the lab-to-on-site ratio developed in California to account for *in situ* variables in the Massachusetts UECs. It is important to note that the California report only considered refrigerators, not freezers; NMR used a refrigerator-to-freezer conversion factor to estimate the UEC for freezers in

[24] Due to the nature of the California model we were unable to create a unique consumption estimate for each of the appliances retired through the program. Instead, one value, based on the characteristics of program appliances, was applied to all refrigerators and freezers respectively.

Massachusetts. More details on these adjustments can be found in the *Assumptions* section of the report.

3 Assumptions

The assumptions used to calculate program impacts were based on the participant survey and a review of secondary research materials. In order to develop unique assumptions and accurately represent the program's participants, NMR evaluated the program's impacts on a participant by participant basis. We present the results based on three participant categories for refrigerators and two participant categories for freezers.

- Refrigerators
    - Participants who retired and replaced a primary refrigerator
    - Participants who retired and replaced a secondary refrigerator
    - Participants who retired, but did not replace, a secondary refrigerator
- Freezers[25]
    - Participants who retired and replaced a secondary freezer
    - Participants who retired, but did not replace, a secondary freezer

[25] All freezers were assumed to be secondary appliances.

Table 3-1 shows the distribution of participants by category. The majority of participants retired secondary refrigerators and freezers that were not replaced.

Table 3-1: Participant Categories

Participant Categories	Refrigerators	Freezers
Sample Size	286	243
Primary replaced	19%	--
Secondary replaced	15	18%
Secondary no replacement	65	82

3.1 AHAM Data

As previously mentioned, AHAM data were available for model years 1972, 1978, and 1980 through 2009. Assumptions were made to populate the rest of the dataset as the program has retired appliances from years with missing data.[26]

A linear interpolation strategy was used to develop annual energy consumption estimates for 1972 through 1978. All appliances with pre-1972 model years were assumed to have an annual energy consumption equivalent to that of the 1972 AHAM estimates. There is some evidence suggesting that the annual energy consumption of a refrigerator in 1950 was about 400 kWh, and annual energy consumption rose, almost linearly, until it peaked in the mid-1970s.[27] It is likely that the typical energy consumption of refrigerators and freezers was lower in the 1950s than in the 1970s, because refrigerators increased in storage capacity over this time period. Having said that, NMR was unable to find clear documentation of refrigerator and/or freezer energy consumption prior to 1972, and therefore used the oldest known data to extrapolate energy consumption for unknown years.

3.2 UEC Assumptions

3.2.1 Lab-to-On-site Factor

Due to the time, complexity, and expense of *in situ* measurements, the gross impacts of the program were determined using the aforementioned *ex ante* estimates. The *ex ante* estimates were based on lab metering results in which the refrigerators and/or freezers were metered in a controlled environment. In order to account for the impacts of *in situ* factors such as door openings and the local climate, we used a lab-to-on-site factor to develop UEC estimates.

Table 3-2 shows the lab-to-on-site differences for "cool" climates as reported in the 2010 evaluation of the California ARP.[28] Only "cool" climate results were considered because "warm"

[26] Appliances retired through the program date back to 1950.
[27] Rosenfeld, "The Art of Energy Efficiency: Protecting the Environment with Better Technology," *Annual Review of Energy and the Environment*24 (1999): 33-82.
[28] "Cool" refers to California climate zones 1 through 8 and 16.

climate results are not as applicable in Massachusetts.[29]Based on information from the participant survey, we applied one of the following lab-to-on-site values to each of the respondents from the participant survey.[30]For example, if a respondent retired a secondary refrigerator through the program and reported that they had a household size of two people, they had a lab-to-onsite value of .787 applied to their initial consumption estimate (100%-21.3%).

Table 3-2: California ARP Lab-to-On-site Differences for "Cool" Climate Zones*

California Results			
Primary Appliance	**Household Size**	**Climate Zone**	**% *In Situ* Delta**
Yes	1-2	Cool	-30.8%
	3+		-16.0%
No	1-2	Cool	-21.3%
	3+		-6.8%

***Source: Cadmus et al. (2010). *Residential Retrofit High Impact Measure Evaluation Report.* February 8th, 2010.**

Table 3-3 displays the average Massachusetts participant information that was used to adjust the lab-to-on-site results from California. Please note this table is just for reference, lab-to-onsite factors were applied on a participant by participant basis according to survey responses.

Table 3-3: Household Size by Use of Removed Refrigerator

(Base: All participants who had a refrigerator removed by the program except those who responded DK/Ref)

Use of Removed Refrigerator		**Participants**
Sample size		*257*
Used as primary/main		22%
Used as secondary/spare		78
Use of Removed Refrigerator	**Household Size**	**Participants**
Sample size		*257*
Used as primary/main	1-2	61%
	3+	39
Used as secondary/spare	1-2	62%
	3+	39

3.2.2 Degradation Factor

A number of refrigerator metering studies have found that refrigerators and/or freezers degrade over time, in turn increasing their annual energy consumption. The NMR team reviewed three reports to determine what degradation factor should be applied in Massachusetts.

[29] We considered including "warm" climate zone data, but we had no monthly or seasonal usage patterns for survey participants that would support greater partial usage during summer months compared to the rest of the year. Regardless of how an appliance is used (i.e. varying partial use or location of equipment) the "cool" climate zones of California more likely represent the Massachusetts climate than do the "warm" climate zones.

[30] NMR assumed that the lab-to-on-site factor was the same for both refrigerators and freezers, even though the California evaluation only metered refrigerators.

In 2004, KEMA compared lab-based metered energy consumption to manufacturer-reported energy consumption in order to determine the impacts of degradation on annual UEC.[31] KEMA found that 93% of the 136 refrigerators and freezers they studied showed degradation and increasing UEC over time. However, based on uncertainties in their model, KEMA was unable to provide a final degradation factor.

As part of their evaluation of the 2009 Second Refrigerator Recycling Program (RRP) in Nevada, ADM calculated the per-unit net savings for refrigerators that were recycled through the program.[32] ADM used data from the 2010 evaluation of the California ARP to estimate a degradation factor of 1.25% per year for refrigerators recycled through the Nevada RRP. ADM did not detail how they arrived at this value, just that the estimate was based on the California report. The RTF used ADM's degradation factor in their net impact methodology citing the "moderate" nature of the value, the sample sizes used to develop the value, and that the study was conducted recently.

In 1998, Miller and Pratt metered 95 existing and 15 new refrigerators in New York City Housing Authority (NYCHA) apartments.[33] Miller and Pratt used the *in situ* meter results to develop a regression model that accounted for the impacts of variables such as climate, household size, door openings, and age on the annual energy consumption of refrigerators. Miller and Pratt found that refrigerators showed significant degradation over time and they estimated an annual degradation factor of 1.37%, meaning that the energy consumption of a refrigerator increases by 1.37% per year.

The NMR team selected the degradation factor reported by Miller and Pratt (1.37%) for the net impact evaluation in Massachusetts. This value was selected due to the fact that the Miller and Pratt study metered 95 existing refrigerators, *in situ*, in the state of New York, where the weather is similar to that of Massachusetts.

The degradation factor was only applied to the NMR AHAM methodology; it is not included in the NMR DOE testing methodology. The regression model used in the DOE testing methodology considered degradation of refrigerators over time, but did not find it to be significant. In fact, Cadmus stated the following in the California report, "To account for non-linear appliance degradation over time, an age-squared term was considered for the model, but was not significant in the presence of the other model terms."

[31] KEMA (2004). *2003 EM&V RARP Study: Verification, Degradation & Market Potential Analysis.* December 23, 2004.
[32] ADM (2010). *2009 Second Refrigerator Recycling Program, NV Energy—Southern Nevada, Program Year 2009, Measurement & Verification Report.* February, 2010.
[33] Miller and Pratt (1998). *Estimates of Refrigerator Loads in Public Housing Based on Metered Consumption Data.* October, 1998.

3.3 Refrigerator-to-Freezer Factor

The NMR DOE testing methodology only applies to refrigerators as the California model did not consider freezers. Due to this, NMR reviewed secondary sources to develop a refrigerator-to-freezer factor as a means of developing a freezer UEC using the DOE testing methodology. It was not necessary to apply this factor to the AHAM methodology as AHAM provides annual energy consumption estimates for both refrigerators and freezers.

In 2004, KEMA-XENERGY produced a report detailing their evaluation of the 2002 California RARP in which they developed UEC estimates for both refrigerators and freezers.[34] Using the DOE lab testing methodology, KEMA-XENERGY metered a sample of 100 refrigerators and freezers. These results were combined with metering results from other studies in California to develop a regression model identifying the impacts of various characteristics on energy consumption, and to develop UECs for refrigerators and freezers. Ultimately, the study identified UECs of 1,946 kWh per year and 1,662 kWh per year for refrigerators and freezers respectively, indicating that freezers use 15% less energy than refrigerators.

The 2008 ADM evaluation of the 2004-05 California RARP produced similar results to the KEMA-XENERGY study. This evaluation built off of the 2004 KEMA-XENERGY study, and added 200 DOE-based meter results to the modeling effort. ADM estimated UECs of 1,834 kWh per year and 1,560 kWh per year for refrigerator and freezers respectively, again indicating that freezers use 15% less energy than refrigerators.

Each of the studies reviewed used DOE lab-based meter results in conjunction with regression models to develop UECs for refrigerators and freezers. This is consistent with the methodology used in the California study, and thus is applicable to the Massachusetts NMR DOE testing methodology. Based on the study results, NMR selected a refrigerator-to-freezer factor of 0.85.

3.4 Adjusted Gross Assumptions

Gross program savings were adjusted to account for the partial use and replacement of appliances retired through the program.

3.4.1 Partial Use Factor

A partial use factor was developed for each participant, to adjust UEC estimates to reflect the adjusted gross savings of appliances that were removed through the program. The partial use factor is designed to account for the fact that not all refrigerators and freezers are plugged in year round. Secondary appliances are more likely to be unplugged for a portion of the year than primary appliances, and since this is a secondary appliance turn-in program, the partial use factor is an important consideration when developing adjusted gross savings estimates.

[34] KEMA-XENERGY (2004). *Final Report, Measurement and Evaluation Study of 2002 Statewide Residential Appliance Recycling Program.* February 13, 2004.

Table 3-4 shows the amount of time that each participant category had their refrigerator or freezer plugged in during the year prior to having their appliance recycled through the program. This table is just for reference as the adjustment for partial use was done on a participant by participant basis. Based on these responses we assumed the following plug-in patterns:

- All the time—appliance was plugged in for the entire year
- Most of the time—appliance was plugged in for nine months of the year
- Occasionally—appliance was plugged in for four months of the year
- Never—appliance was never plugged in during the year prior to recycling

Table 3-4: Amount of Time Appliance Plugged In[35]
(Base: All participants except those who responded DK/Ref)

How often appliance was plugged in	Refrigerators			Freezers	
	Primary Replaced	Secondary Replaced	Secondary No Replace	Secondary Replaced	Secondary No Replace
Sample Size	*56*	*44*	*186*	*47*	*196*
All the time	100%	64%	41%	79%	42%
Most of the time	--	14	14	11	14
Occasionally	--	16	31	7	24
Never	--	7	13	4	20

For each participant, usage (in months) was divided by 12 to develop the partial use factors for the various plug-in time frames. For example, if a participant reported using their refrigerator "most of the time" we applied a partial use factor of 0.75 to that participant, assuming that their refrigerator was plugged in nine months out of the year.

[35] Participants who recycled a refrigerator through the program were asked if the refrigerator was their primary or secondary refrigerator. Participants who said that it was their primary refrigerator were assumed to have kept the appliance plugged in year round. Participants who recycled a freezer through the program were not asked this question, so the same assumption does not apply.

3.4.2 Replacement Equipment

Some of the appliances retired by the program were ultimately replaced by participants. In order to accurately identify the adjusted gross savings of the program, replacement equipment must be taken into account. Three factors were considered while adjusting savings to account for replacement equipment:

1) Was the appliance that was retired by the program ultimately replaced by the participant?
2) If yes, was the replacement appliance new or used?
3) How frequently was the retired appliance plugged in?

Table 3-5 shows the average "age" of replacement refrigerators and freezers. This table is just for reference as the adjustment for replacement equipment was done on a participant by participant basis.

Table 3-5: Replacement of Appliances

(Base: All participants who replaced appliances, except those who responded DK/Ref when asked about the age of replacement equipment)

Age of Replaced Appliance	Refrigerators		Freezers
	Primary Replaced	Secondary Replaced	Secondary Replaced
Sample Size	*56*	*44*	*47*
New	85%	73%	91%
Used	15	27	9

New replacement equipment was assumed to have an annual energy consumption equivalent to that of the 2009 AHAM estimates, while used replacement equipment was assumed to have an annual energy consumption equivalent to that of the 2000 AHAM estimates (Table 3-6). In the 2010 evaluation of the California ARP, it was found that used appliances that were five to ten years old had market value, while appliances older than that did not. Therefore, the 2000 AHAM estimates were selected for used replacement equipment as these values offer the most conservative estimates of annual energy consumption with regard to the adjusted gross savings of the program.

Table 3-6: Energy Consumption of Replacement Appliances (kWh/year)

Annual energy consumption	Refrigerators	Freezers
New replacement kWh/year (2009 AHAM)	450	423
Used replacement kWh/year (2000 AHAM)	704	476

The results from Table 3-6 were used in combination with any given participants partial use factor and applied where applicable. That is, if a respondent reported that they replaced their

retired refrigerator with a new one, and their retired refrigerator was plugged in all of the time, their savings were reduced by 450 kWh (assuming a partial use factor of 1.0). On the other hand, if a respondent retired a refrigerator that was only plugged in "occasionally," and replaced it with a new one, we assumed the new refrigerator was also only plugged in "occasionally," and subsequently reduced savings by 148.5 kWh (assuming a partial use factor of 0.33).

4 Free Ridership

Free ridership rates were developed based on a series of questions from the participant survey. Respondents were asked what they would have done with their refrigerator and/or freezer without the program. Those who reported that they would have kept the appliance unplugged or removed the appliance from their homes were considered free riders (FR1). As shown in Table 4-1, the initial free ridership rates were 44% for refrigerators and 50% for freezers.

A second free ridership rate (FR2) was developed in which respondents who initially said they would have gotten rid of the appliance were asked again, after considering additional factors, what they would have done with their appliance without the program. Participants were asked to consider the practical aspects of removing an appliance without the program's assistance, such as physically moving it themselves, or the need to pay a hauler to remove the appliance. Free ridership rates dropped slightly to 41% for refrigerators and 46% for freezers when participants reconsidered their anticipated course of action in the absence of the program.

Table 4-1: Overall Free Ridership Rates [36]

(Base: All participants identified as either full free riders or non-free riders)

Free Ridership	Refrigerators	Freezers
Sample Size	*268*	*226*
FR1 (free riders)	44%	50%
NFR1 (non-free riders)	56	50
Sample Size	*277*	*232*
FR2 (free riders)	41%	46%
NFR2 (non-free riders)	59	54

[36] Based on responses to the participant survey, NMR was unable to identify a handful of participants as either free riders or non-free riders. These respondents were removed from this analysis.

For the purposes of the impact evaluation, NMR applied free ridership values (FR2) on a participant-by-participant basis. Table 4-2 displays the average free ridership values for each category of participants. If a participant was labeled a free rider they were given a savings value of zero.

Table 4-2: Categorical Free Ridership Rates
(Base: Participant categories identified as either full free-riders or non-free riders)

Free Ridership	Refrigerators			Freezers	
	Primary Replaced	Secondary Replaced	Secondary No Replace	Secondary Replaced	Secondary No Replace
Sample Size	*54*	*43*	*179*	*45*	*187*
Free riders	50%	28%	41%	25%	51%
Non-free riders	50	72	59	75	49

5 Program Impacts

5.1 UEC Development

UEC estimates were developed for refrigerators and freezers using the NMR AHAM and the NMR DOE testing methodologies. This section details the calculations and findings for each methodology.

5.1.1 NMR AHAM UECs

As discussed in the *NMR AHAM Methodology* section, the following equation was used to develop the refrigerator and freezer UECs:

$$UEC_i = [(AHAM_i) + (kWh\ degradation_i)] \times \left(\frac{\text{Site}}{\text{Lab}}\text{Factor}\right)$$

Individual UECs were developed for all survey participants that had refrigerators or freezers retired through the program. AHAM data was applied to each participant to develop a unique UEC depending on the age of the refrigerator or freezer that was retired through the program. Among survey participants, the average annual energy consumption of recycled units was 1,215 kWh and 983 kWh for refrigerators and freezers respectively. After adjusting for degradation (1.37%), the average energy consumption increased to 1,756 kWh for refrigerators and 1,436 kWh for freezers. The final step in developing the NMR AHAM UECs was to apply the lab-to-on-site factors for each participant. The final NMR AHAM UECs, by participant category, are presented in Table 5-1.

Table 5-1: Categorical NMR AHAM UECs (kWh/year)

UECs	Refrigerators			Freezers	
	Primary Replaced	Secondary Replaced	Secondary No Replace	Secondary Replaced	Secondary No Replace
UEC	1,004	1,565	1,500	1,170	1,207

Table 5-2 presents the average UECs for refrigerators and freezers using the NMR AHAM methodology.

Table 5-2: Average NMR AHAM UECs (kWh/year)

UECs	Refrigerators	Freezers
UEC	1,410	1,200

5.1.2 NMR DOE Testing UECs

Table 5-3 displays the coefficients of the independent variables that were used in the California DOE-based regression model. As stated previously, NMR used the Massachusetts Program's appliance characteristics and summed the product of the coefficients to develop a UEC for refrigerators recycled through the program.

Table 5-3: California DOE UEC Regression Details*

(Dependent Variable-DOE Estimated UEC, R^2=0.41)

Independent Variables	Coefficient	t-Value
Intercept	491.83	1.9
Dummy: Side-by-Side Configuration	98.96	0.5
Size (Cubic Feet)	35.30	2.9
Age (Years)	25.25	4.7
Interaction: Side-by-Side x Age	19.98	2.2
Dummy: 2006-2008 Metering Sample	-413.99	-6.3

Source: Cadmus et al. (2010).** ***Residential Retrofit High Impact Measure Evaluation Report. **February 8th, 2010.**

Twelve percent of refrigerators recycled through the program had a side-by-side configuration. The average size of program refrigerators was 16.8 cubic feet, and the average age was 26.6 years old (Table 5-4).

Table 5-4: Program Refrigerator Characteristics

(Base: Refrigerators retired through the program from June 2009 through August 2010, except those with no size or age information)

Appliance Characteristics	Refrigerators
Sample Size	*6,969*
Side-by-Side percentage	12%
Average size (Cubic Feet)	16.8
Average age	26.6
Interaction: Side-by-Side x Age	3. 2

The refrigerator characteristics shown in Table 5-4 were used in conjunction with the model coefficients in Table 5-3 to calculate annual energy consumption estimates for program refrigerators. The refrigerator-to-freezer factor of 0.85 was applied to develop annual energy consumption estimates for freezers. These calculations are shown here:

Refrigerator UEC

$$[491.83 + (98.96 \times .012\ SidebySide) + (35.3 \times 16.8\ Size) + (25.25 \times 26.6\ Age) + (19.98 \times 3.2\ Interaction) + (-413.99)] = 1{,}420\ kWh$$

Freezer UEC

$$(1{,}420\ kWh) \times (0.85) = 1{,}207\ kWh$$

The NMR DOE UECs differ from the AHAM UECs in that all participant refrigerators have the same gross starting point, and all participant freezers have the same starting point. Due to the nature of the California model it is impossible to create a unique starting point for each participant. While each participant has the same starting point, key factors (lab-to-onsite, partial use, replacement, and free ridership) are still applied on a participant-by-participant basis depending on survey responses. The final DOE based refrigerator and freezer UECs were developed after applying the lab-to-on-site factor for each participant (Table 5-5).

Table 5-5: Categorical NMR DOE UECs (kWh/year)

UECs	Refrigerators			Freezers	
	Primary Replaced	Secondary Replaced	Secondary No Replace	Secondary Replaced	Secondary No Replace
UEC	1,065	1,228	1,183	1,032	1,005

Table 5-6 displays the average UECs using the DOE methodology.

Table 5-6: Average NMR DOE UECs (kWh/year)

UECs	Refrigerators	Freezers
UEC	1,168	1,010

5.2 Adjusted Gross and Net Savings

The same assumptions were used to calculate adjusted gross and net savings for each methodology. NMR adjusted the UECs to account for partial use and replacement equipment to develop adjusted gross savings estimates for refrigerators and freezers

Table 5-7 displays the partial use factors for each of the participant categories, as well as the variables that were used to calculate the impacts of replacement equipment. Overall, about one-

third of the refrigerators (34%) and about two-fifths of the freezers (18%) retired by the program were ultimately replaced by participants. The majority of the replacement refrigerators (79%) and freezers (91%) were new appliances. This table is just for reference as the adjusted gross and net savings were calculated on a participant-by-participant basis.

Table 5-7: Partial Use Factors and Replacement Equipment Variables

Partial Use and Replacement Equipment Variables	Refrigerators			Freezers	
	Primary Replaced	Secondary Replaced	Secondary No Replace	Secondary Replaced	Secondary No Replace
Sample Size	*56*	*44*	*186*	*47*	*196*
Partial Use Factor	1.00	0.79	0.62	0.89	0.60
Percent of appliances replaced	100%	100%	--	100%	--
Percent of replacement appliances-new	85%	73%	--	91%	--
Percent of replacement appliances-used	15%	27%	--	9%	--
New appliances kWh (2009 AHAM)	450	450	--	423	--
Used appliances kWh (2000 AHAM)	704	704	--	476	--

Table 5-8 shows the average impact of partial use adjustments on the savings for each category of participants. Again, these are just averages, the calculations were done line by line and each participant has a unique partial use adjustment and subsequent savings.

Table 5-8: Categorical Savings after Partial Use Adjustment (kWh/year)

Methodology	Refrigerators			Freezers	
	Primary Replaced	Secondary Replaced	Secondary No Replace	Secondary Replaced	Secondary No Replace
NMR AHAM	1,004	1,241	941	1,030	738
NMR DOE Testing	1,065	968	731	918	606

The average savings for refrigerators and freezers, after adjusting for partial use, are 1,001 kWh per year and 794 kWh per year respectively using the AHAM methodology. Using the DOE methodology, the average savings are 833 kWh for refrigerators and 665 kWh for freezers after adjusting for partial use (Table 5-9).

Table 5-9: Average Savings after Partial Use Adjustment (kWh/year)

Methodology	Refrigerators	Freezers
NMR AHAM	1,001	794
NMR DOE Testing	833	666

The next step in moving from UEC to net savings was to adjust for replacement equipment. This step, in combination with accounting for partial use, led to our adjusted gross savings estimates. As previously mentioned, we were consistent with the partial use patterns of participants when

adjusting for replacement equipment. That is, if a participant reported that they only had their retired refrigerator plugged in "occasionally," then we assumed that any replacement equipment was also plugged in "occasionally." Table 5-10 shows the adjusted savings, for each category of participant, after accounting for replacement equipment.

Table 5-10: Categorical Adjusted Gross Savings

Methodology	Refrigerators			Freezers	
	Primary Replaced	Secondary Replaced	Secondary No Replace	Secondary Replaced	Secondary No Replace
NMR AHAM	483	832	941	652	738
NMR DOE Testing	579	556	731	539	606

The average annual savings, after accounting for replacement equipment, were 835 kWh for refrigerators and 722 kWh for freezers using the AHAM methodology. Using the DOE methodology the savings were 675 kWh and 539 kWh for refrigerators and freezers respectively (Table 5-11).

Table 5-11: Average Adjusted Gross Savings

Methodology	Refrigerators	Freezers
NMR AHAM	835	722
NMR DOE Testing	675	594

For each survey participant free ridership was applied to the adjusted gross savings to calculate the per unit net savings attributable to the program. Free ridership status, as determined for each respondent in the participant survey, was applied on a participant by participant basis, where those participants that were identified as free riders were given a savings value of zero and all other participants were given their full adjusted gross savings (free ridership rates are listed in Table 4-1). Table 5-12 shows the average net savings for each category of participants.

Table 5-12: Net Savings per Unit (kWh/year)

Methodology	Refrigerators			Freezers	
	Primary Replaced	Secondary Replaced	Secondary No Replace	Secondary Replaced	Secondary No Replace
NMR AHAM	292	611	666	464	424
NMR DOE Testing	293	401	520	400	337

NMR developed final per unit net savings for each methodology by weighting the refrigerator and freezer categories to reflect the program proportions ((Table 3-1). The final per-unit net savings under the NMR AHAM methodology were 585 kWh per year and 432 kWh per year for refrigerators and freezers respectively. Under the NMR DOE Testing methodology the final per unit savings were 459 kWh per year for refrigerators and 349 kWh per year for freezers. Note that the net savings presented in Table 5-13 are based on the units surveyed and have been calculated on a unit-by-unit basis.

Table 5-13: Final Net Savings (kWh/ year)

Methodology	Refrigerators	Freezers
NMR AHAM	585	432
NMR DOE Testing	459	349

6 Impact Conclusions

Table 6-1 displays a comparison of the overall program savings using the *ex ante* assumptions currently used by program sponsors (annual per unit savings of 724 kWh for both refrigerators and freezers), the NMR AHAM methodology, and the NMR DOE testing methodology. The savings for the NMR methodologies were calculated using the adjusted free ridership values (FR2). Each of these methodologies produced savings that are substantially lower than the savings calculated using the *ex ante* values. Total program savings using the NMR AHAM methodology represent a 24% decrease relative to savings using the current program assumptions, and the NMR DOE testing methodology represents a 40% decrease in savings.

Table 6-1: Comparison of Overall Program Savings (MWh)—June, 2009 to November, 2010

Sponsor	2009				2010			
	Ex ante	NMR AHAM	NMR DOE	AHAM/DOE Avg.	Ex ante	NMR AHAM	NMR DOE	AHAM/DOE Avg.
National Grid	3,762	2,834	2,237	2,536	3,627	2,747	2,167	2,457
NSTAR	--	--	--	--	1,956	1,473	1,163	1,318
CLC	--	--	--	--	185	140	110	125
WMECo	--	--	--	--	159	123	97	110
Total	**3,762**	**2,834**	**2,237**	**2,536**	**5,926**	**4,483**	**3,537**	**4,010**

While the program's current assumptions account for free ridership based on KEMA-Xenergy's 2002 study, the gross savings estimates are based on ADM's 2008 report on the California RARP. These gross savings estimates are based on the DOE testing methodology, in which appliances are tested in a controlled environment, creating results that do not account for factors such as climate, household size, location, or door openings. The NMR methodologies account

for these *in situ* factors through the lab-to-on-site adjustment, and also account for the partial use and replacement of appliances retired through the program. These additional adjustments, and likely our free ridership estimate, are responsible for the decreased savings under the NMR methodologies.

Each of the NMR methodologies has strengths and weaknesses. The major advantages of the NMR AHAM methodology are the inherent sample sizes in the data, and the inclusion of freezers in the annual energy consumption estimates.[37] The NMR DOE testing methodology is based on a smaller sample than the NMR AHAM methodology, and the model does not account for freezers. Having said that, the NMR DOE testing methodology does not require the interpolation or extrapolation of data, as the NMR AHAM methodology does, and the model encapsulates degradation, unlike the NMR AHAM methodology.

The program may want to consider *in situ* metering on a sample of Massachusetts refrigerators and freezers that are representative of the program. *In situ* metering could be compared to the results of this evaluation to determine if program specific metering is necessary for future impact evaluations, or if applying program appliance characteristics to secondary sources, as is done here, is sufficient.

[37] AHAM includes data from most of the major refrigerator and freezer manufacturers in their annual energy consumption estimates.

7 Overall Findings and Recommendations

The findings and recommendations presented here draw from all 2009-10 appliance evaluation activities: the impact evaluation presented in this report and the participant survey and secondary market analysis.

The program seems to be quite successful, with high satisfaction ratings, customer suggestions to continue and expand the program, and evidence that most of the retired appliances were older, working, and in use before removal. The program offers an attractive financial incentive to customers with secondary appliances and it is also far more convenient than most traditional options for disposing of a secondary appliance in Massachusetts. Nevertheless, the findings from the evaluation efforts suggest that improvements can be made to some aspects of the program in order to increase participation and the resulting energy savings and to reduce the few problems experienced by participants. The Sponsors and JACO have been proactive about addressing issues as they arise and have already started to work on some of these areas.

7.1 Summary

7.1.1 Profile of Units Recycled through the Program

More than two-thirds (70%) of the removed refrigerators were being used as spares before they were picked up, and more than three quarters (79%) were over ten years old. About one-third (32%) of the refrigerators were over twenty years old. The freezers that were picked up tended to be older than the refrigerators: 82% were over ten years old, and about half (49%) were over twenty years old. Nearly all the appliances were in working condition, close to two-thirds of the appliances had been plugged in all or most of the time, and eighty-one percent of the units were secondary appliances. These results indicate that, for the most part, the appliances that were removed through the program were in line with those targeted by the program—refrigerators and freezers tended to be secondary, older, in working condition, and plugged in.

Free ridership (FR) among respondents who used the program to dispose of primary units is higher than those who disposed of secondary units. Among the subgroups of participants who recycled refrigerators, 19% of participants removed a primary fridge, 16% removed a secondary fridge and replaced it with another fridge, and 65% removed a secondary fridge and did not replace it. The FR rate for the primary group (48%) is substantially higher than for the secondary groups (37% overall), and the FR rate for the secondary/replaced group (27%) is lower than that of the secondary/non-replaced group (40%).

7.1.2 Calculation of Program Impacts

Program participants can be categorized into three general groups: Participants who recycled a primary appliance (19% of participants); those who recycled a secondary appliance and replaced it with another appliance (16% of participants); and those who recycled a secondary appliance,

but did not replace it (65% of participants). The savings profile is different for each of these participants and may necessitate different program approaches.

1) Primary units were not targeted by the Massachusetts Appliance Turn-in Program; the program requires that removed refrigerators are secondary refrigerators. Nevertheless, about one in five (19%) of the respondents in the refrigerator group reported that the surrendered unit was the primary unit in the home. A primary unit, as the main refrigerator in the home, is on all of the time but will be replaced, so the savings potential from replacement is contingent on the difference between the energy consumption of the old unit and the replacement unit. Eighty-five percent of participants replaced the primary unit with a new unit and 15% replace it with a used unit. By including primary units in the program, Sponsors can claim savings for the difference in energy consumption and can be assured that the unit will never become a secondary unit. Targeting primary units would necessitate a change in program goals and marketing techniques with retailers.
2) Secondary units that were replaced are among the group of units that the program was targeting, but the savings claims for this group are reduced by the replacement unit. Seventy-three percent of the replacement units were new unit and 27% were used. Sponsors can increase savings by discouraging replacements, and if that is not acceptable to participants, encourage them to replace with a newer more efficient ENERGY STAR unit and keep it plugged in only when absolutely necessary.
3) Secondary units that are not replaced represent the largest share of participants and the largest share of program savings on a per-unit basis. This is the group targeted by the program.

7.1.3 Appliance Disposal Options

NMR estimates that there are about one million secondary refrigerators and stand-alone freezers in Sponsor households. In 2010, the program removed about 1% of those units. Add to that the number of new refrigerators purchased in a year (for almost every new refrigerator purchased, an existing unit could potentially be transferred to use as a secondary unit), and we estimate there are approximately 1.3 million units in Sponsor service areas that could potentially be removed from use.[38]

Through the research on the secondary market for this evaluation NMR is able to characterize the flows of all refrigerators and freezers (primary, secondary, working, and non-working units) from homes; direct comparison of these flows to flows from program activity is difficult because the program is focused on secondary units only. We estimate that retailers and the haulers contracted by them—the major source of removals in the state—remove about 7% of all primary

[38] Using a variety of sources, NMR estimates the number of units that potentially would be considered for disposal in Massachusetts and the means for disposal. We caution, however, that these are rough estimates—the study was designed as an exploration of the likely flows of products through the secondary and recycling/disposal market; the sample was not designed with the rigor to definitively describe the precise quantities of units that market actors transfer to the secondary market or remove from the grid.

units that were recently replaced and secondary units (potential units). Municipal programs, the second largest source of removals, are responsible for the removal of about 4% of all potential units, from about 2% of households. The program is the third largest source of removals, responsible for about 1%. In total, we estimate that about 10% of secondary refrigerators and freezers and newly displaced refrigerators due to new purchases in Sponsor service areas were removed from service in 2010.

There is evidence that no more than 25% of the units that are picked up by these sources are redirected to the secondary appliance market, and thus could potentially end up back on the grid. From a program savings perspective, this transfer does not appear to be a factor that needs to be included in the impact measurement because it is a small percentage of units overall. To illustrate: In the absence of the program, 9% of refrigerator participants and 8% of freezer participants said that they would have used a hauler or retailer to remove the units. Assuming that 25% of those units went to the secondary market instead of being destroyed, about 3% of refrigerators (about 9 refrigerators) and 1% of freezers (about 3 freezers) picked up through the program would have ended up in the secondary market. Caveats for our estimates are included as notes in Table 7-1 below.

Table 7-1: Rough Estimates of Ultimate Unit Status in Sponsor Area

Number of residential customers	Estimates	Source	Notes
National Grid	1,200,000	Sponsor website	
NSTAR	987,000	Sponsor website	
Cape Light Compact	200,000	Sponsor website	All customers
WMECo	200,000	Sponsor website	All customers
TOTAL Sponsor Households	2,587,000		Rough estimates (may include some C/I customers)
Secondary refrigerators in use (Sponsor territory)	517,400	2005 RECS	Assumed same usage rates across New England
Stand-alone freezers in use (Sponsor territory)	564,436	2005 RECS	Assumed same usage rates across New England
MA Program-eligible units	1,081,836		Secondary, working units only
New refrigerator purchases per year (Sponsor territory)	*235,182*	2005 RECS	New purchases represent potential transfers to secondary status. Calculation includes half of primary refrigerators less than 2years old
Total potential removals in MA Sponsor territory	*1,317,018*		Sum of secondary units in use and new refrigerator purchases in 2010
Units removed from service			
Annual units removed by municipal programs	51,740	NMR in-depth interviews	Assume 2% of households per year. Includes primary, secondary, working and nonworking units
Annual units removed by/on behalf of retailers	94,073	NMR in-depth interviews	Assume 100% of retailers offer removal and 40% of customers use retail service for disposal. Mostly former primary units, but these become secondary units if kept. Includes working and nonworking units.
Number of units collected by haulers/recyclers directly from households	3,000	NMR in-depth interviews	Assume 30 units per hauler/recycler and assume 100 haulers/recyclers total (very rough estimate). Includes primary, secondary, working and nonworking units
Number of units removed through Program	10,570	Program records 2010	
Units kept on grid			
Annual units sold on Craigslist	2,150	Cadmus secret shopping	Assume 57% units sold (17/30) every 3 weeks (52/3=17.3 cycles per year), with 218 total units available per cycle
Number of used units sold through used dealers	24,268	NMR in-depth interviews	Assume 25% of units collected by haulers/retailers return to grid
TOTAL Units Removed from service	135,115		All types of units, adjusted by those put back on grid through used dealer sales

7.2 Recommendations

This section presents overall findings and recommendations from the impact study, the participant telephone survey and an exploration of the secondary appliance market.

7.2.1 Program Structure

Finding: About one in five (19%) of the refrigerators recycled through the program had most recently been used as the primary unit in the home.

Recommendation: Weigh the value of removing primary refrigerators—The Sponsors should consider either reducing the number of primary fridges removed by the program by reinforcing the requirement (e.g., in marketing materials and verification of eligibility) or alternatively, opening up the program to include primary fridges, as does the parallel program in Rhode Island. There are several advantages and disadvantages of accepting primary refrigerators. Relevant points to consider in this decision include the following:

- The program ensures that the refrigerators don't end up on the secondary market and that they are properly recycled.
- Participants who remove primary fridges through the program appear to be more likely than those who remove secondary fridges to get rid of the fridge in the absence of the program, as reflected in their higher free ridership rates. However, some customers might decide to replace their older primary fridges with new ones in part *because of* the opportunity to receive $50 to have their old fridge removed.
- Primary fridges are plugged in all the time, but when they are removed, they are replaced, versus fewer than one in five of the secondary fridges. The savings potential from replacement is contingent on the difference between the energy consumption of the old unit and the energy consumption of the replacement unit. Replacement appliances, on average, will be newer and more energy-efficient than the old ones that are removed. Replaced primary fridges are more likely than replaced secondary fridges to be new.
- Accepting primary fridges will help achieve program goals for number of appliances removed, particularly in more urban areas with smaller homes and fewer secondary appliances, and would allow opportunities to partner with appliance retailers in marketing for the program.

Finding: Fewer than one-half of major retailers' customers use their haul-away services; it seems likely that significant numbers of appliances may remain in use as secondary units after a new unit is purchased.

Recommendation: Consider partnering with major retailers to market and implement the program. Major retailers could promote the program in their stores to customers who may be making a decision to keep or discard an existing unit. Using retailers would necessitate a shift in targeted appliances for the program—the program would be more likely to pick up primary refrigerators and nearly dead units.

- Major retailers already work with electric companies, JACO, and ARCA in other states to implement similar programs – one reported a 5% to 7% increase in program participation due to the retail partnership.
- Sponsors may want to consider outreach to new appliance buyers, regardless of whether or not they accept primary refrigerators in the program in order to influence disposal decisions by consumers and purchase behavior of participants who recycle a secondary refrigerator and replace it.
- Retailers that sell new appliances provide a means of reaching customers who likely are reaching a decision point about what to do with an appliance about to be replaced. Messaging to new appliance buyers should communicate that even though it is a good idea to reuse or repurpose many household items, the right thing to do with older, inefficient refrigerators and appliances is to take them off the grid completely and to recycle them.
- All of the Sponsors' material that promotes purchases of ENERGY STAR® refrigerators and freezers should also present information about the Massachusetts Appliance Turn-in Program, so customers have information about an easy option for removing and recycling an older, inefficient appliance.
- Retailers' sales staffs can screen for functioning secondary appliance ownership before discussing the program, so as to discourage misrepresentation of primary units as secondary units. This is a particularly important part of discouraging free-ridership, and it may be happening in some cases – one appliance retailer reported that it encourages customers to use the program to haul away units being replaced with new units.
- Major retailers pick up many of the used appliances being discarded in Massachusetts through their haul-away programs. Retailers usually sell these appliances to haulers and recyclers who then sell the appliances in the scrap metal market and a small number of the newest or like-new looking appliances may be sold into the used appliance market. If the Sponsors partner with major retailers, they could require that all units picked up by the retailer are fully demanufactured, rather than being resold by haulers.
- Retailers may be willing to partner with the Sponsors, as some retailers already offer hauling services to other dealers and to customers who do not otherwise purchase new appliances. This may be profitable for retailers – they charge for the service, sell the units for scrap, more fully utilize delivery trucks already driving through neighborhoods, and increase their "green" reputation.

7.2.2 Process Issues

Finding: About one-third of the scheduled pick-up appointments were cancelled or no-shows. The idea of removing an extra refrigerator or freezer resonated on some level with people who went through the effort of scheduling an appointment but cancelled or missed the pick-up time.

Some of these customers may have reconsidered their decision and found a need that justifies keeping the appliance; others may have forgotten or been too busy to keep the appointment.

Recommendation: Target missed appointments—JACO said that it intends to increase outreach to these customers through post cards, phone calls, and emails in another attempt to reschedule. The point is not to harass these customers, but to facilitate the participation process for them. The program already offers Saturday pick-ups and choices for pick-up times based on schedule and geography, but additional effort should be made to give these customers priority for pick-up times that might include Saturdays, early mornings, evenings, next day pick-up, or small, one- to two-hour windows for pick-up times. Messaging with these customers should reinforce their good decision making for initiating the removal and recycling of an appliance through the program.

Finding: Program goals were based in part on the number of residential customer accounts from each Sponsor and JACO's ability to collect units from 1% to 2% of the customer base per year in other programs. While this rule of thumb seems to be sufficient for National Grid and Cape Light Compact, both NSTAR and Western Massachusetts Electric have had trouble meeting the initial unit goals.

*Recommendation: Adjust goals to reflect demographics of the residential customer base for each Sponsor—S*ervice areas in NSTAR and Western Massachusetts Electric have a large number of apartments and multifamily homes and residents typically do not have areas where they can keep second refrigerators, such as basements or garages. Adjusting the goals of the program to reflect the pool of single family homes may result in more realistic targets for these Sponsors.

7.2.3 Program Marketing

Finding: A few respondents thought the program was selling the removed appliances or giving them to the needy; others didn't know why the appliance had to be plugged in or running before the scheduled pick-up or why it had to be in working condition.

Recommendation: Educate participants about the program goals—The program should emphasize that the primary goal of the program is to save energy and reduce demand on the electric grid by removing older, less efficient secondary refrigerators and stand-alone freezers. The program helps customers get rid of the appliances before they might do so on their own. Reductions in energy bills and the participation incentive are additional bonuses for customers.

Finding: Municipal programs may remove appliances in up to 2% of households, but most municipal programs are fee-based and burdensome, requiring door removal, moving an appliance to the curb, etc. In addition, hauling companies typically charge for appliance removal, and those that pay based on scrap value pay less than the program.

Recommendations: Continue messaging about the ease of removal through the program—Physical and financial barriers may encourage some consumers to keep their secondary

appliances, and marketing the program to residents faced with these barriers might allow the Sponsors to collect additional units that would not otherwise be removed from the grid.

- *Consider partnering with municipalities to promote the program, and discourage charitable donation of working units.* Sponsors could consider allowing residents to recycle their appliance, and donate the $50 incentive to a charity of their choice, rather than donating the inefficient appliance. This would prevent customers from thinking that the Sponsors are trying to reduce charitable donations. JACO could potentially pick up the units from the municipalities to facilitate the effort.
- *Consider increasing marketing efforts outside of urban areas and targeting residents of towns without municipal recycling programs*. Residents in less densely populated areas may be more likely to have secondary appliances than their counterparts in cities. Also, some towns do not have municipal appliance recycling programs at all, making the program particularly attractive to these residents.

Finding: Advertising through local newspapers and media has been the most effective means for reaching customers; more participants heard about the program through paid media than any other source. Word-of-mouth also has been an effective means for participants to learn about the program.

Recommendation: Continue promoting the program through existing channels—The Sponsors' communications network to customers through bill inserts, notations on bills, newsletters, and emails should continue to be used to promote the program on a continuous basis, or when a quick boost in participation is desired. Promotions through schools and community groups and options for rebate donations to these groups help to promote the program and provide a community service.

- School promotions may be particularly appropriate for younger customers with children in school. Younger participants (under 55 years) were more likely to turn in a refrigerator they were going to replace or had recently replaced, and to have signed up for the program online, than their older counterparts.
- Also, although few respondents first learned about the program on the Sponsor website, the younger group was more likely than those 55 years and older to find out about the program on the internet (11% versus 3%) and to enroll online (40% versus 14%), showing that they did seek out the program information and enrollment opportunity on the internet and that more online advertising might be fruitful for this younger subset of participants.
- Let viral marketing work for the program. A previous recommendation was to make participants more informed about the program; invite those participants to tell their friends and neighbors about the program.

Finding: About one-third of the participants who removed a refrigerator through the program and 18% of those who removed a freezer replaced the appliance after it was picked up.

Recommendation: Reinforce the idea of saving energy by not using appliances that are not essential and buying products with the ENERGY STAR label—Tell participants how much energy and money they saved by getting rid of their inefficient model and will continue to save if they do not replace the appliance. If they must replace the appliance, encourage them to consider the more efficient ENERGY STAR labeled units.

Finding: Craigslist appears to be a significant outlet for used appliances, but mostly for newer, more efficient refrigerators. Retailers that sell used appliances have few models available at any given time and those dealers also are interested in only newer units or new-looking units.

Recommendation: Sponsors should consider reaching out to Craigslist sellers. Units offered on Craigslist are likely to be working units. The average listing price on Craigslist was $230 more than the program's incentive. However, 10% of units were $50 or less, and 23% percent were $100 or less, and six postings offered their refrigerator for free. Although those with high-value refrigerators may not be dissuaded from selling them on Craigslist, sellers with low-priced units may prefer the ease and environmental benefits of the program.

Finding: Messages about recycling and the environment resonate with Massachusetts customers. Reducing dependence on foreign oil through energy efficiency also resonates with many people, particularly older participants. Younger participants (under 55 years) were more likely than older ones to cite recycling or helping the environment (15% versus 10%) as a reason for participating.

Recommendation: *Let participants know about the environmental benefits they generated*—It should also be emphasized that appliances will be recycled in a way that is less harmful to the environment than other disposal options. They will not be sold, donated to charity, or disposed of in a landfill.

- Emphasize that ninety-five percent of the components are recycled. Metal, glass, and plastic from the collected appliances is reclaimed and reused for other purposes. Foam insulation is incinerated at a waste to energy plant, producing energy rather using it. Materials have been diverted from landfills. Plus appliances collected through the program are disposed of in a way that prevents the release of ozone depleting substances and greenhouse gases to the atmosphere.
- Adjust language in marketing materials on the website and elsewhere to reflect Massachusetts-specific accomplishments. Over 13,000 units have been taken off the grid in Massachusetts; now the program has a track record of its own that tells a compelling story about savings and the environmental benefits of the program.
- The collection team should leave information with the customer thanking them for their participation and letting them know that their decision to participate was a good one. Emphasize the cost savings, energy savings, and environmental benefits of removing and recycling the appliance. When the rebate check is sent, the messaging should be repeated.