

A Profile of a Refrigerator Recycling Program

Cynthia M. Austin, Heschong Mahone Group
Cathy Chappell, Heschong Mahone Group
Ed Hamzawi, Sacramento Municipal Utility District
Warren Lindeleaf, Sacramento Municipal Utility District
Roger L. Wright, RLW Analytics

ABSTRACT

In response to California's electricity supply and demand crisis of 2001, the Sacramento Municipal Utility District (SMUD) implemented a portfolio of programs funded by the California Legislature, through Senate Bill 5X. As part of its SB5X portfolio, SMUD implemented a Refrigerator Recycling program through a third-party contractor. The program picked up old inefficient appliances and shipped them to a recycling center, permanently removing them from further use. This program was similar to programs being operated by other California utilities. SMUD's program goal was to collect 6,000 refrigerators and freezers by December 31, 2002. SMUD's initial savings targets were to reduce summer capacity by 1.5 MW and reduce energy consumption by 10.2 GWh/yr, making it SMUD's largest SB5X program in terms of energy savings.

An evaluation was undertaken to determine the characteristics of the recycled units. Also, we estimated the gross energy savings and demand reduction achieved by the program.

Introduction

The Refrigerator Recycling program offered rebates to consumers for the pick-up of their old, inefficient (yet operable) refrigerator(s) or freezer(s). The old appliances were sent to a recycling center and permanently removed from further use. The program was advertised and customers who wish to participate called to arrange a pick-up appointment. SMUD had experience from two previous programs on refrigerator recycling. In the early 1990s, they managed a refrigerator pick-up program in conjunction with a rebate program for new refrigerators. In the late 1990s, they administered a refrigerator pick-up program similar to the current program.

Recycling included the recovery and reclamation of PCBs and other hazardous or regulated materials and all refrigerants (CFCs, HCFCs). Mercury switches and the oil from all compressors were removed during the recycling process. Upon the disposal of the regulated materials and substances, the remaining metals were transported to ferrous and non-ferrous recycling facilities.

The goal of the program was to collect 6,000 refrigerators and freezers with expected savings from 1.5 MW and 10.2 million kWh. The program was rolled out on September 7, 2001 and completed in April 6, 2002.

The M&V effort was to assess and compare gross and net energy savings to determine the effectiveness of the program. The M&V approach consisted of analyzing energy savings for all units, and analyzing "decision-maker" data for a sample of units. The implementation contractor collected the decision-maker data for all customers by

administering a brief questionnaire. The questionnaire was intentionally designed to be short and simple. A follow-up telephone survey was used to collect additional specific decision-maker questions.

Analysis

Appliance Characteristics

The entire program population was used for most of the analysis. The pick-up questionnaire data, seen in Appendix A, collected extensive information on the appliance. For the subset of customers who recycled their primary unit, a follow-up telephone survey, seen in Appendix B, was administered to a sample of 82 participants. The survey data were used for the net energy analysis by determining what would have happened to the appliances had they not been surrendered under this program.

Gross Analysis

Gross savings were assumed to be the total energy consumption of all units that were recycled. The gross energy consumption and demand for all units were obtained from the AHAM (Association of Home Appliance Manufacturers) database. The AHAM historical database of refrigerator/freezers contained units from 1975 to current models.

We used data from the California Statewide Lighting and Appliance Saturation Study to define the baseline. For that study, size and efficiency data were collected on household appliances, including refrigerators/freezers. The average annual unit energy consumption (UEC) data for refrigerator/freezers were obtained from the model number matches to manufacturer data. A sample of 797 UECs were obtained for the statewide summary, and 197 were obtained in SMUD territory.

To assign the appropriate consumption and demand values to the recycled units, we followed a matching protocol utilizing the AHAM database and the California Statewide Lighting and Appliance Saturation Study. Energy consumption values were generated using one of the following options:

- Finding the closest corresponding unit in the AHAM database,
- Averaging the energy data for the closest corresponding units in the AHAM database,
- Matching the contractor's estimate vintage with the average of energy data in the AHAM database found for units within the corresponding manufactured decade, or
- Using a default estimate from the California Statewide Lighting and Appliance Saturation Study database, based on unit type and size.

The AHAM values represented energy consumption for the unit when it was new. After each unit's energy consumption was determined, a degradation factor was added to the energy consumption value based on manufactured year. To adjust for energy consumption of the "aged" unit, we developed degradation factors based on the following equation:

$$E(t) = L(1 + 0.0137t)$$

Where:

$E(t)$ = UEC adjusted for age

L = DOE-test label ratings (kWh/yr) or AHAM UEC

t = age of refrigerator in years

This equation¹ represented an assumed degradation of 1.37% per year. The adjusted energy consumption estimates were used to estimate energy savings.

Net Analysis

The net to gross ratio currently being used for this program was 0.80. This net to gross ratio was consistent with other California statewide Refrigerator Recycling programs. As part of the ongoing evaluation of this program, we were exploring a methodology for calculating net savings based on customer self-reported data.

We planned to define the net to gross ratio as the probability that the unit was either (a) in service as a secondary appliance and was not replaced after it was recycled, or (b) it was a primary unit and would have been put in use as a secondary appliance had it not been recycled. Using this assumption we were preparing to calculate a net to gross ratio based on the customer's responses to the decision-maker survey.

We were determining net savings of the program by estimating whether or not the unit would have remained in use if it had not been picked up. For example if the customer reported that the unit was a secondary unit and would not be replaced after it was picked up, then we considered the net savings to be the gross energy use of the unit. If, on the other hand, the customer reported that the unit was a secondary unit and would be replaced after it was picked up, then we considered the net savings to be zero.

If the unit was a primary unit, we used information from a follow-up telephone survey to estimate the net to gross ratio. The survey was administered to a sample of 82 program participants and asked what the customer would have done with the primary refrigerator or freezer if SMUD's recycle program was not available..

Results

Appliance Characteristics

The pick-up questionnaire provided details on the types of units being collected. From the model number, we used corresponding data from the AHAM database to determine the manufactured year. Figure 1 displays the percentage of units recycled based on the decade the unit was manufactured. The majority of recycled units in the program are manufactured before 1990.

¹ See Table 2.1, Pratt and Miller. 1998.

Figure 1. Manufactured Decade as Percent of Total

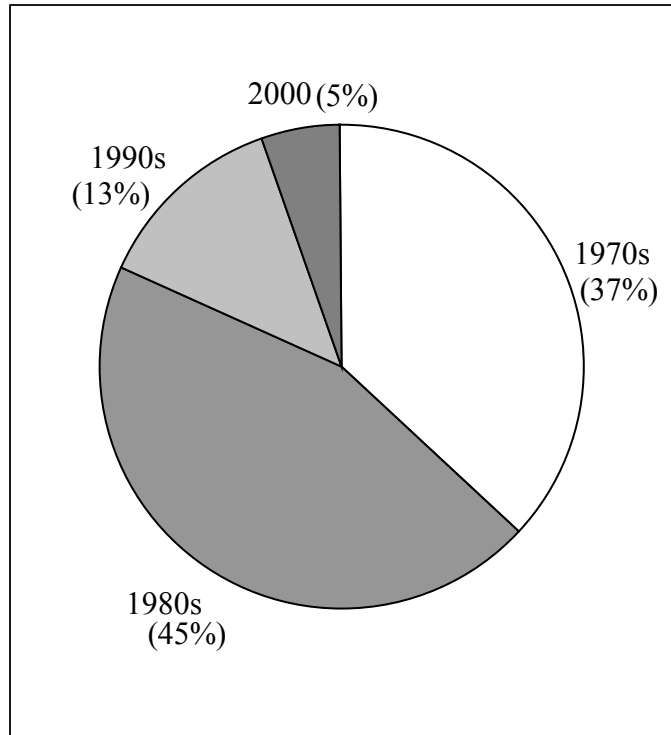


Table 1 presented the number of units per use (secondary, primary, not in use) in household. The majority of customers were recycling their primary unit. Of the 2947 secondary units, Table 2 provided the percentage the seasonal use. Almost all of the secondary units were in use all months of the year.

Table 1. Number of Units by Type of Use in Household

Unit Use	Number of Units	% of Total
Primary	3982	57%
Secondary	2947	42%
Not in Use	81	1%
Unknown	26	0.4%

Table 2. Percent of Secondary Units per Season Used

Seasons of Secondary Unit Use	% of Total
All months	97.3%
Summer	2.4%
Spring/Fall	0.2%
Winter	0.2%

In Table 3, we found that the majority of the recycled units will be replaced by another appliance. Of the replacement units, most were of a later vintage (Table 4) and larger (Table 5) than the recycled unit.

Table 3. Number of Units Replaced

Unit Replaced	Number of Units	% of Total
No	2073	29%
Yes	4887	69%
Unknown	43	1%

Table 4. Percent of Replacement Units by Type

Type of Replacement Unit	% of Total
New	94%
Used	6%

Table 5. Percent of Replacement Units by Size Comparison to Recycled Unit

Size of Replacement Unit	% of Total
Larger	44.9%
Same	37.5%
Smaller	14.7%
Unknown	2.9%

In Table 6, the results of the first question in the phone survey were given. Most customers would have given or thrown away their appliance if not for the SMUD recycle program.

Table 6. Response Options to Phone Survey

Response Options	# Responses	% of Total
Thrown it away, or otherwise disposed of	34	41%
Given it away for someone else to use	25	30%
Sold it through a local advertisement	13	16%
Kept it as a secondary refrigerator	6	7%
Had it picked up by the appliance dealer when new appliance was delivered	4	5%
Sold it to an appliance dealer	0	0%
Total	82	100%

Gross Results

The gross demand and energy savings, based on the protocol described above were presented in this section. The following tables present summaries of quantity, demand reduction (for two definitions of “peak period”), total energy savings, and average unit energy savings. The contractor had picked up 7,036 units to date, of which 5,615 are refrigerators and 1,421 are freezers. Based on the type and age of the unit and the reported use, we estimated that these units had an annual use of 10,847,041 kWh. We considered this to be the gross savings of the program.

Table 7 presented results by unit type (refrigerator or freezer) as well as total for the program. The number of refrigerators recycled were greater than the number of freezers. The average UEC (unit energy consumption) values were similar between the two unit types. As can be seen, the program met its savings goal of 1.5 MW and 10.2 million kWh.

Table 8 expanded on the results found in Table 7 by offering data according to size categories. The average UEC among the various size categories remained closely similar,

with a small amount of variation, probably due to the interaction of appliance vintage. For refrigerators, the most common size was found between 16.5 to 20.49 cubic feet. For freezers, the most common size category was 14.5 to 16.49 cubic feet.

Table 9 was the savings broken down by reference types. The following abbreviations were used to describe the refrigeration units and defrost types:

- Refrigerators
 - BF = Bottom Mounted Freezer (All Automatic)
 - SD = Refrigerator with a Single Door (All Manual Defrost)
 - SI = Side by Side with Ice Dispense (All Automatic)
 - SS = Side by Side without Ice Dispenser (All Automatic)
 - TF = Top Mounted Freezer without Ice Dispenser (Partial and Automatic Defrost)
 - TI = Top Mounted Freezer with Ice Dispenser (All Automatic)

- Freezers
 - CFA = Chest Freezer (All Automatic)
 - CFM = Chest Freezer (All Manual Defrost)
 - UFA = Upright Freezer (All Automatic)
 - UFM = Upright Freezer (All Manual Defrost)

The majority of recycled units were TF (52%). TF units had the lowest average UEC among refrigerators and were comparable to the average UEC of freezers. There was a 20% variation of the average UEC within all refrigeration units.

Table 7. Refrigerator Recycling Program Summary

Unit Type	Number of Units	1-9pm kW	2-6 pm kW	kWh/year	Average UEC
Refrigerator	5,615	1,192	1,189	8,714,176	1,552
Freezer	1,421	315	315	2,132,865	1,501
Total	7,036	1,507	1,504	10,847,041	1542

Table 8. Savings Details by Size Categories

Unit Type	Size Category	Number of Units	1-9pm kW	2-6 pm kW	kWh/year	Average UEC
Refrigerator	12.5 or less	463	107.00	106.77	782,388	1,690
	12.5 to 14.49	589	120.64	120.38	882,121	1,498
	14.5 to 16.49	706	153.68	153.36	1,123,757	1,592
	16.5 to 18.49	1,271	255.64	255.10	1,869,271	1,471
	18.5 to 20.49	1,218	244.10	243.58	1,784,918	1,465
	20.5 to 22.49	788	176.06	175.68	1,287,365	1,634
	22.5 to 24.49	303	74.37	74.21	543,771	1,795
	24.5 to 26.49	183	40.63	40.55	297,121	1,624
	26.5 or more	27	6.47	6.46	47,336	1,753
	Unknown	67	13.15	13.12	96,129	1,435
	Total	5,615	1,192	1,189	8,714,177	1,552
Freezer	12.5 or less	183	38.66	38.66	261,850	1,431
	12.5 to 14.49	153	32.97	32.97	223,323	1,460
	14.5 to 16.49	428	94.57	94.57	640,519	1,497
	16.5 to 18.49	156	36.09	36.09	244,456	1,567
	18.5 to 20.49	225	51.18	51.18	346,618	1,541
	20.5 to 22.49	155	34.12	34.12	231,093	1,491
	22.5 to 24.49	50	11.99	11.99	81,189	1,624
	24.5 to 26.49	28	6.34	6.34	42,970	1,535
	26.5 or more	17	3.84	3.84	26,035	1,531
	Unknown	26	5.14	5.14	34,811	1,339
	Total	1,421	315	315	2,132,864	1,501

Table 9. Savings Details by Reference Type

Unit Type	Reference Type	Number of Units	1-9pm kW	2-6 pm kW	kWh/year	Average UEC
Refrigerator	BF	137	32	32	232,691	1,771
	SD	321	78	78	568,130	1,745
	SI	539	129	129	946,019	1,740
	SS	624	152	152	1,111,236	1,846
	TF	3,673	736	735	5,385,045	1,348
	TI	277	56	56	411,930	1,410
	Unknown	44	8	8	59,124	1,267
	Total	5,615	1,192	1,189	8,714,175	1,552
Freezer	CFA	86	18	18	122,711	1,494
	CFM	150	34	34	231,112	1,603
	UFA	348	79	79	537,055	1,459
	UFM	837	183	1,552	1,241,988	1,500
	Total	1,421	315	1,683	2,132,866	1,501

Net Results

Table 10 displayed the gross and net annual energy savings of the program for each of the two appliance categories. Program results were calculated using a net to gross ratio of 0.80. Combined across both appliances, the program reduced annual consumption by 8,677,633 kWh.

Table 10. Total Program Annual Energy Savings

Unit Type	Number of Units	Gross kWh	Net kWh
Refrigerator	5,615	8,714,176	6,971,341
Freezer	1,421	2,132,865	1,706,292
Total	7,036	10,847,041	8,677,633

Summary

An evaluation of SMUD’s Refrigerator Recycling program was underway through a combination of “pick-up” questionnaires and telephone surveys, to determine the appliance characteristics of the recycled appliances. The gross energy savings were estimated through appliance comparison to historical data. The information gathered from the questionnaire and telephone surveys were used in the net analysis. Net energy savings was determined for the program to provide a net to gross ratio on the energy savings and demand reduction.

References

- R.G. Pratt and J.D. Miller. 1998. *The New York Power Authority's Energy Efficient Refrigerator Program for the New York City Housing Authority - 1997 Savings Evaluation*. PNNL-11990. Seattle, WA: Pacific Northwest National Laboratory.
- RLW Analytics, Inc. 2000. *San Diego Gas and Electric, Statewide Residential Lighting and Appliance Saturation Study*. San Diego, CA: San Diego Gas & Electric Company.
- RLW Analytics, Inc. 2000. *SMUD Follow-on to the Statewide Residential Lighting and Appliance Study*. Sacramento, CA: Sacramento Municipal Utility District.

Appendix A – Pick-Up Questionnaire

- Q1. What is the model number? _____
- Q2. What is the make of the appliance? _____
- Q3. What is the capacity of the unit? (size in cubic feet) _____
- Q4. Is there an icemaker?
- Yes
 - No
- Q5. What is the estimate vintage? (age) _____
- Q6. What is the defrost type?
- Automatic
 - Manual
- Q7. What is the reference type?
- UFA
 - UFM
 - CFA
 - CFM

- BF
- SD
- SI
- SS
- TF
- TI

Q8. Where was this unit located prior to recycling?

- Garage
- Kitchen
- Outside
- Other

Q8. Was this unit being used as a primary or secondary refrigerator/freezer prior to recycling?

- Primary
- Secondary
- Not in use

Q10. If secondary, during what seasons was the unit typically used?

- Summer
- Winter
- Spring/Fall
- All months

Q11. Are you planning to replace this unit with another one?

- Yes
- No

Q12. If yes, is the replacement unit new or used?

- New
- Used

Q13. If yes, is the replacement unit larger or smaller than this one?

- Larger
- Smaller
- The Same

Appendix B – Follow-up Survey

Introduction – Our records show that you recently had a (refrigerator / freezer) picked up by SMUD's appliance recycle program. (Confirm)

Do you have a minute for 3-4 questions that will help us evaluate the energy savings due to the program?

Q1. What would you have done with if your (refrigerator / freezer) SMUD's recycle program were not available to you?

- Had it picked up by the appliance dealer when they delivered the new appliance
- Kept it as a secondary refrigerator
- Sold it to an appliance dealer

- Sold it through a local advertisement
- Given it away for someone else to use (Go to Q2)

Q2. If you gave it away, where would it have been located?

- In the Sacramento area
- Outside of the Sacramento area
- Don't know

Q3. Were you satisfied with the appliance recycle program?

- Yes _____
- No _____

Q4. Do you have any other comments about the program?
