New York Upstate Refrigerator and Freezer Recycling Energy Efficiency Program
Metering Study Report

Final

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Submitted to:

National Grid

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Executive Summary

This report presents the results of a refrigerator metering study of National Grid's Refrigerator-Freezer Recycling Program in upstate New York. The program is designed to encourage households to retire and recycle secondary, inefficient refrigerators and freezers. The metering study was conducted by NMR Group, Inc. (NMR). The study included metering at 50 sites located in two areas in Upstate New York (Albany and Syracuse).

The primary goal of the study was to obtain metered energy usage data for a sample of secondary refrigerators removed through the program. The study was conducted in conjunction with the 2010 process evaluation performed by Tetra Tech, Inc.

Sampling Design

The original sampling design called for metering 25 refrigerators in the Albany area and 25 refrigerators in the Syracuse area during the fall of 2010.[1] The fall was chosen as a mild temperature period that would offer an opportunity to study energy usage without weather extremes or holiday periods that might affect the metered energy usage. However, due to difficulty recruiting participants, metering was halted at the end of November 2010 before the extreme winter weather began. Metering began again in the spring of 2011 (also chosen for mild temperatures). In addition to splitting the metering study between the fall and spring, due to difficulty recruiting participants in the Albany area and in consideration of the project schedule, NMR elected to reduce the number of refrigerators metered in Albany to 22 and increase the number of refrigerators metered in Syracuse to 28. Twenty-seven refrigerators were metered in the fall of 2010, eight in Albany and 19 in Syracuse, and 23 refrigerators were metered in the spring of 2011, 14 in Albany and nine in Syracuse.

Comparison of Sample and Population

In general, the characteristics of the sample of metered refrigerators closely match the characteristics of the population of refrigerators recycled through the program between July 1, 2010 and July 5, 2011. Refrigerators in the sample are of similar size, age, style and make as the population as a whole.

[1] The Albany and Syracuse areas included a twenty mile radius from a central zip code.

Sampling Error

Based on the results of the metering study, NMR estimates an error margin of +/-12.3% at the 90% confidence level. This is based on the mean energy savings and the standard deviation of the differences of individual estimated compared to the mean. The original sampling plan was designed to achieve an error margin of +/-10% at the 90% confidence level; however, the final sample proved to be less homogeneous than expected.

Metering Results

The primary objective of this evaluation was to develop independent estimates of energy and demand savings of secondary refrigerators removed and recycled by the program based on metered energy use. To achieve this goal, field technicians installed a power meter at each site to monitor and measure the energy consumption of secondary refrigerators for a minimum of a two week period. Field technicians confirmed whether refrigerators were eligible for the metering project once onsite. This step of eligibility included checking to ensure that refrigerators were indeed true secondary refrigerators, not empty, unplugged, inoperable, or in a condition that would not allow metering.[2]

In order to determine the annual energy usage for each of the 50 refrigerators metered, NMR divided the total kWh of metered refrigerators by the number of hours metered to determine the average hourly usage for each refrigerator. The annual energy usage was determined simply by multiplying the average hourly energy usage by 8,760 hours. On average, the metered annual energy usage was 812 kWh with a median of 796 kWh. It is important to note that annual energy usage varied widely from as low as 125 kWh to as high as 2,097 kWh.[3,4] The size and age of units, as well as refrigerator location and the usage patterns of owners, are four factors that drive these differences. In general, the smaller units metered resulted in lower annual energy usage and larger units resulted in higher annual energy usage.

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[2] Additional details on confirmation of eligibility can be found in Section 1.5.

[3] The refrigerator with the lowest annual metered energy usage (125 kWh) was a 1987, 12 cubic foot refrigerator, located in an unheated garage. Based on make and model number, this refrigerator was located in the DOE database and had a rated annual energy usage of 400 kWh. The refrigerator was metered in the fall period for 14 days (October 30 through November 13, 2010.)

[4] The refrigerator with the highest annual metered energy usage (2,097 kWh) was a 1988, 19 cubic foot refrigerator, located in a heated basement. Based on make and model number, this refrigerator was not found in the DOE database. Based on the year of manufacture the refrigerator was assigned a rated annual energy usage of 964 per the AHAM database. The refrigerator was located near a heat vent and was metered in the fall period for 14 days (November 4 through November 18, 2010.)

Weather Normalized Savings

In order to account for differences in temperature throughout the year, NMR relied on a previous study conducted in New England by Blasnik (2004).[5] However, it is important to note that the Blasnick study took place in Boston and Worcester and, as such, the results may not be fully transferable to this study. In order to assess the potential to apply the methods and adjustment factors from the Blasnick study, NMR examined typical meteorological year[6] data (TMY3 data) for each of the four areas: Boston, Worcester, Albany and Syracuse. NMR concluded that the average monthly temperatures in the four areas were relatively similar, although Boston is relatively warmer compared to the other three areas. Based on this analysis, it seems reasonable that the findings from the Blasnick study are transferable to this study. However, it is important to note that the Blasnick study was focused on metering primary refrigerators as opposed to secondary refrigerators. Despite this difference, the general principles behind the adjustments described below should remain applicable.

The approach developed in Blasnick study begins by first estimating annual average temperatures by dividing the year into three periods: winter, summer, and mild weather. It defined its periods as follows:

- Winter weather was defined as days with an average temperature below 60°F
- Summer weather was defined as days with an average temperature above 70°F
- Mild weather was defined as days with average temperatures between 60°F and 70°F

In order to calculate the proportion of each year in each period, NMR examined typical meteorological year data (TMY3 data) for Syracuse and Albany.

The proportion of the year in each period—reflecting the outdoor temperatures shown above—as well as the thermostat setting (if applicable) and refrigerator location were used to calculate the average annual location-specific temperatures for each metered site, based on the formulas and coefficients developed for the Blasnick study.[7]

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[5] Blasnik, Michael "Measurement and Verification of Residential Refrigerator Energy Use: Final Report 2003-2004 Metering Study." Submitted July 29, 2004.

[6] A typical meteorological year (TMY) consists of specially selected weather data for a specific location. TMY are created to be consistent with long-term averages while providing a range of weather phenomena. TMY3 data is the third edition of TMY data and is derived from 1991-2005 National Solar Radiation Data Base.

[7] The Blasnick study developed an approach for estimating average annual indoor (site specific) temperatures by using outdoor temperature data, thermostat settings (if applicable), and location information. Additional details on these estimates can be found in Section 2.5.

Table 1 shows the estimated average annual indoor temperatures by location of the refrigerator. Since the majority of the sites metered for this study were unheated spaces (37 out of 50), and more than half were unheated garages (28 out of 50), it is not surprising that the average annual indoor temperature for the sample is relatively low (63°F).

Table 1: Average Annual Temperature by Location

Location	n	Average Annual Temperature	Percent Unheated Locations
Garage	30	60°F	93%
Basement	16	68°F	50%
Kitchen[8]	2	72°F	--
Living Room[9]	1	73°F	--
Porch	1	59°F	100%
All	**50**	**63°F**	**74%**

The temperature conditions during the metering study were somewhat similar to the calculated annual average temperature conditions. On average, the test conditions were four degrees warmer (a six-percent difference in temperature). Based on this, we would expect the metered usage to be slightly higher than the average annual usage.[10]

As expected, after individually adjusting each site's annual energy savings based on average annual temperature and test temperature, we found the average weather normalized energy savings were approximately 10% lower than metered energy savings. Based on the weather normalized savings, we would expect refrigerators to use 732 kWh annually (Table 2).

[8] These refrigerators were positively identified as long-term secondary refrigerators by field staff during metering appointments. They were both located in kitchens containing a primary refrigerator and a secondary refrigerator. Both refrigerators were in-use and operating at the time of metering and were identified as long-term secondary refrigerators by the respondents.

[9] This refrigerator was positively identified as a long-term secondary refrigerator by field staff during the metering appointment. The refrigerator was in-use and operating at the time of metering onsite and was identified as a long-term secondary refrigerator by the respondent.

[10] Additional details on the metering time period, including the date meters were installed and the duration of metering for each refrigerator, is contained in Appendix D.

Table 2: Metered and Weather Normalized Annual Energy Usage

	Metered kWh	Weather Normalized Metered kWh
n (sample size)	50	50
Mean	812	732
Median	796	669
Minimum	125	104
Maximum	2,097	2,136

Peak Demand Calculations

Similar to estimating weather normalized annual energy savings, calculating peak demand savings required NMR to estimate energy usage during peak periods based on estimated site temperatures. Again, NMR relied on the Blasnick study to estimate peak period usage. The regression analysis performed as part of the Blasnick study found that temperature has an effect of increasing usage by 2.65% per °F. This relationship allows for a Peak Adjustment factor to be calculated based on the expected temperature during the peak period. The Peak Adjustment factor can then be used to calculate peak period usage and the average demand during that period can be calculated by dividing peak period usage by the number of hours in the period. Additional details on these calculations can be found in Section 2.6.

NMR calculated coincident peak demand based on the hottest summer non-holiday weekday during the hour ending 5pm, as defined in the New York Technical manual. All calculations were performed individually for each site. Table 3 shows the mean, median, minimum and maximum peak demand in kW calculated for the sample of metered refrigerators.

Table 3: Peak Demand

	Weather Normalized Metered kW
n (sample size)	50
Mean	0.122
Median	0.122
Minimum	0.282
Maximum	0.021

Comparison of Database Savings and Metered Savings

For units where sufficient information was avaiable, NMR compared metered savings to DOE and/or manufacturer databases of expected energy use. The purpose of these comparisons was to determine if these secondary sources of information could provide good estimates of energy savings compared to actual metered data. Field technicians were able to collect model numbers for all but four refrigerators.

Using make and model numbers, NMR looked up each refrigerator's Adjusted Rating in the Refrigerator and Freezer Energy Rating Database. Of the 46 refrigerators with sufficient

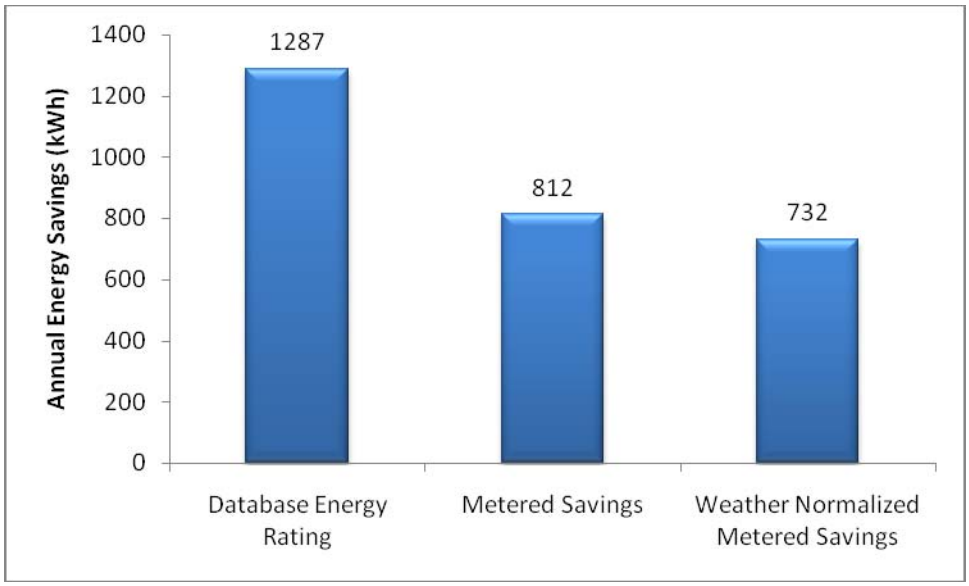
information, 28 were found in the database. For the remaining refrigerators (22), there was either insufficient information to find them in the database or they simply were not included in the database. For these units, NMR identified their energy rating based on AHAM data by year of manufature.

As Figure 1 shows, the database energy ratings are are nearly 60% greater than the metered savings and 76% greater than the weather normalized metered savings.[11] These differences seem reasonable because the energy ratings are estimated using conditions that vary from those found in the Recycling Program. Most notably, the refrigerators included in the sample were exclusively secondary refrigerators and were almost exclusively located in unconditioned space in a relatively cold climate. The Blasnick study came to a similar conclusion, stating that "refrigerators located in unheated basements tended to use less than their rated usage primarily due to the lower temperatures found in basements." The report went on to conclude that while short-term metering worked well for refrigerators located in basements and garages, all approaches based on rated usage performed poorly.

Based on these results, it is clear that while the databases can provide estimates for usage they do not provide a good match with savings found through metering. In order to use the database estimates, a realization rate or adjustment factor must be applied.

[11] National Grid performed a similar analysis of DOE database savings with a sample of nameplate data for 2010 and found an average of 1,175 kWh.

Figure 1: Comparison of Database Savings to Metered Savings



1 Background

1.1 Program Description

The Appliance Recycling program is designed to encourage households to retire and recycle secondary, inefficient refrigerators and freezers. The program offers customers $30 plus free pickup of old working second refrigerators and freezers. National Grid and its vendor JACO Environmental (JACO) remove the appliances from participating customers' homes and then safely dismantle and recycle the appliances in an environmentally responsible manner. In order to participate, customers need to schedule a free pick-up and fill out a $30 incentive rebate form. The program goal is to remove 14,000 appliances from the residential market over two years. The program began in July 2010 and as of the time of report is still in operation.

To qualify, participants must be National Grid electric customers in Upstate New York and own the units for pick-up. In addition, the refrigerator or freezer must meet the following requirements

- Measure between 10 and 30 cubic feet, using inside measurements
- For refrigerators, must be the second refrigerator and not the primary refrigerator
- Clean, empty and in working order at the time of pick-up
- Accessible with a clear path for removal by contractor

Each participating household is limited to pick-up and rebates for two units. The refrigerator or freezer must be picked up at a National Grid electric service address.

For additional details on the program including detailed program background, findings and recommendations please see the Process Evaluation report prepared by Tetra Tech (2011).[12]

1.2 Key Data Collection Activities and Researchable Issues

The key objective of the metering study is to measure and verify energy use and demand for removed appliances.

[12] Tetra Tech and NMR (2011) *New York Upstate Refrigerator and Freezer Recycling Energy Efficiency Program Process Evaluation Report.* Submitted June 17th, 2011

1.3 Onsite Visit Goals

The primary goal of the onsite visits was to obtain metered energy usage data for a sample of secondary refrigerators removed through the National Grid Refrigerator-Freezer Recycling Program in NewYork State. In addition, for units where sufficient information was available, metered savings were compared to Department of Energy (DOE) and/or manufacturer databases of energy use.

The project research plan included the following main tasks:

- Install metering equipment to monitor the electricity usage of 50 secondary refrigerators currently in use in a sample of homes drawn from two target locations (Syracuse and Albany, NY)
- Retrieve the meters within two to three weeks of deployment
- Analyze each site's usage data to develop an estimate of annual usage, correcting for differences in temperature between the metering period and an estimate of the site's annual temperature (relying on the findings of other studies)
- Compare the estimate of annual usage from the sample to program assumptions of energy savings
- Develop load shape estimates for secondary refrigerators in order to assess load shapes

1.4 Sampling Plan

The overall sampling approach was to select a random sample clustered by location (Syracuse and Albany). By limiting the sample to this narrow geographic area, we were able to better control data collection and keep data collection costs to a minimum. The main objective of the sampling plan was to ensure a diverse sample of refrigerators for the evaluation while maximizing customer satisfaction with the program. Meters were deployed on a first-come-first-served basis for houses that met the metering criteria. Originally, customers were asked about their willingness to have their refrigerator metered when they called to inquire about the program; however, this approach failed to result in the number of recruits necessary to complete the metering project. Therefore, NMR switched strategies and instead called individual customers after they had signed up to have their refrigerators removed. Each customer was offered an incentive of $100 to participating in the metering study.

The eligibility criteria for the metering included:

- Must be a secondary refrigerator that is currently being used on a regular basis
- Appliance is plugged in, in working order and in use upon arrival onsite[13]
- Metering is possible (unit can be moved, outlet considered safe)
- The customer agrees to the metering and agrees to meter retrieval in two or three weeks

Customers who did not meet these criteria when the onsite visit was made by the NMR field technician were compensated for their time with $100.

1.4.1 Recruitment

Customers who signed up to have their refrigerators collected through the program were contacted by NMR and offered incentives to participate in onsite visits to their homes. Customers who agreed to participate in onsite visits were asked additional questions to identify whether or not they were eligible to participate in the onsite evaluation. During the telephone call, NMR identified the following information about the refrigerators:

- Make (brand)
- Style (side-by-side, top freezer, bottom freezer, or single door)
- Approximate size
- Approximate age

1.5 Site Visits

1.5.1 Confirmation of Eligibility

Field technicians confirmed whether refrigerators were eligible for the metering project once onsite. This step of eligibility included checking to ensure that refrigerators were indeed true secondary refrigerators, currently in use, plugged in, in operating condition, and in a condition that would allow metering. To determine if the refrigerator was in use, the field technicians measured the internal temperature of the refrigerators using an infrared thermometer (accurate to

[13] In order to ensure that only refrigerators that are in use are metered, field techs will determine if a refrigerator is: 1) in working order, 2) plugged in, and 3) currently in use at the time of the site visit. To determine if a refrigerator is in use field techs measure the temperature of the refrigerator using an infrared thermometer (accurate to within +/- 2° F) and inventory the contents of the refrigerator. Based on the temperature and the inventory, the field tech will decide whether the refrigerator is being used by the customer.

within +/- 2°F) and inventoried the contents of the refrigerator.[14] Based on the internal temperature and the inventory the field technicians determined whether or not the refrigerator was currently being used by the customer. Refrigerators operating at temperatures exceeding 50°F and containing relatively few items (two or three condiments – no food – no beverages – no items in the freezer) were excluded from the study.[15] The reasoning for excluding these refrigerators was that it is unlikely that empty (or nearly empty) refrigerators operating so far outside the recommended setting are being used by the customer. In cases where the field technician identified a refrigerator as ineligible, the customers were informed and still received $100 incentives for their time. Throughout the study period, only one customer was determined to be ineligible while onsite and was removed from the sample. At this site, the customer had removed their refrigerator from his home, removed its door and stored it in his yard. One additional customer was removed from the sample because his metering data (after the fact) showed that he had unplugged the meter and installed it at another location during the metering period. This made it impossible to determine the energy usage of the refrigerator.

1.5.2 Data Collection

Once the field technician confirmed the eligibility of the refrigerators, field technicians obtained authorization from the customers to install the metering equipment, collected information about the refrigerator and asked the customers a series of questions mirroring the usage-related and demographic questions in the telephone survey.[16] In addition, field technicians scheduled removal dates with the customers and provided them with checks for $50. Two to three weeks after the initial visit, the field technicians returned to the customers' homes, retrieved the meters, and provided them with second checks for $50.

[14] The United States Food and Drug Administration recommends keeping refrigerator temperatures at or below 40°F
[15] 50°F allows for some variation from recommended settings due to age and improperly functioning equipment
[16] Tetra Tech and NMR (2011) *New York Upstate Refrigerator and Freezer Recycling Energy Efficiency Program Process Evaluation Report.* Submitted June 17th, 2011

2 Refrigerator Metering

2.1 Onsite Evaluations

This section describes the methodology for the data collection and analysis of the onsite evaluations.

2.2 Quota Sampling Frame

As of September 23rd, 2010, 2,554 refrigerators had been picked up from National Grid customers and recycled. An analysis of this data was used to develop a quota sampling frame that was representative of the brand and style of these earlier customers' refrigerators. At the time of sampling, NMR had no reason to believe that the current customer population would differ from those who had already participated. Using data from these recycled refrigerators would ensure that the most prevalent brands are represented. The sample of refrigerators to be metered eliminated brands that were less than 4% of the total, reducing the participant population from 2,554 to 2,018. Based on the adjusted base, NMR limited the total number of refrigerators made by General Electric to nine per city, four for White-Westinghouse, four for Frigidaire, Whirlpool, Hotpoint, and Kenmore and three for Amana and Coldspot.[17] With regard to style, top freezers were limited to 17 per city, single doors were limited to seven per city, side-by-side were limited to four per city, and bottom freezers were limited to two per city (Table 2-1).

[17] Due to difficulty in recruiting participants for the metering project, NMR chose not to exclude refrigerators of brands not included in the list above.

Table 2-1: Sample Frame

Manufacturer / Brand	**Sample Limit per Location**
General Electric	9
White-Westinghouse[18]	5
Frigidaire	4
Whirlpool	4
Hotpoint	4
Kenmore	3
Amana	3
Coldspot	3
Style	**Sample Limit per Location**
Top Freezer	17
Single Door	7
Side-by-Side	4
Bottom Freezer	2

[18] Includes: Westinghouse, White-Westinghouse, Tappen, Gibson, Philco, and Kelvinator

The original sampling frame called for metering 25 refrigerators in the Albany area and 25 refrigerators in the Syracuse area during the fall of 2010.[19] The fall was chosen as a mild temperature period that would offer an opportunity to study energy usage without weather extremes or holiday periods that might affect the metered energy usage. However, due to difficulty recruiting participants, metering was halted at the end of November before the extreme winter weather began. Metering began again in the spring of 2011.[20] In addition to splitting the metering study between the fall and spring, due to difficulty recruiting participants in the Albany area and in consideration of the project schedule, NMR elected to reduce the number of refrigerators metered in Albany to 22 and increase the number of refrigerators metered in Syracuse to 28. As Table 2-2 shows, 27 refrigerators were metered in the fall of 2010, eight in Albany and 19 in Syracuse, and 23 refrigerators were metered in the spring of 2011, 14 in Albany and nine in Syracuse.

Table 2-2: Sample by Area and Period

Metering Period	Albany	Syracuse	Total
Fall 2010 – October 23rd thru December 12th	8	19	27
Spring 2011 – May 9th thru June 24th	14	9	23
Total	**22**	**28**	**50**

2.3 Comparison of Sample and Population

As the following tables demonstrate, the characteristics of the sample of metered refrigerators closely match the characteristics of the population of refrigerators recycled through the program between July 1, 2010 and July 5, 2011. Refrigerators in the sample are of similar size, age, style and make as the population as a whole.[21]

[19] The Albany and Syracuse areas included a twenty mile radius from a central zip code.

[20] Additional details on the metering time period, including the date meters were installed and the duration of metering for each refrigerator, is contained in Appendix D.

[21] Additional sample characteristics including refrigerator characteristics and respondent demographics can be found in Appendix B.

As Table 2-3 shows, while there were significantly more refrigerators between 20 and 24 cubic feet included in the sample of metered refrigerators, on average the refrigerators were of similar size (17.5 cu. ft. vs. 16.6).

Table 2-3: Refrigerator Size – Comparison of Sample to Population

Cubic Feet	Metered Refrigerators	Population
n (sample size)	**50**	**7,467**
10 or less	2%	6%
11 to 15	28	33
16 to 19	30	40
20 to 24	38	19
25 or more	2	1
Average	**17.5 cu. ft.**	**16.6 cu. ft.**

Similarly, the distribution of ages is similar between the sample of refrigerators metered and the population as a whole. Refrigerators' ages were determined based on information collected from the refrigerators themselves, such as: model numbers or serial numbers. For refrigerators with missing or insufficient information, ages were determined based on the reported age provided by customers (Table 2-4).

Table 2-4: Age of Refrigerator – Comparison of Sample to Population

Year of Manufacture	Metered Refrigerators	Population
n (sample size)	**50**	**7,467**
1950 – 1959	2%	7%
1960 – 1969	10	8
1970 – 1979	24	21
1980 – 1989	40	40
1990 – 1999	24	22
2000 – 2008	--	2

As with age and size, the distribution of styles represented by the sample closely mirror the population as a whole. When less common styles (that are listed as 'other') are removed from the population the metered refrigerators have a nearly identical profile as the population (Table 2-5).

Table 2-5: Style of Refrigerator – Comparison of Sample to Population

Style	Metered Refrigerators	Population	Population with Others Removed
n (sample size)	**50**	**7,467**	**6,439**
Top freezer	68%	60%	69%
Single door	12	11	13
Side-by-side	14	11	13
Bottom freezer	6	4	5
Other[22]	-- σ	14	--

[22] For the population this includes: 828 *upright*, 182 *not applicable*, nine *chest*, eight *undersize round top*, and one *SUUnit* style refrigerators.

Finally, as Table 2-6 shows, the distribution of refrigerator manufacturers among the sample is very similar to the population as a whole.

Table 2-6: Make of Refrigerator – Comparison of Sample to Population

Cubic Feet	Metered Refrigerators	Population
n (sample size)	**50**	**7,467**
GE	32%	24%
Frigidaire	14	9
Kenmore	12	10
Coldspot	4	4
Kelvinator	4	3
Admiral	2	2
Amana	6	6
Estate	2	<1
E-Wave	2	<1
Excellence	2	<1
Hotpoint	6	8
Kitchen Aid	2	1
Whirlpool	8	10
Westinghouse	4	3
Other[23]	--	18

2.4 Metering Results

As described previously, the primary objective of this evaluation was to develop independent estimates of energy and demand savings based on actual metered energy use. To achieve this goal, field technicians installed a "watts up? PRO"[24] power meter at each site to monitor and measure the energy consumption of secondary refrigerators for a minimum of a two week period. At the end of the metering period, field technicians returned to the site to retrieve the meters and

[23] Includes: Ambassador (3), Avanti (7), Caloric (5), Carrier (3), Catalina (1), Citation (4), Columbus Products (3), Crosley (39), Danby (6), Defiance (2), Freezemaster (2), Gerald (1), Gibson (265), Gold Star (1), Harmony (1), Holiday (1), Holland (4), Imperial (13), International Harvester (4), Jann-Air (11), JC Penney (11), LG (1), Magic Chef (158), Maytag (58), Montgomery Ward (140), National (7), Norge (64), Okeefe & Merritt (3), Panasonic (1), Philco (80), Range Air (2), RCA (17), Revco (1), Roper (47), Samsung (1), Sanyo (16), Signature (41), Sub-Zero (4), Summit (7), Tappen (24), Ultra (1), Viva (1), Welbilt (15), and Other-unspecified (303)

[24] https://www.wattsupmeters.com/secure/products.php?pn=0#

the energy usage data was downloaded for analysis. All of the data were examined by hand for anomalies or inconsistency and cleaned to represent the best available information.[25]

In order to determine the annual energy usage for each of the 50 refrigerators metered, NMR divided the total kWh metered by the number of hours metered to determine the average hourly usage for each refrigerator. The annual energy usage was determined simply by multiplying the average hourly energy usage by 8,760 hours. On average, the metered annual energy usage was 812 kWh with a median of 796 kWh (Table 2-7). As Figure 2-1 shows, annual energy usage varied widely from as low as 125 kWh to as high as 2,097 kWh. [26,27] The size and age of units, as well as the refrigerator location and the usage patterns of owners, are four factors that drive these differences. In general, the smaller units metered resulted in lower annual energy usage and larger units resulted in higher annual energy usage.[28,29]

Table 2-7: Metered Annual Energy Usage

	Annual kWh
n (sample size)	50
Mean	812
Median	796
Minimum	125
Maximum	2,097

[25] While examining the data, one site was ultimately removed from the sample and replaced. The metered data showed signs of tampering and it was not possible to save the data. Data from other sites were adjusted as necessary by removing data from the beginning of the metering period so that onsite activities did not interfere with final metered data. In addition, some data was removed from metered files as it appeared to be anomalous and inconsistent with the rest of the metered data.

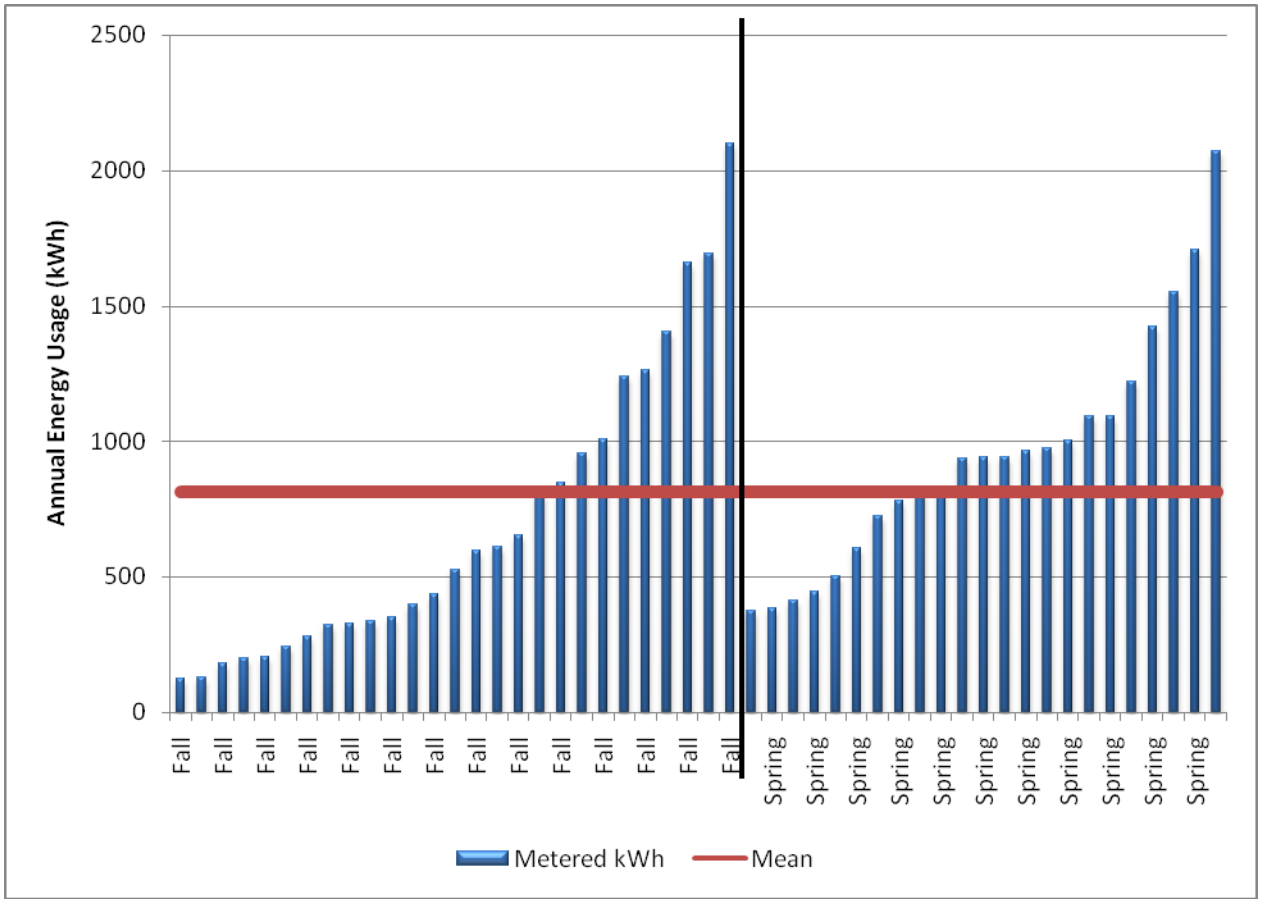
[26] The refrigerator with the lowest annual metered energy usage (125 kWh) was a 1987, 12 cubic foot refrigerator, located in an unheated garage. Based on make and model number, this refrigerator was located in the DOE database and had a rated annual energy usage of 400 kWh. The refrigerator was metered in the fall period for 14 days (October 30 through November 13, 2010.)

[27] The refrigerator with the highest annual metered energy usage (2,097 kWh) was a 1988, 19 cubic foot refrigerator, located in a heated basement. Based on make and model number, this refrigerator was not found in the DOE database. Based on the year of manufacture the refrigerator was assigned a rated annual energy usage of 964 per the AHAM database. The refrigerator was located near a heat vent and was metered in the fall period for 14 days (November 4 through November 18, 2010.)

[28] The Blasnick study found similar dispersion among metered refrigerators with actual annual usage varying from around 500 kWh to more than 3,500 kWh.

[29] Additional details on the metering time period, including the date meters were installed and the duration of metering for each refrigerator, is contained in Appendix D.

Figure 2-1: Metered Annual Energy Usage



2.5 Weather Normalized Savings

Since metering took place during periods of relatively mild weather, the metering results represent the usage of refrigerators during these mild periods and not for the overall year. In an attempt to account for differences in temperature throughout the year, NMR relied on a previous study conducted in New England by Blasnik (2004).[30] The Blasnik study was designed to better understand the field performance of refrigerators and assess the accuracy of audit and diagnostic methods. The study included monitoring electricity usage and room temperatures for 160 existing and 30 new ENERGY STAR replacement refrigerators for two to four week periods.

[30] Blasnik, Michael "Measurement and Verification of Residential Refrigerator Energy Use: Final Report 2003-2004 Metering Study." Submitted July 29, 2004.

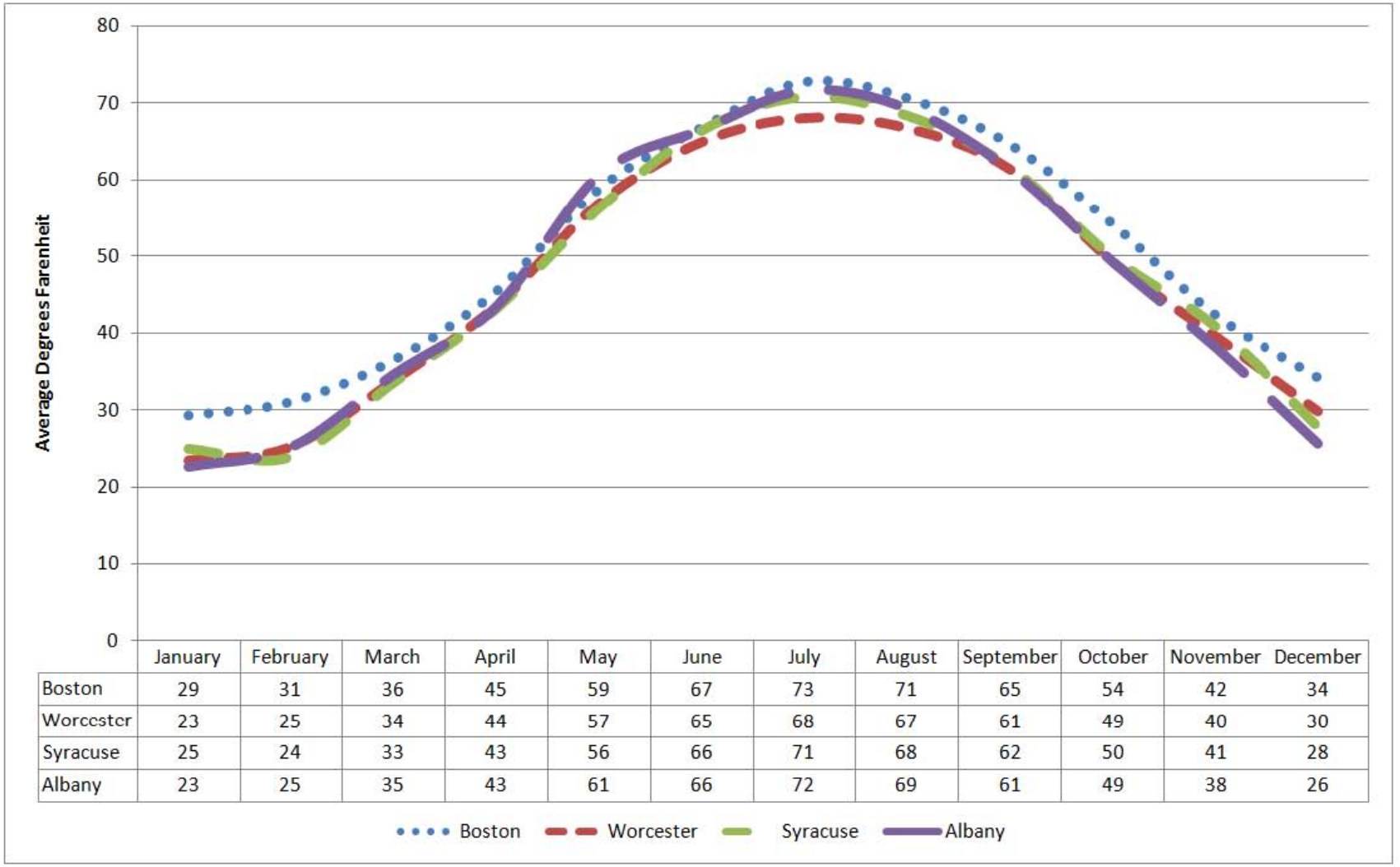
While the study did not focus on secondary refrigerators, it did develop a method for estimating annual average temperatures for locations as well as adjusting metered usage for the difference between current room temperature (at the time of metering) and the estimated average annual temperature of the location. NMR made use of these formulas to adjust the metered energy savings found through this study. However, it is important to note that the Blasnick study took place in Boston and Worcester and, as such, the results may not be fully transferable to this study. In order to assess the potential to apply the methods and adjustment factors from the Blasnick study, NMR examined typical meteorological year[31] data (TMY3 data) for each of the four areas—Boston, Worcester, Albany and Syracuse. As Figure 2-2 shows, the average monthly temperatures in the four areas are relatively similar, although Boston is relatively warmer compared to the other three areas. This is further confirmed by an examination of the average annual temperatures and heating and cooling degrees days shown in Table 2-8. Based on this analysis, it seems reasonable that the findings from the Blasnick study are transferable to this study.

Table 2-8: Climate Comparison

Appliance Type	Average Annual Temperature	Average Annual HDD	Average Annual CDD
Boston	51°F	4,680	346
Worcester	47°F	5,704	256
Albany	47°F	5,835	384
Syracuse	47°F	5,771	339

[31] A typical meteorological year (TMY) consists of specially selected weather data for a specific location. TMY are created to be consistent with long-term averages while providing a range of weather phenomena. TMY3 data is the third edition of TMY data and is derived from 1991-2005 National Solar Radiation Data Base.

Figure 2-2: Comparison of Monthly Average Temperatures



	January	February	March	April	May	June	July	August	September	October	November	December
Boston	29	31	36	45	59	67	73	71	65	54	42	34
Worcester	23	25	34	44	57	65	68	67	61	49	40	30
Syracuse	25	24	33	43	56	66	71	68	62	50	41	28
Albany	23	25	35	43	61	66	72	69	61	49	38	26

2.5.1 Average Annual Temperature

The Blasnick study developed an approach for estimating average annual indoor (site specific) temperatures by using outdoor temperature data, thermostat settings (if applicable), and location information.

The approach begins by dividing the year into three periods: winter, summer, and mild weather. It defined its periods as follows:

- Winter weather was defined as days with an average temperature below 60°F
- Summer weather was defined as days with an average temperature above 70°F
- Mild weather was defined as days with average temperatures between 60°F and 70°F

In order to calculate the proportion of each year in each period, NMR examined typical meteorological year data (TMY3 data) for Syracuse and Albany. Table 2-9 shows the results of this analysis.

Table 2-9: Typical Meteorological Year Analysis

Area	Winter Weather		Summer Weather		Mild Weather	
	Proportion	Avg. Temp	Proportion	Avg. Temp	Proportion	Avg. Temp
Albany	0.677	36°F	0.145	77°F	0.178	65°F
Syracuse	0.691	37°F	0.139	77°F	0.170	65°F

The Blasnick study also presents several coefficients for use in calculating location-specific indoor annual average temperatures. These coefficients are presented in Table 2-10. To the extent possible, these coefficients have been updated to reflect the specific weather conditions in the two areas of interest in these studies.

Table 2-10: Temperature Coefficients

	Living Space	Unheated Basement	Other Unheated Space
Winter (<60°F)			
Constant	22.7	65.9	30.0
Thermostat factor	0.71	n/a	0.5
Heating DD60 per day (ALB=23.6, SYR=22.9)	-0.05	-0.16	-0.5
Summer (>70°F)			
Constant	76.5	71.4	76.5
Thermostat factor	0.40	0.21	0.40
Heating DD60 per day (ALB=7.3, SYR=6.7)	-0.32	n/a	n/a
Mild (60-70°F) (constant)	73.7	68.3	65.0

Based on the proportion of the year in each period and the above coefficients, the average annual indoor temperature can be calculated as follows:

$$Twinter = Constant + (TF \times WTS) + (DDF \times HDD)$$

$$Tsummer = Constant + (TF \times STS) + (DDF \times CDD)$$

$$Tmild = Constant$$

$$Tannual = WProp \times Twinter + SProp \times Tsummer + MProp \times Tmild$$

Where,

Constant = Constant from the temperature coefficients
TF = Thermostat factor – adjustment based on thermostat setting
WTS = Winter thermostat setting
DDF = Degree day factor
HDD = Heating degree days per day during the winter (base 60°F)
STS = Summer thermostat setting
DDF = Cooling degree day factor
CDD = Cooling degree days per day during the summer (base 60°F)

For example, an unconditioned basement in Syracuse with no heat or air conditioning would have an average annual indoor temperature calculated as follows:

$$Twinter = 65.9 + (0.71 \times 0) + (-0.16 \times 22.9) = 62.2°F$$

$$Tsummer = 71.4 + (-0.32 \times 0) + (0 \times 6.7) = 71.4°F$$

$$Tmild = 68.3°F$$

$$Tannual = 0.691 \times 62.2°F + 0.139 \times 71.4°F + 0.170 \times 68.3°F = 64.3°F$$

The above formulas were applied to each site individually in order to determine the average annual temperature for each site. Table 2-11 shows the average annual temperatures by location of the refrigerator. Since the majority of the sites metered for this study were unheated spaces (36 out of 50) and more than half were unheated garages (28 out of 50), it is not surprising that the average annual temperature for the sample is relatively low (63°F).

Table 2-11: Average Annual Temperature by Location

Location	n	Average Annual Temperature
Garage	30	60°F
Basement	16	68°F
Kitchen	2	72°F
Living Room	1	73°F
Porch	1	59°F
All	**50**	**63°F**

2.5.2 Temperature Adjustment

The Blasnik study concludes that the relationship between usage during the metering period and average usage can be found using the following formula:

$$Usage_{avg} = Usage_{test} \times \frac{Tavg - 33}{Ttest - 33}$$

Where,

avg = annual average conditions

test = test conditions (metering period)

For each sampled site, NMR applied the above formula to estimate weather normalized usage under annual average conditions. The annual average temperature for each site was calculated as described in the previous section and the test period temperature was calculated, in the same manner, based on the actual average daily temperature during the metering period for each site.[32]

As Table 2-12 shows, the temperature conditions during the metering study were somewhat similar to the annual average temperature conditions expected. On average, the test conditions were four degrees warmer (a six-percent difference in temperature). Based on this, we would expect the metered usage to be slightly higher than the average annual usage. This makes intuitive sense given the fact that the majority of locations were unheated basements or garages.

Table 2-12: Average Annual and Test Temperatures

Location	n	Average Annual Temperature	Test Temperature
Mean	50	63°F	67°F
Median	50	60°F	65°F
Maximum	50	73°F	74°F
Minimum	50	59°F	64°F

As expected, after individually adjusting each site's annual energy savings based on average annual temperature and test temperature, we found the average weather normalized energy savings were approximately 10% lower than metered energy savings. Based on the weather

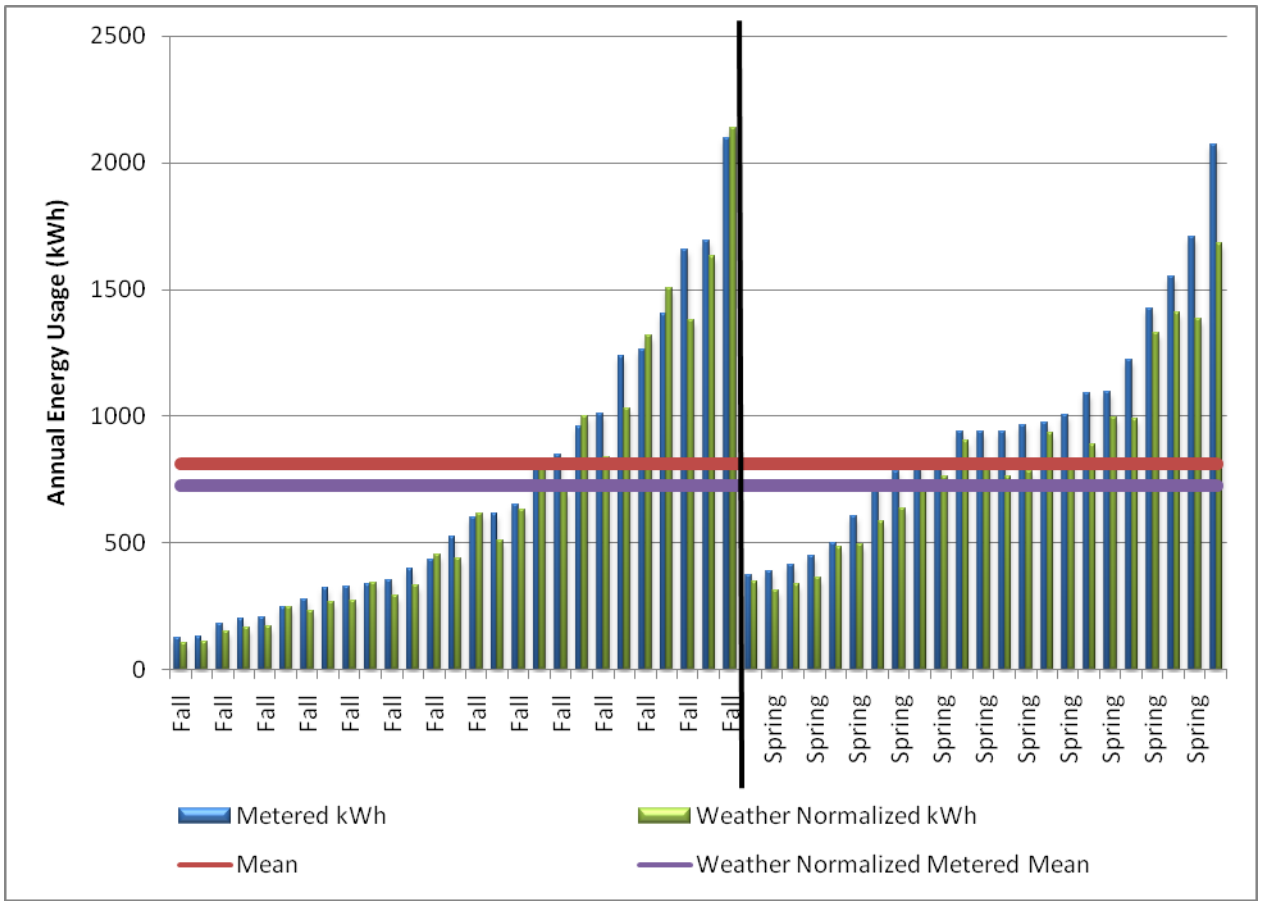
[32] Temperature data source: National Oceanic and Atmospheric Administration (NOAA).

normalized savings, we would expect refrigerators to use 732 kWh annually (Table 2-13 and Figure 2-3).

Table 2-13: Metered and Weather Normalized Annual Energy Usage

	Metered kWh	Weather Normalized Metered kWh
n (sample size)	50	50
Mean	812	732
Median	796	669
Minimum	125	104
Maximum	2,097	2,136

Figure 2-3: Metered and Weather Normalized Annual Energy Usage



2.6 Peak Demand Calculations

In order to develop an estimate of peak demand, we first must estimate the usage during the peak period of interest. To calculate peak period usage we must adjust the annual usage estimate for the temperature conditions during the period of interest using the temperature model as discussed

in Section 2.5. The regression analysis performed as part of the Blasnick study found that temperature has an effect of increasing energy usage by 2.65% per °F. Therefore, we can calculate the peak period usage with the following formula:

$$Peak\ Adjustment = 1 + 0.0265 \times (Constant + (TF \times (Tpeak - 70)) - Tannual)$$

Where,

Constant = Constant from the temperature coefficients
TF = Thermostat factor
T_{peak} = Outdoor average temperature at peak
T_{annual} = Estimated annual site temperature

The average demand (kW) can then be calculated as:

$$kW = \frac{Peak\ Adjustment \times AAkWh}{8{,}760\ hours}$$

Where,

AAkWh = Adjusted Annual Energy (kWh)

According to the New York State Technical Manual,[33] system peaks generally occur during the hour ending at 5 PM on the hottest non-holiday weekday. The NYISO directs Program Administrators to calculate coincident peak demand savings based on the hottest summer non-holiday weekday during the hour ending 5 pm. The Technical Manual provides a peak temperature of 96°F for Albany and 97°F for Syracuse (for the purposes of calculating peak demand). For example, for a refrigerator with an Adjusted Annual Energy usage of 1,319 kWh located in a basement in Albany with no air conditioning, we would calculate the following:

$$Peak\ Adjustment = 1 + 0.0265 \times (71.4 + (0.21 \times (96 - 70)) - 72) = 1.129$$

$$0.169\ kW = \frac{1.129 \times 1{,}319}{8{,}760\ hours}$$

[33] Pete Jacobs, Brian Evans, Nick Hall, Paul Horowitz, Rick Ridge, Gil Peach, and Ralph Prahl (2010) *New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs.* Submitted October 15th, 2010

Based on the above formulas, NMR calculated the average demand savings during individually for each metered refrigerator at peak conditions. Table 2-14 shows the mean, median, minimum and maximum peak demand in kW calculated for the sample of metered refrigerators.

Table 2-14: Peak Demand

	Weather Normalized Metered kW
n (sample size)	50
Mean	0.122
Median	0.122
Minimum	0.282
Maximum	0.021

2.7 Sampling Error

In order to determine the precision of the sample of metered sites we use the formula below:

$$E = \left(\frac{z \times CV}{\sqrt{n}}\right)$$

Where,

n = the required sample size before adjusting for the size of the population,

z = a constant based on the desired level of confidence—e.g., 1.645 for the 90% level of confidence,

E = error margin,

CV = coefficient of variation (error ratio), the actual variation observed between the sample points and the deemed energy savings estimate. Calculated as the ratio of the standard deviation of differences to the mean.

To calculate the error margin, NMR first calculated the mean annual weather normalized energy usage (732) and the standard deviation of the differences of individual estimates compared to the mean (387). This results in a coefficient of variation of 0.53 (see below). Based on this and the formula above NMR calculated the error margin at the 90% confidence level as follows:

$$CV = \frac{387}{732} = 0.53$$

$$E = \left(\frac{1.645 \times 0.53}{\sqrt{50}}\right) = 0.123$$

This results in an error margin of approximately +/-12.3% at the 90% confidence level. The original sampling plan was designed to achieve an error margin of +/-10% at the 90% confidence level, however, the final sample proved to be less homogeneous than expected.

2.8 Comparison of Database Savings and Metered Savings

For units where sufficient information was avaiable, NMR compared metered savings to DOE and/or manufacturer databases of expected energy use. The purpose of these comparisons was to determine if these additional sources of information provided good estimates of energy savings. To facilitate comparison, field technicians sought to record models numbers for refrigerators that were metered. Field technicians were able to collect model numbers for all but four refrigerators. Using make and model numbers, NMR looked up each refrigerator's Adjusted Rating in the Refrigerator and Freezer Energy Rating Database.[34] Of the 46 refrigerators with sufficient information, 28 were found in the database. For the remaining refrigerators (22), there was either insufficient information to find them in the database or they simply were not included in the database. For these units, NMR identified their energy rating based on AHAM data by year of manufature.[35] National Grid performed a similar analysis of DOE database savings with a sample of nameplate data for 2010 and found an average of 1,175 kWh.

[34] http://www.kouba-cavallo.com/refmods.htm
[35] See Appendix C for additional details.

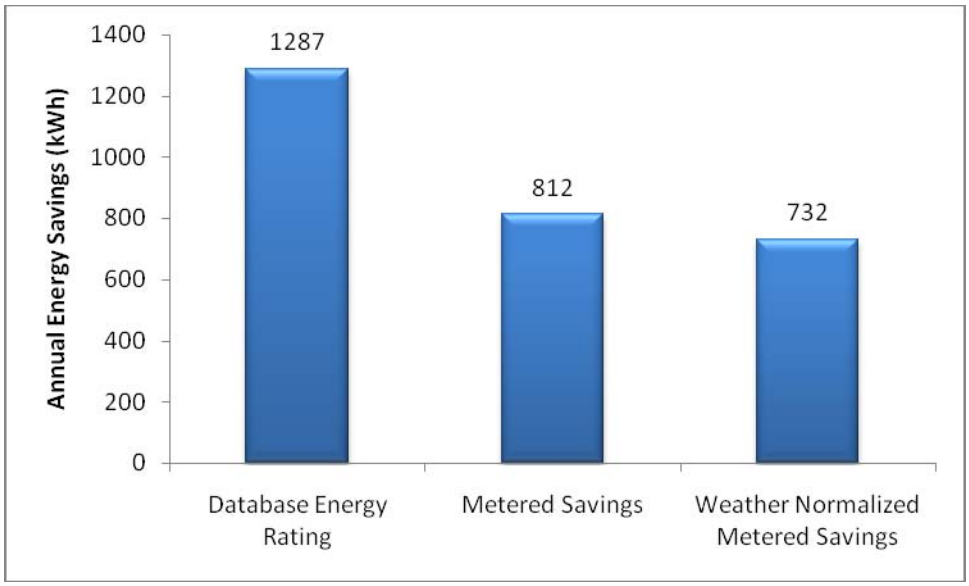
As Table 2-15 and Figure 2-4 show, the database energy ratings are nearly 60% greater than the metered savings and 76% greater than the weather normalized metered savings. These differences seem reasonable because the energy ratings are estimated using conditions that vary from those found in the Recycling Program. Most notably, the refrigerators included in the sample were exclusively secondary refrigerators and almost exclusively located in unconditioned space in a relatively cold climate. The Blasnick study came to a similar conclusion, stating that "refrigerators located in unheated basements tended to use less than their rated usage primarily due to the lower temperatures found in basements." The report went on to conclude that while short term metering worked well for refrigerators located in basements and garages, all approaches based on rated usage performed poorly.

Based on these results, it is clear that while the databases can provide estimates for usage they do not provide a good match with savings found through metering. In order to use the database estimates, a realization rate or adjustment factor must be applied.

Table 2-15: Comparison of Deemed Savings and Metered Savings

	Database Energy Rating[36]	Metered Savings	Weather Normalized Metered Savings
n (sample size)	50	50	50
Mean energy savings (kWh)	1,287	812	732

Figure 2-4: Comparison of Deemed and Database Savings to Metered Savings



Appendix A Onsite Data Collection Form

Date:	**Appointment:**	**Arrival Time:**	**Technician:**
Customer Information			
Name:	**Address:**		**City:**
Phone#:			**Zip Code:**
Refrigerator Information			
Style: Side-by-Side / Top Freezer / Bottom Freezer / Single Door			**Size (est):**
Icemaker: None / Thru Door / Internal / Icemaker not hooked up		**Defrost:**	Auto / Manual / Partial
General Condition:	Like New / Good / Fair / Poor / Very Poor		
Seal Condition:	Good Condition / Some Deterioration / Visible Gaps		
Location: Garage / Basement / Kitchen / Other: _____			Heated **Y/N** Air-conditioned **Y/N**
Recessed into cabinets: Yes / No / Partial			
Clearance (inches):	Left: _____ Right: _____ Rear: _____ Top:		
Other location information:	Sun Exposure / Exterior Wall / Heat source Nearby / Other: _____		
Make:	**Model:**		**Year (est):**
Refrigerator Settings and Use			
Anti-Sweat Switch Position:	On ("reduces condensation" / Off ("saves energy") / NA		
Thermostat Settings:	Fridge: _____	Freezer: _____	
Measured Temperature (°F):	Fridge: _____	Freezer: _____	
Temperature Adjustment:	Never Adjust / Adjust	How Adj: _____	
Other Info:	Doesn't Keep Food Cold / Seasonal Usage: Describe: _____		
Refrigerator Contents:	%	**Description of contents:**	
Customer Interview			
If heated, winter thermostat settings:	Typical (°F): _____	Setback at night or during day? Yes / No	
Setbacks:	Night: _____°F _____ hrs	Day: _____°F _____ hrs	
Heating System Fuel Source: Natural Gas / Fuel Oil / Propane / Electricity / Wood / Other: _____			
If cooled, summer thermostat settings:	Typical (°F): _____	Setback at night or during day? Yes / No	
Setbacks:	Night: _____°F _____ hrs	Day: _____°F _____ hrs	
Frequency of Use: On a scale of 1 to 5, where one means all summer and five means never: _____			
Cooling System: Central Air / Room AC in fridge room / Room AC in adjacent room / Other: _____			
Additional A/C Info:	Only Use at Night / Day	Other: _____	
Where did fridge come from: Bought New / Came with House / Bought or Got Used			**Former Primary Fridge?** Y / N
Was the fridge ever repaired:	No / Yes - minor repair in home / Yes - major repair at shop / Reconditioned		

IMPACT RELATED QUESTIONS FROM TELEPHONE SURVEY:

Refrigerator Use:		Primary	Secondary	Not being used
RFR1.	Yes / No	RFR11.	_____	
RFR2.	_____	RFR11a.	_____	
RFR3.	_____	RRF1.	_____	
RFR4.	_____	RRF2a.	1. _____	2. _____ 3. _____
RFR5.	_____			
RFR5a.	_____			
RFR7a.	_____			
RFR8.	_____			
RFR9.	_____			

Demographics:

Occupancy Year Round / Seasonal
Ownership: Own / Rent
Type: SF / Duplex / Apt. / Condo / Town House
Mobile Home / Other (_____)
# of Units: 2 to 4 / 5 to 10 / 11 to 25 / 26 to 50 / 50+
Sq.ft. of home: <1k / 1-1.5k / 1.5-2k / 2-3k / 3k+
# of people living in home: _____
Household Income: <$10 / 10-20 / 20-30 / 30-40
40-50 / 50-75 / 75-100 / 100-150 / 150-200 / 200+

Logger Equipment Information and Wrap-Up			
No Meter Installed:	fridge not in use / pick-up hassle / can't wait for removal / can't meter / other: _____		
Meter#:	**Time Installed:**		
Customer Signature: _____	Date: _____	Meter Removal Appointment: _____	
Best time to contact: _____	Best phone number: _____		

Appendix B Customer and Refrigerator Characteristics

Prior to the program vendor's pickup of the refrigerator through the program, field technicians collected detailed information on the refrigerator using an onsite form (included in Appendix A), the appliance's settings and the extent it was being used, the effects of the program, and some demographic information. The technicians also installed a "watts Up? PRO" power meter to collect energy usage data. The technicians collected information on twenty-two refrigerators in the Albany area and twenty-eight in the Syracuse area, for a combined total of fifty refrigerators.

This Appendix presents a brief analysis of information collected on the onsite forms, and is intended to inform the reader about the characteristics of the refrigerators included in the onsite sample.

B1. General Refrigerator Information

In Albany, GE was the most common brand of refrigerator, with nine out of 22 cases. The majority of refrigerators in Albany were top freezer style (17), while one was single-door style and four were side-by-side (Table B-1). As in Albany, GE was the most common brand observed in Syracuse, with seven. The majority of the refrigerators in Syracuse were top freezer style as well (17 out of 28) (Table B-1).

Table B-1: Make and Style of Refrigerators – Albany

Make	Style				Total
	Top Freezer	Single Door	Side-by-Side	Bottom Freezer	
GE	4	1	4	--	9
Frigidaire	2	--	--	--	2
Kenmore	3	--	--	--	3
Coldspot	--	--	--	--	--
Kelvinator	1	--	--	--	1
Admiral	--	--	--	--	--
Amana	1	--	--	--	1
Estate	1	--	--	--	1
E-Wave	--	--	--	--	--
Excellence	--	--	--	--	--
Hotpoint	2	--	--	--	2
Kitchen Aid	--	--	--	--	--
Whirlpool	3	--	--	--	3
Westinghouse	--	--	--	--	--
Total	17	1	4	--	22

Table B-2: Make and Style of Refrigerators – Syracuse

Make	Style				Total
	Top Freezer	Single Door	Side-by-Side	Bottom Freezer	
GE	5	1	1	--	7
Frigidaire	3	1	--	1	5
Kenmore	1	1	--	1	3
Coldspot	--	1	1	--	2
Kelvinator	1	--	--	--	1
Admiral	1	--	--	--	1
Amana	1	--	--	1	2
Estate	--	--	--	--	--
E-Wave	1	--	--	--	1
Excellence	--	1	--	--	1
Hotpoint	1	--	--	--	1
Kitchen Aid	1	--	--	--	1
Whirlpool	1	--	--	--	1
Westinghouse	1	--	1	--	1
Total	17	5	3	3	28

Table B-3: Make and Style of Refrigerators – Overall

Make	Style				Total
	Top Freezer	Single Door	Side-by-Side	Bottom Freezer	
GE	9	2	5		16
Frigidaire	5	1		1	7
Kenmore	4	1		1	6
Coldspot		1	1		2
Kelvinator	2				2
Admiral	1				1
Amana	2			1	3
Estate	1				1
E-Wave	1				1
Excellence		1			1
Hotpoint	3				3
Kitchen Aid	1				1
Whirlpool	4				4
Westinghouse	1		1		2
Total	34	6	7	3	50

About three-fifths of the refrigerators did not have icemakers (31 out of 50). Out of the 18 refrigerators that had an icemaker, ten were internal and seven were not hooked up (Table B-4).

Table B-4: Presence of Icemaker

	Albany	Syracuse	Combined
Sample size (n)	*22*	*28*	*50*
None	12	19	31
Icemaker Not Hooked Up	3	4	7
Thru Door	1	--	1
Internal	6	4	10

Overall, four-fifths (40 out of 50) of the refrigerators were in good or fair condition, while the remaining ten were in poor or very poor condition. This pattern was also true in both Albany and Syracuse individually (18 out of 22 in Albany; 22 out of 28 in Syracuse). Slightly less than 30% of refrigerator seals (14) had some deterioration, while the remaining 70% (36) were in good condition. Three refrigerators showed visible gaps in their seals (Table B-5).

Table B-5: Condition of Refrigerator

	Albany	Syracuse	Combined
Sample size (n)	*22*	*28*	*50*
General Condition			
Good	16	16	32
Fair	2	6	8
Poor	4	5	9
Very Poor	--	1	1
Seal Condition			
Good Condition	15	18	33
Some Deterioration	5	9	14
Visible Gaps	2	1	3

Of the twenty-seven refrigerators about which information was collected, three-fifths were located in the garage (30 out of 50). The second most common location was the basement (16), with the majority of those located in Syracuse (ten out of 16) (Table B-6).

Table B-6: Location of Refrigerator

	Albany	Syracuse	Combined
Sample size (n)	*22*	*28*	*50*
Garage	16	14	30
Basement	6	10	16
Kitchen	--	2	2
Other	--	2	2

Overall, only a quarter of the refrigerators were located in heated spaces (13 out of 50). Even fewer (4 out of 50) were located in air-conditioned areas (Table B-7).

Table B-7: Space Heating and Cooling

	Albany	Syracuse	Combined
Sample size (n)	*22*	*28*	*50*
Heated			
No	16	21	37
Yes	6	7	13
Air Conditioned			
No	20	26	46
Yes	2	2	4

The vast majority of refrigerators were not recessed into cabinets (48 out of 50). The remaining two were partially recessed, and none were fully recessed (Table B-8).

Table B-8: Recessed into Cabinets

	Albany	Syracuse	Combined
Sample size (n)	*22*	*28*	*50*
No	21	27	48
Partial	1	1	2

B2. Refrigerator Settings and Use

Technicians recorded the temperature of each refrigerator and freezer onsite to confirm that the refrigerators were in working order and being actively used. The average refrigerator temperature was 39.4°F and the median temperature was 39.3°F. The average freezer temperature was 11°F and the median temperature was 12.5°F (Table B-9).

Table B-9: Measured Temperature

	Albany	Syracuse	Combined
Refrigerator			
Sample size (n)	*22*	*28*	*50*
Mean	38.6°	40.1°	39.4°
Median	39.3°	39.3°	39.3°
Freezer			
Sample size (n)	*22*	*28*	*50*
Mean	10.2°	11.6°	11.0°
Median	11.8°	13.0°	12.5°

During the onsite visit, field technicians observed the contents of the refrigerator; assigning each appliance a value indicating the amount of contents therein (taking into account the refrigerator compartment and freezer together). Field technicians divided refrigerators into four categories: 10% to 25% full, 26% to 50% full, 51% to 75% full and 76% to 100% full.[37] Slightly more than one-half of the refrigerators in both locations were less than 25% full (13 out of 22 in Albany; 16 out of 28 in Syracuse). Overall, 58% of the refrigerators were categorized as 10% to 25% full (Table B-10).

Table B-10: Refrigerator Contents

	Albany	Syracuse	Combined
Sample size (n)	*22*	*27*	*50*
10% to 25%	13	16	29

[37] Per the sampling plan, any refrigerators considered to be less than 10% full were considered not in use and were screened out of the metering sample either onsite or during the recruiting phone call.

26% to 50%	5	7	12
51% to 75%	2	2	4
76% to 100%	2	3	5

B3. Customer Interview

As shown in Table B-11, half (11) of the Albany refrigerators had been purchased new, while a further nine had come with the house. In Syracuse, ten had been bought new and slightly fewer than half (13 out of 28) had come with the house, while four had been bought used. On the whole, 44% of refrigerators had come with the house and 42% had been bought new (13 out of 27).

Table B-11: Source of Removed Refrigerator

	Albany	Syracuse	Combined
Sample size (n)	*22*	*28*	*50*
Bought New	11	10	21
Came with House	9	13	22
Bought Used	--	4	4
Don't know	2	1	3

Few of the refrigerators had ever been repaired (44 out of 50). Three refrigerators had received minor repairs at one time (Table B-12).

Table B-12: Repair History of Removed Refrigerator

	Albany	Syracuse	Combined
Sample size (n)	*22*	*28*	*50*
No Repairs	19	25	44
Minor Repairs	2	1	3
Don't know	1	2	3

B4. Usage-Related Questions

The usage-related questions included in the onsite interview mirror those included in the telephone survey. Originally, NMR had intended to use these questions to supplement the free-ridership analysis performed as part of the process evaluation through the telephone survey. However, during screening it became clear that free riders were being screened out of the sample because their refrigerators were empty or already unplugged, potentially skewing results towards non-free riders.

When asked for the reason why they had decided to dispose of their refrigerators or freezers through the program, respondents in Albany most frequently cited the rebates and incentives provided by the program (16 out of 22 respondents) and the fact that they no longer needed their units (9 out of 22 respondents). In Syracuse, the rebates (11 out of 28 respondents), the fact that they no longer needed their units (five out of 28), and reducing energy costs (four out of 28) were the most frequently cited factors (Table B-13).

Table B-13: Reasons for Program Participation

(Multiple-Response)

	Albany	Syracuse	Combined
Sample size (n)	*22*	*28*	*50*
Rebate/incentive	16	11	27
Old unit was not working well	7	--	7
Didn't need/use it anymore	9	5	14
Reduce energy/electricity costs	3	4	7
Wanted to recycle	3	1	4
Remodeling/expanding	1	1	2
Easy/convenient to turn it in	4	2	6
They would pick it up	6	2	8
Better for the environment	2	2	4
Save energy/electricity	6	1	7
Reduce maintenance costs/appliance needed repairs	--	1	1

Program participants were asked if they had already considered getting rid of the refrigerators or freezers before they had heard of the program. As shown in Table B-14, 17 out of 22 participants in Albany and 23 out of 28 participants in Syracuse had considered it.

Table B-14: Considered Disposing of Refrigerator

	Albany	Syracuse	Combined
Sample size (n)	*22*	*28*	*50*
Yes	17	23	40
No	5	5	10

Table B-15 shows what respondents said they would have done with the appliances if the program had not been available. The majority of respondents (34 out of 50) indicated they would have gotten rid of the units. Of those who would have disposed of the refrigerators, the majority (28 out of 34) would have done so within a year of the date the program collected it.

Table B-15: Action in Absence of the Program

	Albany	Syracuse	Combined
Action in Absence of the Program			
Sample size (n)	*22*	*28*	*50*
Gotten rid of it in any manner	16	18	34
Kept it	6	6	12
Don't know	--	4	4
Timing of Disposal in Absence of the Program			
Sample size (n)	*16*	*18*	*34*
Within a year	13	15	28
More than a year later	3	3	6

Respondents who said they would have disposed of the appliances were asked how they would have gotten rid of them in the absence of the program. In Albany, five out of 16 would have sold their refrigerators; in Syracuse, none would have sold their refrigerators, but five out of 18 would have given them away, and a further five would have recycled them. Of the eight respondents who indicated that they would have a hauler or retailer pick up the refrigerators, two expected that they would be recycled. Another two expected they would be sold as scrap, a further two expected them to be sent to garbage dumps, and one thought it would be re-sold as a used appliance. Of the eight respondents who indicated that they would have recycled the refrigerators in the absence of the program, three did not know how they would have done so. Two would have taken them to a recycling center, two would have put them out for pick-up, and one would have hired someone to take it away (Table B-16).

Table B-16: Method of Disposal without Program

	Albany	Syracuse	Combined
Sample size (n)	*16*	*18*	*34*
Sold it	5	--	5
Given it away for free	2	5	7
Taken it to a garbage dump or put out as trash	2	2	4
Recycled it	3	5	8
Hired hauler to take it away	2	3	5
Had a retail store come and pick it up	2	1	3
Had the County pick it up	--	1	1
Don't know	--	1	1
Ultimate Outcome for Refrigerators Picked Up by Hauler or Retailer			
Sample size (n)	*4*	*4*	*8*
Recycled	1	1	2
Sold as a used appliance	--	1	1
Sold as scrap	--	2	2
Sent to garbage dump	2	--	2
Don't know	1	--	1
Method of Recycling			
Sample size (n)	*3*	*5*	*8*
Take it to a recycling center	--	2	2
Hired someone to take it	--	1	1
Put it out for pick-up	1	1	2
Don't know	2	1	3

Respondents who indicated they would have gotten rid of their appliances in the absence of the program were asked whether the need to physically move the appliances out of their houses and transport them would have prevented them from getting rid of the units. A majority of respondents (22 out of 34) replied that it would not have prevented them from disposing of their refrigerators (Table B-17).

Table B-17: Effect of Transporting Refrigerator

	Albany	Syracuse	Combined
Sample size (n)	*16*	*18*	*34*
No	12	10	22
Yes	3	5	8
Maybe	1	3	4

When asked how much they would have been willing to pay for refrigerator removal or recycling had the program not existed, a majority of participants in Albany (nine out of 16) indicated that they would not be willing to pay anything to have the refrigerators removed. Four indicated that they would have paid up to $20, and three would have been willing to pay more than that. About one-half of the Syracuse participants indicated their unwillingness to pay (nine out of 19), but a further six said they didn't know; three would have paid up to $20, and one would have paid more than that (Table B-18).

Table B-18: Willingness to Pay to Remove Refrigerator

	Albany	Syracuse	Combined
Sample size (n)	*16*	*19*	*35*
Would not pay any amount ($0)	9	9	18
$5-$20	4	3	7
$21+	3	1	4
Don't know	--	6	6

Respondents who said they would have kept the refrigerators in the absence of the program were asked whether they would have continued to use them, stored them unplugged, or done something else with them. As Table B-19 shows, the most frequent response (nine out of 12) was to continue using them as refrigerators.[38]

Table B-19: Outcome for Refrigerator Kept in Absence of Program

	Albany	Syracuse	Combined
Sample size (n)	*6*	*6*	*12*
Continued to use as a refrigerator	5	4	9
Unplugged and stored	1	1	2
Don't know	--	1	1

[38] It is important to note that a condition of the study participant was that the refrigerator be operating and in use at the time of the study.

Program participants were also asked about the number and ages of the refrigerators or freezers that remained in use in the house after the program removed and recycled one unit. In all, 31 out of 50 households indicated that only one refrigerator would remain in use after the program, and a further 13 indicated that two would remain. Of the remaining refrigerators, 70% (35 out of 50) were ten years old or newer. About half (24 out of 50) were five years old or newer (Table B-20).

Table B-20: Refrigerators in Use after Removal by Program

	Albany	**Syracuse**	**Combined**
Sample size (n)	*22*	*28*	*50*
0	1	--	1
1	14	17	31
2	7	6	13
Refused	--	5	5
Refrigerator Age (multiple response)			
Sample size (n)	*22*	*28*	*50*
0 to 5 years old	18	6	24
6 to 10 years old	5	6	11
11 to 16 years old	3	5	8
17 to 20 years old	--	5	5
More than 20 years old	1	--	1
Don’t know	2	9	11

B5. Demographics

Onsite field technicians asked all participants a series of demographic questions regarding their housing tenure. The majority of participants own their homes (46 out of 50). In addition, all of the homes except one (in Albany) are year-round residences, and most are single-family dwellings (47 out of 50) (Table B-21).

Table B-21: Housing

	Albany	Syracuse	Combined
Home Ownership			
Sample size (n)	*22*	*28*	*50*
Own	20	26	46
Rent	2	1	3
Refused	--	1	1
Type of Housing			
Sample size (n)	*22*	*27*	*49*
Single Family House	20	27	47
Apartment Building (2-4 Units)	2	--	2

Thirteen out of 50 onsite participants lived in homes larger than 2,000 square feet and 17 out of 50 lived in homes less than 1,500 square feet (Table B-22).

Table B-22: Housing Square Footage

	Albany	Syracuse	Combined
Sample size (n)	*22*	*28*	*50*
Less than 1,000	2	1	3
1,001 to 1,500	8	6	14
1,501 to 2,000	5	5	10
2,001 to 3,000	4	5	9
More than 3,000	3	1	4
Don't know/Refused	--	10	10

As shown in Table B-23, Albany households reported an average of around 2.4 full-time household residents; similarly, Syracuse participants reported an average of around 2.5 full-time residents.

Table B-23: Number of People Living in Home

	Albany	Syracuse	Combined
Sample size (n)	*22*	*28*	*50*
1	3	4	7
2	11	12	23
3	6	4	10
4	1	5	6
5	1	1	2
Refused	--	2	2
Average	**2.38**	**2.46**	**2.42**

A majority of participants in Albany chose to report household income (17 out of 22), but almost half of the Syracuse participants refused (13 out of 28). Out of the 31 participants overall who reported household income, the most commonly cited range was $50,000 to $75,000 (ten out of 31); half of those were in Syracuse, and half in Albany. The remaining respondents represented a range of incomes (Table B-24).

Table B-24: Income

	Albany	Syracuse	Combined
Sample size (n)	*22*	*28*	*50*
$10,000-20,000	--	2	2
$30,000-40,000	1	2	3
$40,000-50,000	2	--	2
$50,000-75,000	5	5	10
$75,000-100,000	5	2	7
$100,000-150,000	3	2	5
$150,000-200,000	1	1	2
Retired	--	1	1
Refused	5	13	18

Appendix C AHAM Adjusted Methodology

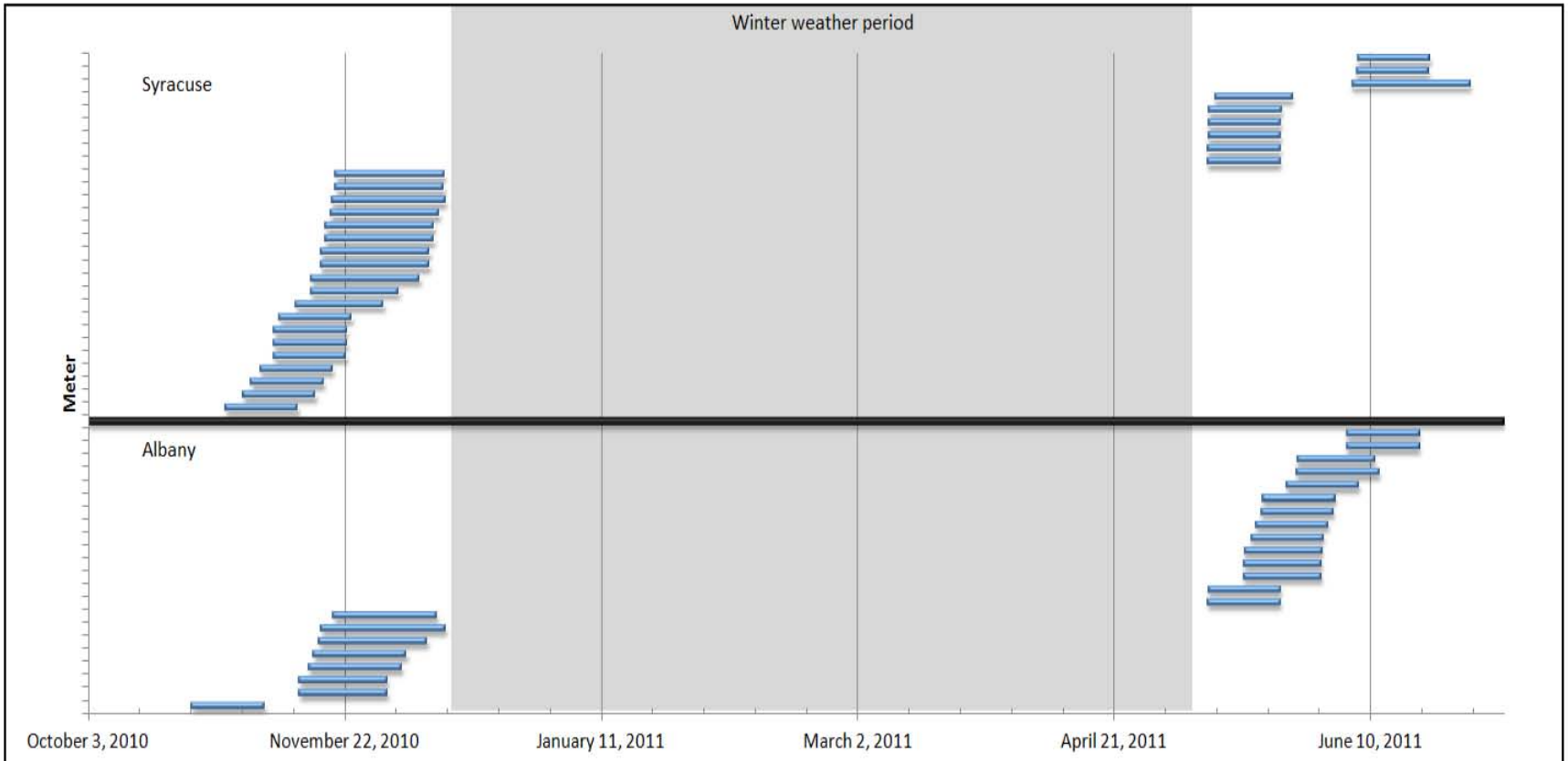
AHAM provides shipment-weighted data that specifies the average UEC for refrigerators and freezers based on model year. AHAM's energy consumption estimates are available for model years 1972, 1978, and 1980 through 2009.

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 sample included retired appliances from years with missing data.[39]

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.[40] 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.

[39] Appliances retired through the program date back to 1950.
[40] Rosenfeld, "The Art of Energy Efficiency: Protecting the Environment with Better Technology," *Annual Review of Energy and the Environment*24 (1999): 33-82.

Appendix D Disposition of Meters by Date Installed and Duration



	Albany																						Syracuse																							
Meter Number	ALB - 1	ALB - 2	ALB - 3	ALB - 4	ALB - 5	ALB - 6	ALB - 7	ALB - 8	ALB - 9	ALB - 10	ALB - 11	ALB - 12	ALB - 13	ALB - 14	ALB - 15	ALB - 16	ALB - 17	ALB - 18	ALB - 19	ALB - 20	ALB - 21	ALB - 22	SYR - 1	SYR - 2	SYR - 3	SYR - 4	SYR - 5	SYR - 6	SYR - 7	SYR - 8	SYR - 9	SYR - 10	SYR - 11	SYR - 12	SYR - 13	SYR - 14	SYR - 15	SYR - 16	SYR - 17	SYR - 18	SYR - 19	SYR - 20	SYR - 21	SYR - 22	SYR - 23	SYR - 24	SYR - 25	SYR - 26	SYR - 27	SYR - 28
Start Date	10/23/10	11/13/10	11/13/10	11/15/10	11/16/10	11/17/10	11/17/10	11/20/10	5/9/11	5/9/11	5/16/11	5/16/11	5/16/11	5/17/11	5/18/11	5/19/11	5/20/11	5/24/11	5/26/11	5/26/11	6/5/11	6/5/11	10/30/10	11/2/10	11/4/10	11/5/10	11/8/10	11/8/10	11/8/10	11/9/10	11/12/10	11/15/10	11/15/10	11/17/10	11/17/10	11/18/10	11/18/10	11/19/10	11/19/10	11/20/10	11/20/10	5/9/11	5/9/11	5/9/11	5/9/11	5/9/11	5/10/11	6/6/11	6/7/11	6/7/11
Duration (days)	14	17	17	18	18	21	24	20	14	14	15	15	15	14	14	14	14	14	16	15	14	14	14	14	14	14	14	14	14	14	17	17	21	21	21	21	21	21	22	21	21	14	14	14	14	14	15	23	14	14