MEASURE AND VERIFY SAVINGS OF REFRIGERATOR RECYCLING PROGRAM

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EXECUTIVE SUMMARY

This report presents the results of the evaluation of the Old Refrigerator Pickup and Recycling Program that SMUD offered for its residential customers during 2006. SMUD sponsored the Old Refrigeration Pickup and Recycling Program during 2006 in order to help customers lower their bills and their energy demand.

The objectives for this study were to measure and analyze the following aspects of the program:

- Numbers of refrigerators and freezers collected and recycled;
- Average annual kWh savings per collected appliance;
- Average kW reduction per collected appliance; and
- Net-to-gross ratio.

Various data were used to accomplish these study objectives, including program tracking data, databases containing at-manufacture energy use for refrigerators and freezers, energy use data collected through *in-situ* monitoring, and interview data collected through a survey of a sample of program participants. *In-situ* monitoring was used to collect data for savings impacts calculations, while telephone surveys provided the information for the net-to-gross analysis.

The results of the evaluation of the gross and net savings from the Old Refrigerator Pickup and Recycling Program are summarized in Table ES-1. The per unit estimates of savings are somewhat lower than the values that SMUD staff used in their planning of the program. A review and comparison of savings estimates is provided in Appendix E.

Table ES-1. Summary of Gross and Net kWh Savings and kW Demand Reductions for Old Refrigerator Pickup and Recycling Program in 2006

	Refrigerators	*Freezers*	*All*
Gross Savings			
Gross kWh savings	3,045,042	829,044	3,874,086
Gross kWh savings during peak hours	406,755	110,775	517,530
Average kW reduced per peak hour	394.14	107.34	501.48
Average peak kW reduced per unit recycled	0.147	0.125	
Net Savings			
Free-ridership rate	39.2%	51.6%	
Net of free-ridership rate	60.8%	48.4%	
kWh savings net of free-ridership	1,850,620	400,898	2,251,518
kW reductions net of free-ridership	239.54	51.91	291.45

1. INTRODUCTION

Under contract with the Sacramento Municipal Utility District (SMUD), ADM Associates has conducted a study to measure and verify the energy savings of refrigerators and freezers recycled through the Old Refrigerator Pickup and Recycling Program that SMUD sponsored during 2006.

SMUD sponsored the Old Refrigeration Pickup and Recycling Program during 2006 in order to help customers lower their bills and their energy demand, especially during the hot summer months. SMUD contracted with Appliance Recycling Centers of America-California (ARCA) to implement the program. ARCA's responsibilities included scheduling pick-ups with participating customers, transporting picked-up appliances to their facility, and recovering and recycling all component parts and properly disposing of potentially harmful chemicals found in the cooling system and insulation.

As an incentive to encourage customers to turn in their spare operating refrigerators and freezers, SMUD paid participating customers $35 for each eligible unit. Payment of the incentive was subject to several program guidelines.

- A refrigerator or freezer had to be in working condition and be between 10 and 27 cubic feet in size.
- Up to two units could be recycled per residential address.
- The program was offered on a "first-come- first-served" basis.

SMUD's goal for the program was to recycle 8,000 spare refrigerators and freezers during 2006.

The objectives for this study were to measure and analyze the following aspects of the program:

- Numbers of refrigerators and freezers collected and recycled;
- Average annual kWh savings per collected appliance;
- Average kW reduction per collected appliance; and
- Net-to-gross ratio.

This report presents the results of evaluating these various aspects of the Old Refrigerator Pickup and Recycling Program. The report is organized as follows:

- Chapter 2 addresses the estimation of the gross savings impacts of the program.
- Chapter 3 addresses the net savings of the program.
- Chapter 4 provides information regarding customers' perceptions of the program, gathered through a survey of a sample of participants.
- Appendix A provides a description of the monitoring approach.
- Appendix B is a copy of the questionnaire used for the survey of participants.

- Appendix C presents tabulations from the survey of participants.
- Appendix D contains the results of regressions to impute at-manufacture energy use for units recycled through the program.
- Appendix E compares and discusses the energy use estimates developed during this study to the savings estimates used by SMUD staff in planning for the program.

2. ANALYSIS OF GROSS SAVINGS

This chapter presents an analysis of the gross kWh savings and kW reductions resulting from the Old Refrigerators Pick-Up and Recycling Program. Section 2.1 provides a summary of program results. Section 2.2 discusses the methodology used to estimate gross savings from the program. Section 2.3 reports the estimates of gross savings that were derived.

2.1 SUMMARY OF PROGRAM RESULTS

Data provided by ARCA from their tracking system showed that a total of 3,538 units were picked up through the program during 2006, of which 2,677 units were refrigerators and 861 were freezers.

Table 2-1 provides summary information on the characteristics of the refrigerators recycled through the program. Of the 2,677 recycled refrigerators, about two-thirds (65%) were top freezer models and over a fourth (28%) were side-by-side models. Overall, the average size of the recycled refrigerators was 19.2 cubic feet, and the average age was 16.0 years.

Table 2-1. Distribution of Refrigerators Recycled in 2006 by Door Style and Type of Defrost

Door Style	*Defrost Type*	*Number of Units*	*Average Size (Cubic Feet)*	*Average Age (Years)*
Bottom Freezer	Frost Free	65	20.7	17.1
	Manual	10	18.8	19.0
Bottom Freezer Totals:		75	20.4	17.4
Side-by-Side	Frost Free	736	22.6	15.5
	Manual	3	17.3	12.3
	Not reported	1	24.0	25.0
Side-by-Side Totals:		740	22.6	15.5
Single Door	Frost Free	7	15.3	17.6
	Manual	116	12.9	23.8
Single Door Totals:		123	13.0	23.4
Top Freezer	Frost Free	1,629	18.3	15.4
	Manual	108	15.3	19.5
	Not Reported	1	18.0	18.0
Top Freezer Totals:		1,738	18.1	15.7
Not reported	Frost Free	1	18.0	8.0
Not reported totals		1	18.0	8.0
Overall totals		2,677	19.2	16.0

Table 2-2 provides similar summary information on the characteristics of the freezers recycled through the program. Of the 861 recycled freezers, about 84% were upright models and about 16% were chest models. Overall, the average size of the recycled freezers was 17.0 cubic feet, and the average age was 18.3 years.

Table 2-2. Distribution of Freezers Recycled in 2006 by Door Style and Type of Defrost

Door Style	*Defrost Type*	*Number of Units*	*Average Size (Cubic Feet)*	*Average Age (Years)*
Chest Freezer	Frost Free	10	15.4	21.3
	Manual	130	15.7	20.1
Chest Freezer Totals:		140	15.7	20.2
Upright Freezer	Frost Free	32	17.8	19.2
	Manual	687	17.2	17.9
Upright Totals:		719	17.2	17.9
Not reported	Manual	2	22.0	15.0
Not reported totals		2	22.0	15.0
Overall totals:		861	17.0	18.3

2.2 METHODOLOGY TO ESTIMATE GROSS SAVINGS

One aspect of this evaluation study was to estimate the average annual kWh savings and average kW reduction for appliances collected through the program. The methodologies for developing these estimates are described in this section.

2.2.1 Estimate Average Annual kWh Savings per Collected Appliance

For an appliance early retirement program such as SMUD's, kWh savings are estimated by using data on the energy use of the collected appliances. Several different measures of energy use have been used in evaluations of refrigerator/freezer recycling programs to determine gross savings. Measures of energy use that have been used include the following:

- At-manufacture nameplate energy use as measured using the DOE test protocol;
- Energy use as measured before recycling with the DOE test protocol for refrigerators or freezers actually recycled; and
- Energy use measured through *in-situ* monitoring of refrigerators or freezers.

All three types of measures were used to evaluate the gross kWh savings for the program. In particular, as discussed in Section 2.1, the tracking system database provided by ARCA (SMUD's implementation contractor) was used to characterize recycled refrigerators and freezers by type, size, and age. An at-manufacture energy use value was imputed for each recycled unit and then adjusted to a current-year usage value based on data obtained through *in-situ* monitoring of actual energy use for samples of refrigerators and freezers.

A major database of at-manufacture energy use estimates is available from the Weatherization Assistance Program Technical Assistance Center (WAPTAC).[1] The WAPTAC database includes energy use and other information on over 40,000 models of refrigerators, refrigerator/freezers, and freezers that were manufactured from 1979 through 1992. The information for each model includes manufacturer (for years available), brand, year of manufacture, model number, style (e.g., side-by-side, top freezer), defrost type, volume (fresh food compartment, freezer, and total), dimensions, kWh/year (low, high, and mean), date of the CEC directory, and the effective date of the appliance efficiency standard with which it complies. Note that the energy use in this database is essentially DOE test data for when a unit is new.

Data from the WAPTAC database were used to develop equations that relate energy use to appliance size. Separate equations were estimated for models characterized by the combination of door style, type of defrost, and year of manufacture. The estimated equations are reported in Appendix D. Using these equations, specific at-manufacture energy use values could be imputed to individual units in the tracking system database.

As an example of the estimated equations, Table 2-3 shows the relationship estimated for side-by-side refrigerators with automatic defrost that were manufactured in 1985.

Table 2-3. Results of Regression Analysis of Annual Energy Use against Refrigerator Size for Side-by-Side Refrigerators with Automatic Defrost Manufactured in 1985

Variables*	***Estimated Coefficient***	***Standard Error***	***T Value***	***Pr > |t|***
Intercept	1191.578	50.679	23.51	< .0001
Unit size (cubic feet)	19.883	2.285	8.68	< .0001
Number of observations: 429				
Mean of dependent variable: 1626.9743				
R-squared: 0.150		Root Mean Square Error: 149.976		

For estimating gross savings, however, at-manufacture energy use values need to be adjusted to at-death energy use values. That is, it is the energy use of the recycled units when they are discarded that is of interest. The approach used in this study to adjust at-manufacture energy to at-death energy use was based on using data on energy use obtained through *in-situ* (i.e., in-house) monitoring of refrigerators and freezers that will be recycled. *In-situ* measurement is the most direct measurement of refrigerator or freezer energy use in that the energy use is measured for the actual conditions under which the unit has been operating. Indeed, several studies (i.e., by Proctor Engineering Group, by AAG and Associates, and by the Pacific Northwest National

[1] The initial WAPTAC database was compiled from information in the *Directory of Certified Refrigerators, Freezers, and Refrigerator Freezers*, published by the California Energy Commission (CEC) from 1979 to 1992. Subsequently, the Wisconsin Division of Energy provided additional funding to expand the number of years represented in the database.

Laboratory) have provided evidence that actual refrigerator energy use for a sample of refrigerators is lower than the energy use estimated through the DOE test protocol.

Measures of *in-situ* energy use have been used relatively little in studies evaluating recycling programs. However, ADM has conducted a dual metering project for the investor-owned utilities in California in which *in-situ* energy use was monitored for a sample of over 200 refrigerators and freezers located throughout the state. The energy use of the appliances in this sample was then also measured through the DOE test protocols and the at-manufacture energy use was obtained from the WAPTAC database. Thus, there are three measures of energy use for each appliance in the sample for that dual monitoring study.

To complement these data, additional *in-situ* monitoring of energy use was conducted during this project. A sample of 28 refrigerators and 13 freezers that were being recycled through SMUD's program were selected for the *in-situ* monitoring. The units selected for the *in-situ* monitoring in this study were units that had usually been operating in non-conditioned spaces. There were several reasons for choosing to monitor primarily units operating in non-conditioned spaces.

- First, a significant percentage of the units recycled through the program were expected to be secondary refrigerators or freezers that were being operated in non-conditioned space.
- Second, the dual monitoring project that ADM had conducted for the investor-owend utilities provided a considerable body of data on energy use of refrigerators and freezers operating in conditioned space. Of the 180 refrigerators targeted for monitoring for that study, about three-fourths were chosen to be in conditioned space and about a fourth to be in non-conditioned space.
- Third, studies by Proctor Engineering and by Pacific Northwest National Laboratory (PNNL) have shown that outdoor temperature was particularly important in affecting actual energy use of refrigerators and freezers. This is particularly true for secondary refrigerators that are being operated in non-conditioned space, where temperature effects on energy use are likely to be significant. Having data with which to analyze the effects of outdoor temperature on energy use of refrigerators and freezers was of particular relevance in evaluating the savings of units recycled through SMUD's program because hot summer months are characteristic of SMUD's service territory and

The procedures used to conduct the *in-situ* monitoring are described in Appendix A.

The at-manufacture energy use for the units monitored *in-situ* for SMUD was obtained from the WAPTAC database. The data for these units were then added to the other *in-situ* energy use data obtained in the dual monitoring project and analyzed to determine the relationship between at-manufacture energy use and *in-situ* measured energy use. For this analysis, refrigerators were divided between two categories, depending on whether they were usually operated in conditioned space or in non-conditioned space. Table 2-4 compares the average at-manufacture and *in-situ* measures of energy use for refrigerators in conditioned space, refrigerators in non-conditioned space, and freezers in non-conditioned space.

Table 2-4. Comparisons of At-Manufacture and In-Situ Energy Use

	Refrigerators in Conditioned Space	***Refrigerators in Non-Conditioned Space***	***Freezers in Non-Conditioned Space***
Number of units in sample	108	70	14
Average At-manufacture kWh per year	1,270.8	1,107.6	969.8
Average In-situ kWh per year (TMY)	1,554.2	1,152.8	1,129.3
Ratio of in-situ to at-manufacture	1.223	1.041	1.165

The ratios of in-situ kWh to at-manufacture kWh in Table 2-4 were used to adjust the at-manufacture kWhs imputed for units in the tracking database to represent actual in-house energy use. For some refrigerator units in the tracking database, the type of space where the unit was usually operated was not reported. For these cases, a ratio was applied that was a weighted average of the ratios for conditioned and non-conditioned space for units of the particular type (e.g., side-by-side refrigerators with frost-free defrost).

2.2.2 Estimate Average kW Reduction per Collected Appliance

The average kW reductions of the recycled appliances were also to be estimated. As specified in the RFP, the kW reduction value being considered is the average demand from the units over the District's defined summer peak demand period of 1-9 P.M.

As a first step to estimating kW reductions, the hours falling into SMUD's summer peak demand period were determined as the hours between 1 and 9 P.M. during weekdays for the months from May through October. The amount of appliance energy use that occurs during these summer peak hours was then determined using analysis performed as part of the dual monitoring project. For that project, regression models relating hourly refrigerator or freezer energy use to outside temperature were developed using hourly load data that PG&E and SCE had collected during the 1990's on samples of refrigerators and freezers. Applying TMY hourly weather data for CEC climate zone 12 (i.e., the weather zone in which the Sacramento area is located) to these models for typical; refrigerators and freezers, it was determined that about 13.4% of a refrigerator's annual energy use occurred during the summer peak hours. That is, multiplying gross kWh savings by .134 gives the kWh used during summer peak hours. Dividing the summer peak kWh by the number of hours in the summer peak period (i.e., 1,032) gives the aggregate average kW reduction per summer peak hour for the recycled units.

As a check on this calculation, the results were compared to the data on appliance energy use collected through *in-situ* monitoring. In the *in-situ* monitoring average AC current data is recorded in 5-minute intervals. Thus, these five-minute interval data provide very high resolution of the energy use profiles of the recycled units, allowing direct measurement of the kW reductions during the specified time period.

2.3 ESTIMATES OF GROSS SAVINGS

The procedures described in Section 2.2 were applied to develop estimates of gross savings for the refrigerators and freezers recycled through the program in 2006. The resulting estimates are presented in Table 2-5 for refrigerators and in Table 2-6 for freezers.

- Table 2-5 shows the estimated gross savings for refrigerators recycled through the program, classified by door style, type of defrost, and type of space where the refrigerator was usually operated. The total gross savings from recycling these refrigerators, measured by estimated current annual energy use, was about 3,045,000 kWh.
- Table 2-6 shows the estimated gross savings for freezers recycled through the program, also classified by style, type of defrost. The total gross savings from recycling these freezers, again as measured by estimated current annual energy use, was about 829,000 kWh.

Taken together, the estimated gross kWh savings from refrigerators and freezers recycled through the program in 2006 was 3,874,063 kWh.

Estimates of the kW reductions during SMUD's summer peak hours are reported in Table 2-7. The average kW reduction per unit was estimated to be 0.147 kW for refrigerators and 0.125 kW for freezers. These estimated values for kW reductions per unit can be compared to the average kW per hour reported in Table 2-8 for the sample of units from the program for which on-site monitoring was conducted. The estimated kW reductions are close in value to the average kW values as determined through the monitoring.

These estimates of gross savings are somewhat lower than the estimates used by SMUD staff in their planning for the program. Accordingly, a review was made of the savings estimates in the studies that SMUD staff used in their planning. This review is discussed in Appendix A. There appear to be two major reasons for the differences.

- The distribution of recycled units across vintages will be an important determinant of the energy savings that can be expected. Because there has been a trend over time toward reducing the energy use of refrigerators and freezers, the appliance recycling programs that SMUD implemented in earlier years would have been on average more likely to gather in older vintage units that had higher energy use.
- Two of the studies that SMUD staff used for their planning estimated annual energy use for refrigerators and freezers using measured data that were collected under relative high ambient temperatures. Because outdoor temperatures differ significantly between months in the Sacramento area, extrapolating energy use estimated under conditions of high ambient temperatures to represent full year energy use will overstate the annual energy use.

Table 2-5. Gross Savings (kWh per Year) for Refrigerators Recycled in 2006 by Door Style, Type of Defrost and Type of Space Where Usually Operated

Door Style	***Defrost Type***	***Type of Space Where Usually Operated***	***Number of Units***	***Savings Based on Imputed At Manufacture Energy Use (kWh per Year***	***Savings Based on Estimated Current Energy Use (kWh per Year)***
Bottom Freezer	Frost Free	Conditioned	35	44,330	54,216
		Non-conditioned	16	17,106	17,808
		Not reported	14	18,030	21,023
	Manual	Conditioned	6	8,237	10,073
		Non-conditioned	4	5,553	5,781
Bottom Freezer Totals:			75	93,256	108,901
Side-by-Side	Frost Free	Conditioned	338	408,878	500,058
		Non-conditioned	228	287,095	298,866
		Not reported	170	236,270	271,711
	Manual	Conditioned	1	746	913
		Non-conditioned	1	763	794
		Not reported	1	1,200	1,359
	Not reported	Not reported	1	1,767	2,032
Side-by-Side Totals:			740	936,719	1,075,731
Single Door	Frost Free	Conditioned	2	1,241	1,518
		Non-conditioned	2	981	1,022
		Not reported	3	1,801	2,039
	Manual	Conditioned	30	17,312	21,173
		Non-conditioned	62	36,942	38,456
		Not reported	24	14,925	16,418
Single Door Totals:			123	73,203	80,626
Top Freezer	Frost Free	Conditioned	678	584,817	715,232
		Non-conditioned	577	522,064	543,469
		Not reported	374	362,556	412,951
	Manual	Conditioned	36	30,211	36,948
		Non-conditioned	44	38,835	40,427
		Not reported	28	25,766	28,935
	Not Reported	Not reported	1	1,032	1,174
Top Freezer Totals:			1,738	1,565,281	1,779,136
Not reported	Frost Free		1	630	718
Not reported totals			1	630	718
Overall totals			2,677	2,669,088	3,045,011

Table 2-6. Gross Savings (kWh per Year) for Freezers Recycled in 2006 by Door Style, Type of Defrost and Type of Space Where Usually Operated

Style of Freezer	***Defrost Type***	***Type of Space Where Usually Operated***	***Number of Units***	***Savings Based on Imputed At Manufacture Energy Use (kWh per Year***	***Savings Based on Estimated Current Energy Use (kWh per Year)***
Chest	Frost Free	Conditioned	1	525	611
		Non-conditioned	5	2,984	3,477
		Not reported	4	3,922	4,569
	Manual	Conditioned	33	23,154	26,974
		Non-conditioned	66	48,022	55,946
		Not reported	31	24,661	28,730
Chest Freezer Totals:			140	103,268	120,307
Upright	Frost Free	Conditioned	6	8,754	10,198
		Non-conditioned	15	15,715	18,307
		Not reported	11	14,057	16,377
	Manual	Conditioned	160	127,807	148,895
		Non-conditioned	366	298,186	347,387
		Not reported	161	142,076	165,519
Upright Freezer Totals:			719	606,595	706,683
Not reported	Manual	Conditioned	1	630	733
		Non-conditioned	1	1,140	1,328
Not reported totals			2	1,770	2,062
Overall totals			861	711,632	829,052

Table 2-7. Estimates of Gross Peak Hour kW Reductions

	Refrigerators	*Freezers*	*All*
Gross kWh savings	3,045,042	829,044	3,874,086
Gross kWh savings during peak hours	406,755	110,775	517,530
Average kW reduced per peak hour	394.14	107.34	501.48
Average peak kW reduced per unit recycled	0.147	0.125	

Table 2-8. Average kW per Hour for Program Refrigerators and Freezers Monitored On-Site

	Refrigerators	*Freezers*
Number of units	28	13
Average kW per hour	0.136	0.139
Standard deviation of kW per hour	0.070	0.056

3. ANALYSIS OF NET SAVINGS

This chapter presents and discusses the results from analyzing the net savings resulting from the program.

3.1 METHODOLOGY FOR FREE-RIDERSHIP ANALYSIS

The purpose of the net savings analysis was to estimate the proportion of gross savings that is program-induced and net of free-ridership estimates. The goal was to determine what would have occurred in the absence of the program. This means determining what proportion of participants would have disposed of their refrigerators without the program in a way that would have removed the refrigerators permanently from the grid.

There are essentially four categories for what could have happened to a refrigerator or freezer had it not been recycled through the program. These categories are:

- Unit is kept by the household but not used;
- Unit is kept by the household and still used;
- Unit is discarded by the household through a method in which the unit would be destroyed; and
- Unit is discarded by the household through a method in which the unit would be transferred and kept in use.

Of these four categories, two are indicative of free-ridership:

- Unit is kept by the household but not used; or
- Unit is discarded by the household through a method in which the unit would be destroyed.

These categories are indicative of free-ridership because the units would have been removed from the grid even if they had not been recycled through the program.

To ascertain the proportion of units falling into the various categories, a telephone survey was conducted of a sample of 203 households that recycled one or more refrigerators or freezers through the program. (Table 4-1 shows the distribution of the sample by types and numbers of appliances recycled.)

As part of the survey interview, respondents were asked three questions, the answers to which were used to assign each respondent to a free-ridership category.

- "Without SMUD's program , would you have still gotten rid of your refrigerator, or would you have kept it?"
- "If you would have gotten rid of the refrigerator even if SMUD had not had its program, which one of [listed] alternatives would you have (most likely) used to get rid of it?"

- "You mentioned you would have kept this refrigerator if it hadn't been picked up by SMUD's program. If you had kept it, would you have stored it unplugged or would you have kept using it to store extra food and beverages? "

The answers to the first and third questions were used to assign respondents to the "Kept but not used" and "Kept and still used" categories. The answers to the second question were used to assign respondents to the "Discarded-Transferred" and "Discarded-Destroyed" categories. Alternative methods of discarding were assigned to the categories as follows:

- Discarded-Transferred:
  - Sell it to a private party (e.g., by running an ad)
  - Sell it to someone you know
  - Sell it to a appliance dealer
  - Give it away to a private party, such as a friend or neighbor
  - Give it away to a charity organization (e.g., Goodwill Industries, a church)
  - Have it removed by dealer you got new or replacement appliance from
  - Trade it in for new appliance or replacement appliance
  - Some other way
- Discarded-Destroyed:
  - Haul it to the dump yourself
  - Haul it to a recycling center yourself
  - Hire someone else to haul it away for junking or dumping
- Don't know/not reported

The responses to these questions are summarized in Tables 3-1, 3-2, and 3-3.

Table 3-1. Survey Responses to Whether Participants Would Have Kept or Gotten Rid of Unit without SMUD's Program

Q9. Without SMUD's program , would you have still gotten rid of your refrigerator, or would you have kept it?		*Refrigerators*		*Freezers*	
		Percent of Units	*Percent of kWh Savings*	*Percent of Units*	*Percent of kWh Savings*
	Would have gotten rid of it	79.79	78.84	85.18	86.71
	Would have kept it	11.17	12.2	5.35	3.97
	Don't know	8.50	8.96	9.47	9.32
	All	100	100	100	100

Table 3-2. How Participants Would Have Disposed of Unit without SMUD's Program

Q10. If you would have gotten rid of appliance even if SMUD had not had its program. which alternative would you have most likely used to get rid of it?		*Refrigerators*		*Freezers*	
		Percent of Units	*Percent of kWh Savings*	*Percent of Units*	*Percent of kWh Savings*
	Sell to private party	2.41	2.48	0	.
	Sell to someone you know	1.81	1.54	3.79	3.25
	Sell to appliance dealer	3.62	3.32	1.89	1.06
	Give away to private party	10.06	9.99	7.57	9.18
	Give away to charity	2.41	3.13	5.68	4.14
	Have it removed by dealer	5.98	7.09	5.52	4.7
	Trade in for new appliance	19.28	17.36	15.95	16.13
	Haul to dump yourself	9.5	9.72	12.76	15.22
	Haul to recycling center	17.29	17.1	18.77	19.26
	Hire someone to haul away for junking	2.83	2.88	7.57	6.87
	Some other way	0.6	0.54	0	.
	Don't know	13.26	13.69	13.25	15.88

Table 3-3. How Participants Would Have Used Unit If They Had Kept It

Q11. If you had kept this appliance, would you have stored it unplugged or would you have kept using it to store extra food and beverages?		*Refrigerators*		*Freezers*	
		Percent of Units	*Percent of kWh Savings*	*Percent of Units*	*Percent of kWh Savings*
	Would have stored it unplugged	1.03	0.89	0.00	0.00
	Would have kept it running	10.31	11.05	3.62	2.82
	Would have both stored and used it	1.78	1.94	1.73	1.15
	Would not have kept it	1.83	2.45	0.00	0.00
	Not applicable	85.06	83.68	94.65	96.03
	All	100	100	100	100

3.2 RESULTS OF NET SAVINGS ANALYSIS

As discussed in Section 3.1, free-ridership is determined by what a customer would have done with the refrigerator had they not recycled it through SMUD's program. If a unit would have been kept but not used or if it would have been discarded in a manner that resulted in its being destroyed, then those units are considered indicative of free-ridership.

Data for estimating the free-ridership rate for refrigerators recycled through the program are presented in Table 3-4. The reported percentages are derived from tabulations of the weighted participant survey data. Taking the four categories for which free-ridership status could be

determined, free-ridership is estimated to be 39.1% when measured by units and 39.2% when measured by kWh savings.[1]

Table 3-4. Data for Estimating Free-Ridership for Refrigerators

What Would Have Happened to Recycled Unit	***Free-ridership?***	***Estimated Percentage of Units in Category***	***Estimated Percentage of kWh Savings in Category***
Kept-Not used	Yes	1.0%	0.9%
Kept-Used	No	9.6%	10.4%
Discarded-Transferred	No	38.1%	37.0%
Discarded-Destroyed	Yes	29.6%	29.7%
Not reported	Unknown	21.7%	22.1%
Totals		100.0%	100.0%

Data for estimating the free-ridership rate for freezers recycled through the program are presented in Table 3-5. Taking the four categories for which free-ridership status could be determined, free-ridership for freezers is estimated to be 48.2% when measured by units and 51.6% when measured by kWh savings.

Table 3-5. Data for Estimating Free-Ridership for Freezers

What Would Have Happened to Recycled Unit	***Free-ridership?***	***Estimated Percentage of Units in Category***	***Estimated Percentage of kWh Savings in Category***
Kept-Not used	Yes	0.0%	0.0%
Kept-Used	No	5.4%	4.0%
Discarded-Transferred	No	36.6%	34.8%
Discarded-Destroyed	Yes	39.1%	41.4%
Not reported	Unknown	18.9%	19.9%
Totals		100.0%	100.0%

Table 3-6 brings together the results of the preceding analysis to estimate the kWh savings net of free-ridership for refrigerators and freezers recycled through the program. The kWh savings for the program net of free-ridership are estimated to be about 2,251,520 kWh. (The free-ridership rates measured by kWh are used for these calculations.)

Table 3-6. Program kWh Savings Net of Free-Ridership

Type of Appliance	***Gross kWh Savings***	***1 - Free-Ridership Rate***	***kWh Savings Net of Free-Ridership***
Refrigerators	3,045,011	60.8%	1,850,620
Freezers	829,052	48.4%	400,898
Total	3,874,063		2,251,518

[1] For example, the free-ridership rate measured by units is calculated as (1.0% + 29.6%)/(1.0% +9.6%+38.1%+29.6%) = 30.6%/78.3% = 39.1%. The free-ridership rate measured by savings is calculated similarly.

Estimates of net kW reductions during SMUD's summer peak hours are presented in Table 3-7.

Table 3-7. Estimates of Net Peak Hour kW Reductions

	Refrigerators	*Freezers*	*All*
Gross kWh savings	3,045,042	829,044	3,874,086
Gross kWh savings during peak hours	406,755	110,775	517,530
Average kW reduced per peak hour	394.14	107.34	501.48
Net of Free-ridership %	60.8%	48.4%	
kW reductions net of free-ridership	239.54	51.91	291.45

4. RESULTS FROM SURVEY OF PROGRAM PARTICIPANTS

As part of the evaluation work effort, a survey was made of a sample of households that participated in the Old Refrigerator Pickup and Recycling Program. The survey provided the information used in Chapter 3 to estimate free-ridership for the program. Moreover, the survey provided more general information pertaining to the decisions made by program participants to recycle old appliances through the program. An analysis of that information is presented and discussed in this chapter.

4.1 SURVEY METHODOLOGY

The sample of participants to interview was selected through a sample design in which participant households were stratified by the types and numbers of appliances that they recycled through the program. There were five strata:

- Households recycling one refrigerator;
- Households recycling two refrigerators;
- Households recycling one freezer;
- Households recycling two freezers; and
- Households recycling one refrigerator and one freezer.

Table 4-1 reports the numbers of participants actually interviewed in the various strata, as well as the number of refrigerators and freezers recycled by the surveyed participants.

Table 4-1. Distribution of Sample for Telephone Survey

Types and Numbers of Appliances Recycled	***Numbers in Sample***		
	House-holds	***Refrige-rators***	***Freezers***
One refrigerator picked up	139	139	0
Two refrigerators picked up	11	22	0
One freezer picked up	43	0	43
Two freezers picked up	1	0	2
One refrigerator and one freezer picked up	9	9	9
Totals	203	170	54

Because of the stratification, different weights were assigned to respondents in the different strata to allow representation of the population of participants from which the respondents came.

Each participant was interviewed using the survey instrument provided in Appendix B. The interviews were conducted by telephone. During the interview, a participant was asked questions about his/her general decision making regarding recycling old appliances through the program and his/her knowledge of and satisfaction with the program.

4.2 SUMMARY OF MAJOR FINDINGS FROM SURVEY

This section provides a summary of major findings from the survey. (Question-by-question tabulations of the survey responses are provided in Appendix C.) Based on the survey tabulations, the following points can be made.

Participants appeared to be relatively satisfied with the program. Table 4-2 reports the distribution of response when participants were asked about their overall satisfaction with the program. Participants representing nearly all of the units recycled indicated that they were either "very satisfied" or "somewhat satisfied" with the overall service they received through the program.

Table 4-2. Participants' Satisfaction with the Program

How satisfied were you with the overall service you received through the program?		*Refrigerators*		*Freezers*	
		Percent of Units	*Percent of kWh Savings*	*Percent of Units*	*Percent of kWh Savings*
	Somewhat unsatisfied	1.27	1.84	0.00	0.00
	Neutral	0.00	0.00	0.00	0.00
	Somewhat satisfied	12.57	13.47	11.03	10.91
	Very satisfied	84.00	83.44	88.97	89.09
	Don't know	1.08	1.25	0.00	0.00
	All	100	100	100	100

Participants were asked about the reasons that they chose to use SMUD's recycling program over other methods of disposing of their old appliances. The responses, which are tabulated in Table 4-3, indicate that the $35 incentive and the free pick-up were the predominant reasons for choosing to dispose of old appliances through the program

Table 4-3. Reasons for Choosing to Dispose of Old Appliances through Program

Q8. What were the reasons you chose to use SMUD's program over <u>other methods</u> of getting rid of your appliance?		*Refrigerators*		*Freezers*	
		Percent of Units	*Percent of kWh Savings*	*Percent of Units*	*Percent of kWh Savings*
	$35 incentive	97.03	97.36	92.59	93.51
	Free pick-up	86.42	84.89	91.63	92.12
	Environmentally safe disposal	2.36	2.32	5.52	5.07
	Friend/relative recommended	2.41	3.51	0.00	0.00
	Retailer/dealer recommended	2.36	2.38	1.73	1.77
	Utility sponsorship	1.16	1.19	3.62	6.06
	Easy Way	3.43	4.06	6.81	8.45

The $35 per unit incentive payment from the program was influential for the participants in their decisions to dispose of old appliances through the program. Table 4-4 shows that most participants indicated that the $35 incentive was either "very influential" or "somewhat influential" in their decisions to dispose of their old appliances through the program.

Table 4-4. Influence of $35 Incentive Payment

How influential was the $35 incentive in your decision to get rid of the refrigerator through SMUD's program?		*Refrigerators*		*Freezers*	
		Percent of Units	*Percent of kWh Savings*	*Percent of Units*	*Percent of kWh Savings*
	Very influential	84.51	83.77	72.26	69.93
	Somewhat influential	14.28	14.89	23.96	26.15
	Not very influential	1.21	1.34	3.79	3.92
	All	100.00	100.00	100/00	100.00

As Table 4-5 shows, participants in the program generally first learned about the program from various sources. TV advertisement was the source cited the most, along with newspaper advertisement, utility bill inserts, and word-of-mouth from friends, relatives, etc.

Table 4-5. Sources for Learning about the Program

How did you learn about SMUD's refrigerator recycling program?		*Refrigerators*		*Freezers*	
		Percent of Units	*Percent of kWh Savings*	*Percent of Units*	*Percent of kWh Savings*
	Newspaper advertisement	14.46	14.01	18.77	19.9
	TV advertisement	25.68	27.46	20.5	20.26
	Radio advertisement	2.97	2.8	3.62	2.47
	Utility website	7.23	7.41	1.89	1.39
	Utility bill insert / information with utility bill	13.17	12.48	16.71	13.46
	Separate mailing/Brochure	6.44	6.33	11.36	12.51
	Called the Utility Co. (e.g., 800 number)	1.81	1.66	5.68	8.25
	Media stories about program	0.00	0.00	1.89	2.77
	From friend, relative or neighbor	14.42	13.67	10.27	9.80
	Appliance retailer	12.01	12.79	9.3	9.18
	Somewhere else	1.21	0.92	0.00	0.00
	Don't know	0.6	0.48	0.00	0.00

Respondents were also asked to rate the following aspects of the program, using a scale of Excellent, Good, Fair or Poor.

- Information you received explaining program;
- Procedures for scheduling pick-up;
- Time it took from scheduling to when contractor performed pick-up;
- Care with which contractor's workers performed pick-up;
- Time it took to receive incentive check; and
- Amount of incentive.

Nearly all respondents rated these various aspects of the program either "Excellent" or "Good".

SMUD's Old Refrigerator Pickup and Recycling Program is only one of the ways available to its customers to dispose of old refrigerators and freezers. In the survey, respondents were asked about which method of disposal they would have used had they not disposed of their old refrigerator or freezer through SMUD's programs. The responses are reported in Table 4-6.

Table 4-6. Methods by Which Customers Would Have Disposed of Old Refrigerators or Freezers Had They Not Used SMUD Program

If you would have gotten rid of appliance even if SMUD had not had its program. which alternative would you have most likely used to get rid of it?		*Refrigerators*		*Freezers*	
		Percent of Units	*Percent of kWh Savings*	*Percent of Units*	*Percent of kWh Savings*
	Sell to private party	2.41	2.48	0	.
	Sell to someone you know	1.81	1.54	3.79	3.25
	Sell to appliance dealer	3.62	3.32	1.89	1.06
	Give away to private party	10.06	9.99	7.57	9.18
	Give away to charity	2.41	3.13	5.68	4.14
	Have it removed by dealer	5.98	7.09	5.52	4.7
	Trade in for new appliance	19.28	17.36	15.95	16.13
	Haul to dump yourself	9.5	9.72	12.76	15.22
	Haul to recycling center	17.29	17.1	18.77	19.26
	Hire someone to haul away for junking	2.83	2.88	7.57	6.87
	Some other way	0.6	0.54	0	.
	Don't know	13.26	13.69	13.25	15.88

APPENDIX A: DESCRIPTION OF MONITORING APPROACH

As part of the evaluation effort, *in-situ* monitoring of energy use was conducted for a sample of 28 refrigerators and 13 freezers that were being recycled through the program. The procedures for that monitoring are described in this appendix.

The refrigerators and freezers that were monitored were selected on a rolling basis throughout 2006 from May through November to ensure that energy use was monitored in both summer and winter months. Households and units that were good candidates for the monitoring were identified by working with SMUD"s implementation contractor.

The procedures used in conducting the *in-situ* monitoring were as follows.

- A portable power meter (AEMC 3910) was used to make one-time measurements of true rms power, voltage, current and power factor.
- A custom-designed monitoring box (see Figure A-1) was used to conduct continuous monitoring of the unit's energy use. This monitoring box has been designed to be easy to use. A current/power logger is mounted in an electrical extension box that plugs into the wall outlet used by the refrigerator or freezer. The unit's power cord is then plugged into the receptacle on the monitoring box. This allowed for quick and easy installation of the monitoring equipment. The logger has appropriately sized split-core current transformers (CT) that record average AC current data in 5-minute intervals.

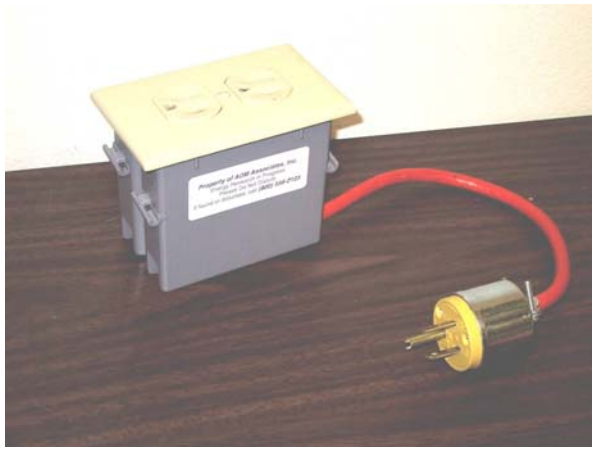

Figure A-1. Plug-In Power Logger Designed by ADM

To complement the monitoring of electric use, temperature monitoring was also conducted.

- A temperature sensor was placed inside both the refrigerator and the freezer compartment (where applicable). Hobo temperature loggers were used to measure the interior temperatures at 5-minute intervals as well. The logger or sensor was placed such that it would not interfere with refrigerator use.

- The external temperature for the space where the refrigerator was located was measured at 30-minute intervals to provide information from which to develop a better understanding of the conditions that the refrigerator is operating in.

A lighting logger was used to monitor refrigerator door openings. This monitoring measured the amount of time a door remains open each time it is opened.

Digital photographs of the internal contents of the refrigerator or freezer were taken, both at the time when the monitoring equipment was installed and when that equipment was removed.

An example of the data collected for each monitored refrigerator or freezer is shown in Figure A-2. The time steps for the temperature readings were 5 minutes for inside the refrigerator or freezer and 30 minutes for the temperature of the environment.

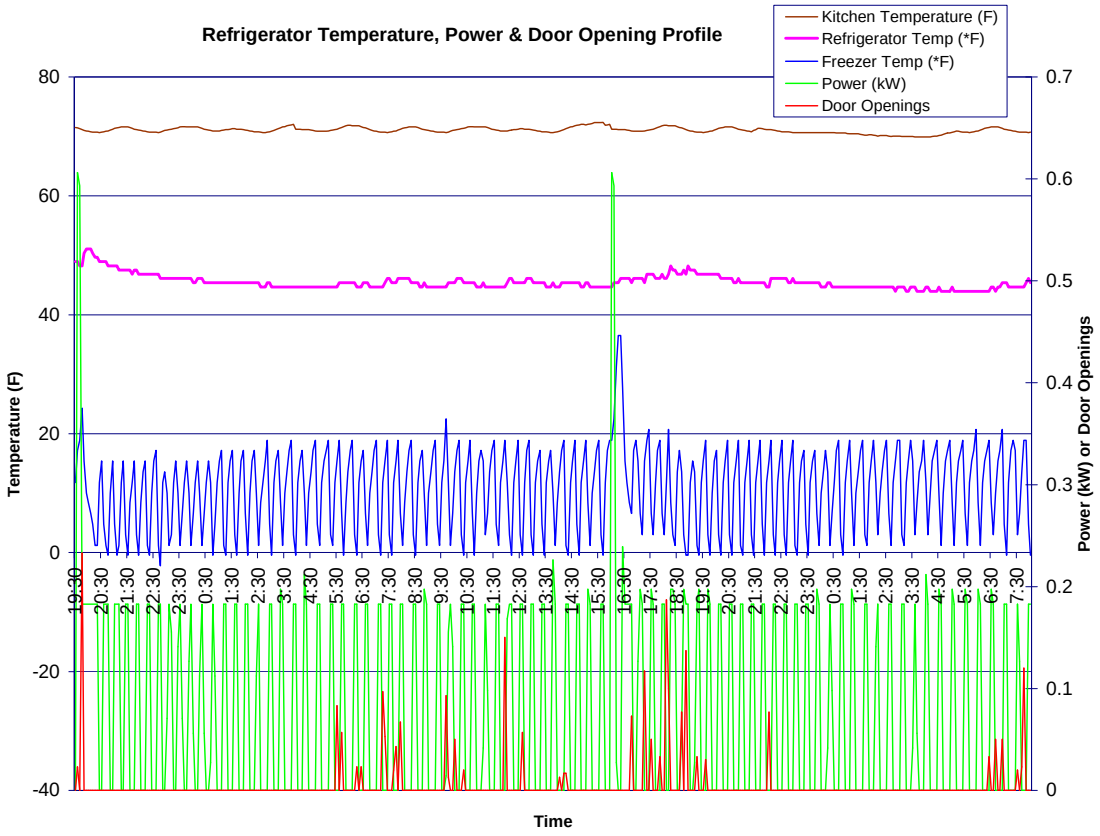

Figure A-2. Example of Monitoring Data

The monitoring at each site was conducted for at least one week and up to two weeks for some sites, if appropriate. The actual number of days for the monitoring at a site was determined to accommodate the convenience of the customer. A monitoring period of at least one week was sufficient to capture many defrost cycles. One defrost cycle was considered to be the minimum

monitoring period to adequately capture the refrigerator energy use for annual consumption projections. Refrigerator-only units do not have a defrost cycle.

As part of ADM's work in evaluating the Statewide RARP, algorithms have been developed for extrapolating *in-situ* data on energy use that are collected over a period of one or two weeks to represent full-year energy use of the monitored refrigerator or freezer. Those algorithms were applied to the *in-situ* data on energy use collected for the sample of refrigerators and freezers that were monitor during this project.

APPENDIX B: QUESTIONNAIRE FOR SURVEY OF PARTICIPANTS

The survey questionnaire is provided under separate cover.

APPENDIX C: TABULATIONS FROM SURVEY OF PARTICIPANTS

Question-by-question tabulations of the responses from the survey of participants are presented in this appendix. Each table provides the responses to a question from the survey interview form (see Appendix B.) Each table shows the percentage distributions across response categories, with responses weighted so that respondents reflect the population in terms of both number of units recycled through the program and the kWh savings realized for those units.

Q5. What was the condition of this refrigerator?		*Refrigerators*		*Freezers*	
		Percent of Units	*Percent of kWh Savings*	*Percent of Units*	*Percent of kWh Savings*
	Worked and was in good condition	91.05	90.93	82.33	82.4
	Worked but needed minor repairs	1.81	1.23	6.81	6.03
	Worked but had some problems	5.33	6.01	10.87	11.57
	Didn't work	1.81	1.82	0	.
	All	100.00	100.00	100.00	100.00

Q6. Did you decide to get rid of this refrigerator before or after hearing about SMUD's Recycling Program?		*Refrigerators*		*Freezers*	
		Percent of Units	*Percent of kWh Savings*	*Percent of Units*	*Percent of kWh Savings*
	Before	71.86	72.79	79.34	78.01
	After	26.39	25.80	18.77	20.01
	Don't' know	1.21	1.41	1.89	1.98
	All	100.00	100.00	100.00	100.00

Q7. How influential was the $35 incentive in your decision to get rid of the refrigerator through SMUD's program?		*Refrigerators*		*Freezers*	
		Percent of Units	*Percent of kWh Savings*	*Percent of Units*	*Percent of kWh Savings*
	Very influential	84.51	83.77	72.26	69.93
	Somewhat influential	14.28	14.89	23.96	26.15
	Not very influential	1.21	1.34	3.79	3.92
	All	100.00	100.00	100/00	100.00

Q8. What were the reasons you chose to use SMUD's program over other methods of getting rid of your appliance?		*Refrigerators*		*Freezers*	
		Percent of Units	*Percent of kWh Savings*	*Percent of Units*	*Percent of kWh Savings*
	$35 incentive	97.03	97.36	92.59	93.51
	Free pick-up	86.42	84.89	91.63	92.12
	Environmentally safe disposal	2.36	2.32	5.52	5.07
	Friend/relative recommended	2.41	3.51	0.00	0.00
	Retailer/dealer recommended	2.36	2.38	1.73	1.77
	Utility sponsorship	1.16	1.19	3.62	6.06
	Easy Way	3.43	4.06	6.81	8.45

Q9. Without SMUD's program , would you have still gotten rid of your refrigerator, or would you have kept it?		*Refrigerators*		*Freezers*	
		Percent of Units	*Percent of kWh Savings*	*Percent of Units*	*Percent of kWh Savings*
	Would have gotten rid of it	79.79	78.84	85.18	86.71
	Would have kept it	11.17	12.2	5.35	3.97
	Don't know	8.50	8.96	9.47	9.32
	All	100	100	100	100

Q10. If you would have gotten rid of appliance even if SMUD had not had its program. which alternative would you have most likely used to get rid of it?		*Refrigerators*		*Freezers*	
		Percent of Units	*Percent of kWh Savings*	*Percent of Units*	*Percent of kWh Savings*
	Sell to private party	2.41	2.48	0	.
	Sell to someone you know	1.81	1.54	3.79	3.25
	Sell to appliance dealer	3.62	3.32	1.89	1.06
	Give away to private party	10.06	9.99	7.57	9.18
	Give away to charity	2.41	3.13	5.68	4.14
	Have it removed by dealer	5.98	7.09	5.52	4.7
	Trade in for new appliance	19.28	17.36	15.95	16.13
	Haul to dump yourself	9.5	9.72	12.76	15.22
	Haul to recycling center	17.29	17.1	18.77	19.26
	Hire someone to haul away for junking	2.83	2.88	7.57	6.87
	Some other way	0.6	0.54	0	.
	Don't know	13.26	13.69	13.25	15.88

Q11. If you had kept		*Refrigerators*		*Freezers*	
		Percent	*Percent*	*Percent*	*Percent*

this appliance, would you have stored it unplugged or would you have kept using it to store extra food and beverages?		*of Units*	*of kWh Savings*	*of Units*	*of kWh Savings*
	Would have stored it unplugged	1.03	0.89	0.00	0.00
	Would have kept it running	10.31	11.05	3.62	2.82
	Would have both stored and used it	1.78	1.94	1.73	1.15
	Would not have kept it	1.83	2.45	0.00	0.00
	Not applicable	85.06	83.68	94.65	96.03
	All	100	100	100	100

Q13. Where would you have kept it?		*Refrigerators*		*Freezers*	
		Percent of Units	*Percent of kWh Savings*	*Percent of Units*	*Percent of kWh Savings*
	Kitchen	1.16	0.78	1.73	1.15
	Garage	9.41	10.76	1.73	1.53
	Porch	1.21	1.19	1.89	1.29
	Other	1.21	1.07	0.00	0.00
	Not applicable	87.02	86.2	94.65	96.03
	All	100	100	100	100

Q14. Is the space where you would have kept it heated or cooled?		*Refrigerators*		*Freezers*	
		Percent of Units	*Percent of kWh Savings*	*Percent of Units*	*Percent of kWh Savings*
	Neither heated or cooled	11.29	12.19	3.62	2.82
	Heated only	0.61	1.1	0.00	0.00
	Both heated and cooled	1.77	1.2	1.73	1.15
	Not applicable	86.33	85.5	94.65	96.03
	All	100	100	100	100

Q15. During the time just before you decided to get rid of the refrigerator, was it being used as your main refrigerator, or had it been a secondary unit used for extra storage or as a spare?		*Refrigerators*		*Freezers*	
		Percent of Units	*Percent of kWh Savings*	*Percent of Units*	*Percent of kWh Savings*
	Main unit	55.96	57.5	80.05	80.59
	Space or secondary unit	43.43	41.94	18.06	17.57
	Not reported	0.60	0.57	1.89	1.84
	All	100	100	100	100

Q17. Where was the secondary refrigerator located when it was running?		*Refrigerators*		*Freezers*	
		Percent of Units	*Percent of kWh Savings*	*Percent of Units*	*Percent of kWh Savings*
	Kitchen	5.23	5.77	0.00	0.00
	Garage	35.37	34.6	19.24	20.06
	Porch/Patio	4.73	4.2	3.79	3.63
	Other	0.6	0.42	0.00	0.00
	Not applicable	54.06	55.01	76.97	76.32
	All	100	100	100	100

Q18. What best describes how the space where the secondary refrigerator was located was heated or cooled?		*Refrigerators*		*Freezers*	
		Percent of Units	*Percent of kWh Savings*	*Percent of Units*	*Percent of kWh Savings*
	Neither heated nor cooled	40.37	38.95	23.03	23.68
	Heated only	0.6	0.34	0.00	0.00
	Both heated and cooled	3.75	4.38	0.00	0.00
	Not applicable	55.27	56.32	76.97	76.32
	All	100	100	100	100

Q19. Did you have the secondary unit plugged in and running?		*Refrigerators*		*Freezers*	
		Percent of Units	*Percent of kWh Savings*	*Percent of Units*	*Percent of kWh Savings*
	Plugged in and running all the time	44.13	42.65	19.24	20.06
	Plugged in and running but only part of time	1.81	2.18	1.89	2.37
	Not plugged in and running	0.00	0.00	1.89	1.26
	Not applicable	54.06	55.17	76.97	76.32
	All	100	100	100	100

Q20 How did you learn about SMUD's refrigerator recycling program?		*Refrigerators*		*Freezers*	
		Percent of Units	*Percent of kWh Savings*	*Percent of Units*	*Percent of kWh Savings*
	Newspaper advertisement	14.46	14.01	18.77	19.9
	TV advertisement	25.68	27.46	20.5	20.26
	Radio advertisement	2.97	2.8	3.62	2.47
	Utility website	7.23	7.41	1.89	1.39
	Utility bill insert / information with utility bill	13.17	12.48	16.71	13.46
	Separate mailing/Brochure	6.44	6.33	11.36	12.51
	Called the Utility Co. (e.g., 800 number)	1.81	1.66	5.68	8.25
	Media stories about program	0.00	0.00	1.89	2.77
	From friend, relative or neighbor	14.42	13.67	10.27	9.80
	Appliance retailer	12.01	12.79	9.3	9.18
	Somewhere else	1.21	0.92	0.00	0.00
	Don't know	0.6	0.48	0.00	0.00

Using the scale: Excellent, Good, Fair or Poor
How would you rate the refrigerator pick-up program on the following features:

Q21a. Information you received explaining program		*Refrigerators*		*Freezers*	
		Percent of Units	*Percent of kWh Savings*	*Percent of Units*	*Percent of kWh Savings*
	Excellent	73.07	71.78	86.91	85.64
	Good	25.73	26.46	13.09	14.36
	Fair	1.21	1.77	0.00	0.00
	All	100	100	100	100

Q21b. Procedures for scheduling pick-up		*Refrigerators*		*Freezers*	
		Percent of Units	*Percent of kWh Savings*	*Percent of Units*	*Percent of kWh Savings*
	Excellent	74.87	74.22	86.91	85.95
	Good	25.13	25.78	13.09	14.05
	All	100	100	100	100

Q21c. Time it took from scheduling to when contractor performed pick up		*Refrigerators*		*Freezers*	
		Percent of Units	*Percent of kWh Savings*	*Percent of Units*	*Percent of kWh Savings*
	Excellent	74.27	73.26	88.8	87.24
	Good	25.73	26.74	11.2	12.76
	All	100	100	100	100

Q21d. Care with which contractor's workers performed pick up		*Refrigerators*		*Freezers*	
		Percent of Units	*Percent of kWh Savings*	*Percent of Units*	*Percent of kWh Savings*
	Excellent	70.7	70.08	87.07	85.16
	Good	28.7	28.91	12.93	14.84
	Fair	0.60	1.01	0.00	0.00
	All	100	100	100	100

Q21e. Time it took to receive incentive check		*Refrigerators*		*Freezers*	
		Percent of Units	*Percent of kWh Savings*	*Percent of Units*	*Percent of kWh Savings*
	Excellent	69.45	69.52	86.91	85.98
	Good	27.54	27.36	13.09	14.02
	Fair	0.00	0.00	0.00	0.00
	Poor	3.01	3.12	0.00	0.00
	All	100	100	100	100

Q21f. Amount of incentive		*Refrigerators*		*Freezers*	
		Percent of Units	*Percent of kWh Savings*	*Percent of Units*	*Percent of kWh Savings*
	Excellent	71.86	70.97	88.8	87.24
	Good	23.32	24.2	11.2	12.76
	Fair	0.00	0.00	0.00	0.00
	Poor	3.01	3.12	0.00	0.00
	Not reported	1.81	1.71	0.00	0.00
	All	100	100	100	100

Q22. How satisfied were you with the overall service you received through the program?		*Refrigerators*		*Freezers*	
		Percent of Units	*Percent of kWh Savings*	*Percent of Units*	*Percent of kWh Savings*
	Somewhat unsatisfied	1.27	1.84	0.00	0.00
	Neutral	0.00	0.00	0.00	0.00
	Somewhat satisfied	12.57	13.47	11.03	10.91
	Very satisfied	84.00	83.44	88.97	89.09
	Don't know	1.08	1.25	0.00	0.00
	All	100	100	100	100

Q23. Did you have any significant problems with the program?		*Refrigerators*		*Freezers*	
		Percent of Units	*Percent of kWh Savings*	*Percent of Units*	*Percent of kWh Savings*
	Yes	2.36	3.42	1.73	0.99
	No	95.41	94.71	94.48	93.88
	Don't know	1.68	1.87	3.78	5.12
	All	100	100	100	100

Q24. Including yourself and children, how many people live in your household at least six months of the year?		*Refrigerators*		*Freezers*	
		Percent of Units	*Percent of kWh Savings*	*Percent of Units*	*Percent of kWh Savings*
	1	12.84	12.42	25.58	24.88
	2	45.48	45.48	31.53	29.85
	3	14.79	15.13	9.14	11.59
	4	12.06	11.43	24.61	24.65
	5	8.57	8.90	5.35	4.28
	6	2.83	3.30	1.89	1.89
	7	2.22	2.54	1.89	2.87
	99	1.20	0.80	0.00	0.00
	All	100	100	100	100

Q25. What is the age of the head of the household?		*Refrigerators*		*Freezers*	
		Percent of Units	*Percent of kWh Savings*	*Percent of Units*	*Percent of kWh Savings*
	18-25	6.63	5.70	0.00	0.00
	26-35	6.44	6.00	1.89	1.94
	36-45	9.83	10.07	5.52	4.71
	46-55	19.65	19.60	18.61	18.69
	55-65	18.22	20.25	18.61	19.69
	65 or older	35.00	35.25	51.59	50.63
	Don't know	1.21	0.71	1.89	1.98
	Refused	3.01	2.41	1.89	2.37
	All	100	100	100	100

Q26. Of the people in your household, how many are under 18 years of age?		*Refrigerators*		*Freezers*	
		Percent of Units	*Percent of kWh Savings*	*Percent of Units*	*Percent of kWh Savings*
	0	74.27	74.14	86.91	87.62
	1	7.84	7.94	5.68	6.23
	2	11.64	12.49	7.41	6.14
	3	4.64	3.55	0,00	0.00
	4	0.00	0.00	0.00	0.00
	5	1.02	1.53	0,00	0.00
	Don't know	0.6	0.34	0.00	0.00
	All	100	100	100	100

Q27. What language do you speak in your home most often?		*Refrigerators*		*Freezers*	
		Percent of Units	*Percent of kWh Savings*	*Percent of Units*	*Percent of kWh Savings*
	English	76.36	77.13	81.39	82.74
	Spanish	7.42	7.81	7.41	5.83
	Cantonese	0.60	0.43	1.89	2.61
	Japanese	0.60	0.61	3.79	3.26
	Tagalog	2.36	2.34	1.73	1.53
	Vietnamese	0.60	0.68	0.00	0.00.
	Other	9.64	8.98	1.89	2.77
	Don't know	2.41	2.01	1.89	1.26
	All	100	100	100	100

Q28. What category best describes your household's total annual income before taxes?		*Refrigerators*		*Freezers*	
		Percent of Units	*Percent of kWh Savings*	*Percent of Units*	*Percent of kWh Savings*
	Under $10,000	4.22	4.23	1.89	2.18
	$10,000-$25,000	12.79	12.63	15.95	15.46
	$25,000-$50,000	20.44	19.88	18.61	18.72
	$50,000-$75,000	15.21	16.06	18.61	20.57
	$75,000-$100,000	13.21	13.96	13.09	11.95
	$100,000-$150,000	4.73	5.16	11.03	9.22
	Over $150,000	0.60	0.65	3.79	3.90
	Refused	7.29	6.28	5.68	5.04
	Don't know	20.95	21.15	11.36	12.97
	All	100	100	100	100

APPENDIX D: RESULTS OF REGRESSIONS TO IMPUTE AT-MANUFACTURE ENERGY USE

This appendix provides the results for the regressions estimated for imputing at-manufacture energy use for refrigerators and freezers recycled through the Old Refrigerator Pickup and Recycling Program.

Style	*Defrost*	*Year*	*Intercept*	*Coefficient for Total Volume*	*Degrees of Freedom*	*R-Squared*
Bottom Freezer	Automatic	1979	(1,443.910)	167.469	40	0.559
Bottom Freezer	Automatic	1980	102.232	76.927	42	0.460
Bottom Freezer	Automatic	1981	92.556	77.182	44	0.479
Bottom Freezer	Automatic	1982	391.248	60.507	46	0.319
Bottom Freezer	Automatic	1983	314.244	64.650	47	0.356
Bottom Freezer	Automatic	1984	323.418	63.981	45	0.263
Bottom Freezer	Automatic	1985	428.130	58.277	47	0.508
Bottom Freezer	Automatic	1986	584.958	47.223	52	0.231
Bottom Freezer	Automatic	1987	560.699	44.883	53	0.185
Bottom Freezer	Automatic	1988	517.386	44.927	61	0.228
Bottom Freezer	Automatic	1989	195.424	52.459	30	0.406
Bottom Freezer	Automatic	1990	516.642	29.824	28	0.881
Bottom Freezer	Automatic	1992	411.296	37.579	28	0.108
Chest Freezer	Manual	1979	392.128	44.073	427	0.488
Chest Freezer	Manual	1980	334.206	32.784	653	0.919
Chest Freezer	Manual	1981	329.992	32.994	658	0.924
Chest Freezer	Manual	1982	324.615	32.844	732	0.918
Chest Freezer	Manual	1983	320.704	32.665	802	0.907
Chest Freezer	Manual	1984	325.118	31.829	629	0.897
Chest Freezer	Manual	1985	348.092	30.029	715	0.852
Chest Freezer	Manual	1986	343.556	30.072	678	0.807
Chest Freezer	Manual	1987	343.504	27.944	702	0.677
Chest Freezer	Manual	1988	344.453	27.624	707	0.664
Chest Freezer	Manual	1989	228.603	28.699	343	0.656
Chest Freezer	Manual	1990	277.881	18.705	299	0.857
Chest Freezer	Manual	1992	232.874	20.855	338	0.916
Side-by-Sid	Automatic	1979	378.311	71.973	267	0.522
Side-by-Sid	Automatic	1980	677.826	46.158	184	0.637
Side-by-Sid	Automatic	1981	644.256	46.768	240	0.566
Side-by-Sid	Automatic	1982	855.549	35.789	322	0.313
Side-by-Sid	Automatic	1983	554.647	48.926	403	0.411
Side-by-Sid	Automatic	1984	615.142	46.046	368	0.357
Side-by-Sid	Automatic	1985	1,191.578	19.833	427	0.150
Side-by-Sid	Automatic	1986	549.186	47.465	388	0.312
Side-by-Sid	Automatic	1987	397.729	52.467	372	0.238
Side-by-Sid	Automatic	1988	504.613	44.934	449	0.176
Side-by-Sid	Automatic	1989	697.413	27.367	283	0.194
Side-by-Sid	Automatic	1990	866.984	16.402	259	0.178

Style	Defrost	Year	Intercept	Coefficient for Total Volume	Degrees of Freedom	R-Squared
Side-by-Sid	Automatic	1992	(2,030.314)	155.293	241	0.396
Single Door	Automatic	1985	196.828	56.658	10	0.965
Single Door	Automatic	1986	649.720	(77.333)	3	0.312
Single Door	Automatic	1987	415.742	8.889	18	0.174
Single Door	Automatic	1988	387.043	14.804	20	0.440
Single Door	Automatic	1989	384.842	14.844	25	0.444
Single Door	Automatic	1990	371.727	18.920	31	0.580
Single Door	Automatic	1992	576.849	87.821	83	0.228
Single Door	Manual	1979	350.011	25.571	173	0.630
Single Door	Manual	1980	388.035	20.239	212	0.603
Single Door	Manual	1981	375.822	20.206	214	0.547
Single Door	Manual	1982	371.692	20.266	301	0.481
Single Door	Manual	1983	385.660	17.291	345	0.397
Single Door	Manual	1984	369.592	20.258	286	0.453
Single Door	Manual	1985	367.800	19.389	318	0.410
Single Door	Manual	1986	364.057	20.219	336	0.411
Single Door	Manual	1987	312.264	23.384	347	0.519
Single Door	Manual	1988	306.729	23.886	358	0.544
Single Door	Manual	1989	313.091	19.283	369	0.521
Single Door	Manual	1990	299.313	17.471	302	0.738
Single Door	Manual	1992	284.361	15.669	234	0.731
Top Freezer	Automatic	1979	957.047	36.110	615	0.168
Top Freezer	Automatic	1980	600.251	43.735	625	0.412
Top Freezer	Automatic	1981	650.912	39.395	778	0.341
Top Freezer	Automatic	1982	551.182	40.484	1,031	0.293
Top Freezer	Automatic	1983	588.380	36.820	1,291	0.261
Top Freezer	Automatic	1984	479.182	38.651	1,096	0.372
Top Freezer	Automatic	1985	1,139.357	0.109	1,091	0.001
Top Freezer	Automatic	1986	444.155	37.132	1,225	0.428
Top Freezer	Automatic	1987	487.046	32.068	1,196	0.313
Top Freezer	Automatic	1988	508.958	29.037	1,398	0.292
Top Freezer	Automatic	1989	525.621	24.040	1,180	0.423
Top Freezer	Automatic	1990	424.660	26.982	1,483	0.672
Top Freezer	Automatic	1992	464.170	21.859	1,478	0.368
Top Freezer	Partial	1979	641.566	25.234	100	0.045
Top Freezer	Partial	1980	490.806	34.773	142	0.180
Top Freezer	Partial	1981	489.284	34.043	148	0.292
Top Freezer	Partial	1982	416.091	41.497	163	0.505
Top Freezer	Partial	1983	416.774	40.679	198	0.445
Top Freezer	Partial	1984	415.227	38.696	151	0.358
Top Freezer	Partial	1985	422.154	37.893	125	0.367
Top Freezer	Partial	1986	458.543	34.143	96	0.156
Top Freezer	Partial	1987	416.167	32.592	89	0.496
Top Freezer	Partial	1988	416.878	29.476	90	0.416
Top Freezer	Partial	1989	432.553	25.940	89	0.600
Top Freezer	Partial	1990	439.453	23.591	82	0.526
Top Freezer	Partial	1992	409.411	17.781	84	0.191

Style	Defrost	Year	Intercept	Coefficient for Total Volume	Degrees of Freedom	R-Squared
Upright Freezer	Automatic	1979	34.766	94.005	57	0.832
Upright Freezer	Automatic	1980	335.924	63.289	60	0.520
Upright Freezer	Automatic	1981	290.453	64.368	38	0.666
Upright Freezer	Automatic	1982	430.427	57.433	56	0.490
Upright Freezer	Automatic	1983	522.317	52.380	58	0.429
Upright Freezer	Automatic	1984	597.872	46.834	46	0.401
Upright Freezer	Automatic	1985	504.506	49.726	64	0.259
Upright Freezer	Automatic	1986	241.378	50.452	92	0.336
Upright Freezer	Automatic	1987	286.660	56.084	67	0.523
Upright Freezer	Automatic	1988	168.425	62.720	74	0.397
Upright Freezer	Automatic	1989	307.184	45.175	46	0.576
Upright Freezer	Automatic	1990	567.248	26.633	51	0.261
Upright Freezer	Automatic	1992	(172.008)	70.464	78	0.543
Upright Freezer	Manual	1979	345.454	44.803	287	0.637
Upright Freezer	Manual	1980	378.715	34.701	421	0.736
Upright Freezer	Manual	1981	374.150	36.050	434	0.627
Upright Freezer	Manual	1982	371.286	34.939	474	0.805
Upright Freezer	Manual	1983	374.098	34.568	506	0.807
Upright Freezer	Manual	1984	354.481	34.475	455	0.823
Upright Freezer	Manual	1985	361.470	34.028	488	0.798
Upright Freezer	Manual	1986	351.550	35.187	426	0.692
Upright Freezer	Manual	1987	352.502	32.763	463	0.749
Upright Freezer	Manual	1988	358.534	32.130	473	0.755
Upright Freezer	Manual	1989	319.113	29.715	259	0.812
Upright Freezer	Manual	1990	376.061	23.124	312	0.812
Upright Freezer	Manual	1992	367.899	19.739	224	0.886

APPENDIX E: REVIEW OF UNIT SAVINGS ESTIMATES

This appendix provides a review of the unit savings estimates developed in this study in comparison to the savings estimates that SMUD has used for planning the refrigerator recycling program.

As discussed in Chapter 2, a two-step method was used in this study to estimate gross kWh savings for refrigerators and freezers recycled through the Old Refrigerator Pickup and Recycling Program. In the first step of the method, data from the WAPTAC database were used to develop equations that related at-manufacture energy use to appliance size. Separate equations were estimated for models characterized by the combination of door style, type of defrost, and year of manufacture. Using these equations, specific at-manufacture energy use values were imputed to individual units in the tracking system database.

For estimating gross savings, the at-manufacture energy use values were then adjusted to at-death energy use values. That is, it is the energy use of the recycled units when they are discarded that is of interest. Accordingly, the second step in the method used in this study was to adjust at-manufacture energy to at-death energy use by using data on energy use obtained through *in-situ* (i.e., in-house) monitoring of refrigerators and freezers that will be recycled.

ADM has conducted a dual metering project for the investor-owned utilities in California in which *in-situ* energy use was monitored for a sample of over 200 refrigerators and freezers located throughout the state. To complement these data, additional *in-situ* monitoring of energy use was conducted during this project. A sample of 28 refrigerators and 13 freezers that were being recycled through SMUD's program were selected for the *in-situ* monitoring. The units selected for the *in-situ* monitoring in this study were units that had usually been operating in non-conditioned spaces.

The at-manufacture energy use for the units monitored *in-situ* was obtained from the WAPTAC database. The data for the *in-situ* monitored units were analyzed to determine the relationship between at-manufacture energy use and *in-situ* measured energy use. For this analysis, refrigerators were divided between two categories, depending on whether they were usually operated in conditioned space or in non-conditioned space. The ratios of in-situ kWh to at-manufacture kWh were used to adjust the at-manufacture kWhs imputed for units in the tracking database to represent actual in-house energy use. For some refrigerator units in the tracking database, the type of space where the unit was usually operated was not reported. For these cases, a ratio was applied that was a weighted average of the ratios for conditioned and non-conditioned space for units of the particular type (e.g., side-by-side refrigerators with frost-free defrost).

Table E-1 shows the averages estimated for at-manufacture and at-death kWh usage when refrigerators recycled through the program are classified by style, type of defrost, and type of space where the unit was usually operated. Table E-2 shows the averages for freezers.

Table E-1. Average Gross Savings (kWh per Year) for Refrigerators Recycled in 2006 by Door Style, Type of Defrost and Type of Space Where Usually Operated

Door Style	***Defrost Type***	***Type of Space Where Usually Operated***	***Average kWh Savings Based on Imputed At Manufacture Energy Use (kWh per Year***	***Average kWh Savings Based on Estimated Current Energy Use (kWh per Year)***
Bottom Freezer	Frost Free	Conditioned	1,267	1,549
		Non-conditioned	1,069	1,113
		Not reported	1,288	1,502
	Manual	Conditioned	1,373	1,679
		Non-conditioned	1,388	1,445
Bottom Freezer Totals:			1,243	1,452
Side-by-Side	Frost Free	Conditioned	1,210	1,479
		Non-conditioned	1,259	1,311
		Not reported	1,390	1,598
	Manual	Conditioned	746	912
		Non-conditioned	763	794
		Not reported	1,200	1,358
	Not reported	Not reported	1,767	2,031
Side-by-Side Totals:			1,266	1,454
Single Door	Frost Free	Conditioned	621	759
		Non-conditioned	491	511
		Not reported	600	680
	Manual	Conditioned	577	706
		Non-conditioned	596	620
		Not reported	622	684
Single Door Totals:			595	656
Top Freezer	Frost Free	Conditioned	863	1,055
		Non-conditioned	905	942
		Not reported	969	1,104
	Manual	Conditioned	839	1,026
		Non-conditioned	883	919
		Not reported	920	1,033
	Not Reported	Not reported	1,032	1,175
Top Freezer Totals:			901	1,024
Not reported	Frost Free		630	719
Not reported totals			630	719
Overall totals			997	1,138

Table E-2. Average Gross Savings (kWh per Year) for Freezers Recycled in 2006 by Door Style, Type of Defrost and Type of Space Where Usually Operated

Style of Freezer	***Defrost Type***	***Type of Space Where Usually Operated***	***Average kWh Savings Based on Imputed At Manufacture Energy Use (kWh per Year***	***Average kWh Savings Based on Estimated Current Energy Use (kWh per Year)***
Chest	Frost Free	Conditioned	525	611
		Non-conditioned	597	695
		Not reported	981	1,142
	Manual	Conditioned	702	817
		Non-conditioned	728	848
		Not reported	796	927
Chest Freezer Totals:			738	859
Upright	Frost Free	Conditioned	1,459	1,700
		Non-conditioned	1,048	1,220
		Not reported	1,278	1,489
	Manual	Conditioned	799	931
		Non-conditioned	815	949
		Not reported	882	1,028
Upright Freezer Totals:			844	983
Not reported	Manual	Conditioned	630	733
		Non-conditioned	1,140	1,328
Not reported totals			885	1,031
Overall totals			827	963

SMUD assumed that the gross savings that would be realized from units recycled through the program would be 1,500 kWh and 0.22 kW per unit. These estimated savings reflected a weighted averaging across both refrigerators and freezers. By contrast, the weighted average that would be obtained from the results presented in this report would be about 1,095 kWh per unit.

To identify reasons for this difference, the studies that SMUD cited as sources for the information it used in deriving the savings estimates for its planning of the program were reviewed. The estimated savings reported by these sources are shown in Table B-3. Examination of the methods used in these studies suggests reasons why the savings they estimated were higher than the savings estimated in this study.

Table E-3. Savings Estimates Cited in Studies Used by SMUD for Planning

Study Author	***Refrigerators***		***Freezers***	
	kWh per Year	***kW***	***kWh per Year***	***kW***
KEMA-Xenergy[1]	1,946		1,662	
RMA[2]	1,625	0.365	2,009	0.348
HMG[3]	1,539	0.210	1,495	0.220

Sources:
1) KEMA-XENERGY, "Measurement and Evaluation Study of 2002 Statewide Residential Appliance Recycling Program," Final Report prepared for SCE, 2/13/04.
2) Robert Mowris & Associates (RMA)., "Measurement & Verification Report for NCPA SB5X Refrigerator Recycling," Final Report prepared for NCPA, 3/7/03,
3) Heschong Mahone Group (HMG), "SMUD Refrigerator Recycling Program Impact Analysis," Final Report prepared for SMUD, 9/17/02

The studies by KEMA-Xenergy and RMA applied the AHAM and/or DOE Test Methods to samples of refrigerators and freezers being recycled to determine energy use for the analyses. An important aspect of these two studies is that the data used to estimate savings were collected at relatively high ambient temperatures. For the KEMA-Xenergy study, energy use for the sampled units was estimated using the DOE Test Method, for which the ambient temperature is set at 90^{o}F. For the RMA, energy use data were obtained through in-situ metering in unconditioned spaces at customer sites and warehouses, with the ambient temperatures during metering ranging from 80^{o} F to 105^{o} F.

The ambient temperature of the space in which a refrigerator or freezer is located is of course a major factor in determining the amount of energy that the unit will consume. This is illustrated in Figure E-1, which plots average kWh per hour against average ambient temperature for 156 top freezer refrigerators for which ADM has conducgted in-situ monitoring. The units monitored were located in both conditioned and unconditioned space. (The averaging is done across the period for which the units were monitored, generally one to two weeks.) As can be seen in Figure E-1, energy use is higher at higher ambient temperatures.

Figure E-2 compares average ambient temperatures for units measured in conditioned and unconditioned spaces for particular months of the year. As can be seen, ambient temperatures in both conditioned and unconditioned spaces are affected by outdoor temperature, being higher in summer months (e.g., July and August) than in other months. Two observations can be made from these data.

- First, the differences in ambient temperatures throughout the months of the year indicate that using data on energy use measured when ambient temperatures are high will overstate annual energy use if simply extrapolated to other times of the year. Indeed, TMY temperature data for CEC Climate Zone 12 (which includes Sacramento) show that outdoor temperatures of 80^{o}F or higher occur for only about 11% of the hours in the year. Temperatures less than 65^{o}F occur for nearly 69% of the hours, and temperatures between 65^{o} F and 79^{o} F occur for about 20% of the hours.

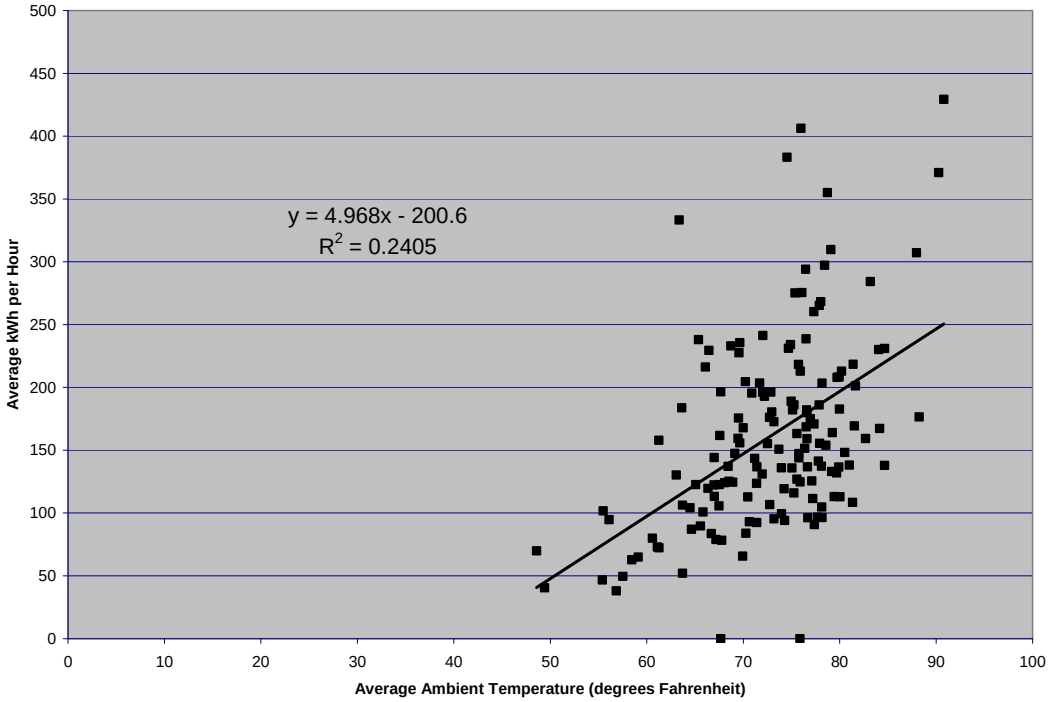

Figure E-1. Average Energy Use versus Average Ambient Temperature for Sample of Top Freezer Refrigerators

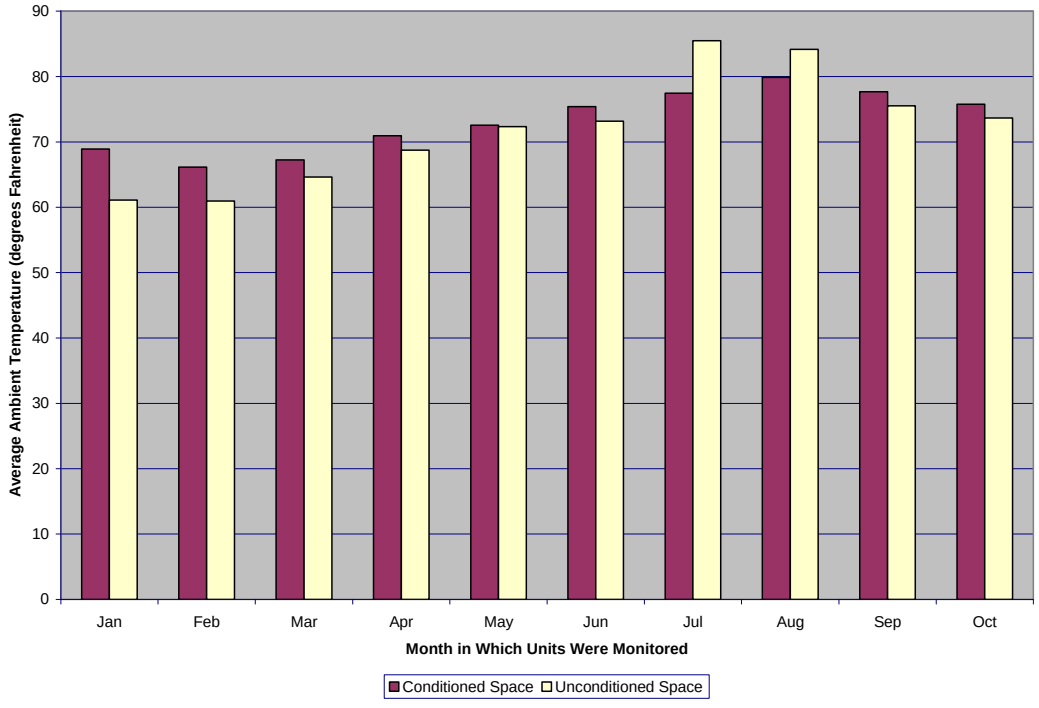

Figure E-2. Average Ambient Temperatures for Units Monitored in Conditioned and Unconditiioned Spaces, by Month in Which Monitoring Occurred

- Second, these data indicate one factor as to why the energy use that ADM estimated for units monitored in unconditioned space would be lower than for equivalent units measured in conditioned space. Except for July and August, the average ambient temperature was higher in conditioned spaces than in unconditioned spaces. (Other analysis also shows that the units monitored in unconditioned space were somewhat smaller than units monitored in conditioned space.)

In estimating annual energy use for refrigerators and freezers from data collected over a short period of monitoring, ADM uses a method of extrapolation that takes into account the differences in temperatures and hence energy use across different months of the year. That is, lower temperatures during, say, January, than during, say, July, means that energy use in January is generally less than in July. Simple extrapolation of January energy use would therefore understate annual energy use, while simple extrapolation of July energy use would overstate annual energy use. Based on analysis of full year monitoring data for a sample of refrigerators and freezers, ADM has developed monthly weights for extrapolating energy use estimated from monitoring during a particular month to represent full year energy use. (Essentially, thereis a higher weight for January than for July, with the magnitude of the weights derived from the analysis of the full year monitored data.)

Turning to the HMG study, they imputed at-manufacture energy use values to recycled units identified in the tracking system, as was done in this study. However, the method used in the HMG study differed from the method used here in two major respects.

- First, HMG imputed energy use values for just over half of the units in the tracking system by matching the estimated vintage with the average of energy data in the AHAM database found for units within the corresponding manufactured decade. By contrast, this study used imputations based on the same year.
- Second, HMG applied a degradation function to at-manufacture energy use values to estimate at-death energy use, whereas this study used the ratio of metered at-death energy use to at-manufacture energy use to adjust the at-manufacture energy use values. HMG used a degradation rate of 1.37%.[1] At an average age of 16 years for recycled units in the 2006 program, this implies at-death energy use values that are on average about 21.9% higher than at-manufacture energy use values. By comparison, this study showed an overall increase of at-death over at-manufacture energy use of about 14.1% for refrigerators (from data in Table E-1) and of about 16.4% for freezers (from data in Table E-2).

Because the ratios for at-death to at-manufacture energy use are not dramatically dissimilar between this study and the HMG study, the difference in estimates of at-death energy use appear

[1] Miller, J. D. and Pratt, R.G., Pacific Northwest National Laboratory, *Estimates of Refrigerator Loads in Public Housing Based on Metered Consumption Data,* Report prepared for the U. S. Department of Energy, October 1998.

to arise primarily from differences in imputing at-manufacture energy use. Because there has been a trend over time toward reducing the energy use of refrigerators and freezers, the HMG method of applying a decade-long average of energy use to a particular unit would either overstate or understate its energy use, depending on whether the unit was manufactured later or earlier in the decade. Moreover, although detailed data for the HGM study are not available, it is likely that the distribution of recycled units across vintages was different between the earlier program years evaluated by HMG and the 2006 program year evaluated in this study. The earlier SB5X program evaluated by HMG would have been on average more likely to gather in older vintage units that had higher energy use.