2003 EM&V RARP STUDY: VERIFICATION, DEGRADATION & MARKET POTENTIAL ANALYSIS

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1 INTRODUCTION

1.1 OVERVIEW

This document represents the final report for the monitoring and evaluation of the 2003 Residential Appliance Recycling Program, sponsored by Southern California Edison, Pacific Gas and Electric Company, and San Diego Gas and Electric Company.

This introductory section provides a brief overview of the program background, discusses the evaluation objectives, and presents the organization of the remainder of the report.

1.2 PROGRAM BACKGROUND

The Residential Appliance Recycling Program (RARP) is designed to achieve energy savings by removing older, inefficient refrigerators and freezers from households and keeping them from entering the secondary market. A rebate of either $35 or a 5-pack of CFLs is offered to customers in exchange for a working refrigerator or freezer.

1.3 EVALUATION OBJECTIVES AND APPROACH

The monitoring and evaluation of the 2003 RARP included three activities discussed below.

1.3.1 Verification

In this task we conducted two activities to verify program tracking data base information. First, we obtained the program tracking databases from the two program vendors and recalculated:

- The number participants,
- Claimed energy- and demand-savings, and
- The percentage of program activity attributable to hard-to-reach customers.

Second, we conducted a survey of a random sample of participants to verify participation in the program.

1.3.2 Program Market Potential

The broad objective of this task was to provide data to support the development of future years' program goals for the number of units available for recycling. We used earlier evaluation data, the recently completed statewide Residential Appliance and Saturation Study and program tracking data to estimate the program potential for recycling refrigerators and freezers.

1.3.3 Degradation Analysis

The objective of the degradation analysis was to determine the extent to which unit energy consumption (UEC) of refrigerators increase as the unit ages. We used both manufacturer and metering data to model the change in refrigerator energy consumption over time.

1.4 LAYOUT OF THE REPORT

The results of these monitoring and evaluation activities are reported in the following three sections and one appendix.

Section 2: Verification
Section 3: Market Potential
Section 4: Degradation Analysis
Appendix A: Verification survey

2 VERIFICATION

2.1 INTRODUCTION

In this section we provide the results of two activities to verify reported participation in the 2003 Residential Appliance Recycling Program (RARP). First, we conducted a tracking database verification in which we compared utility filings to tracking data provided by the recycling subcontractors. Second, we conducted a participant survey to verify that a unit was recycled, to confirm other aspects of eligibility, and to identify any problems with the program.

2.2 TRACKING DATABASE VERIFICATION

2.2.1 KEMA findings

The two recycling subcontractors, ARCA and JACO, provided KEMA with program tracking data. ARCA recycles for all three utilities; JACO recycled 47 percent of the units in the Pacific Gas and Electric (PG&E) territory in 2003. Table 2–1 provides the results from the first verification task.

Table 2-1
Units by Utility, Filed versus Verified in Database

Row	Unit Description	PG&E*		SDG&E		SCE	
		Refrigerators	Freezers	Refrigerators	Freezers	Refrigerators	Freezers
1	Reported Units (Filed May 2004)	10,358	1,972	4,681	614	31,051	3,092
2	Units in Tracking Database	10,352	1,973	4,681	614	30,783	3,072
3	Less than 14 ft^3, post 4/18/03	108	47	22	9	121	16
4	Units greater than two per household	40	8	37	2	122	10
5	**Total Verified**	**10,204**	**1,918**	**4,622**	**603**	**30,540**	**3,046**
6	% Difference	-1.5%	-2.8%	-1.3%	-1.8%	-1.7%	-1.5%

Table 2–1 compares the number of units reported by each utility in fourth-quarter filings with the California Public Utility Commission (CPUC) to the number of units we verified in the program tracking databases. The utilities' claimed number of units is reported in the first row of Table 2–1. The number of units in the tracking database provided by the recycling subcontractors is reported in the second row.

KEMA identified two eligibility requirements that were not met in all cases: unit size and a limit on units per household. As of April 18, 2003, no units less than 14 cubic feet were to be accepted into the program. Units less than 14 cubic feet and for which the request for pickup was made after April 18, 2003, are considered ineligible and counted as so in Table 2–1, Row 3.

Since the initial JACO tracking data did not include unit size,[1] we could not directly determine the number of ineligible units collected by JACO. We estimated the percentage of units less than 14 cubic feet and picked up by JACO based on ARCA's performance in PG&E's service territory. This estimate assumes JACO and ARCA responded similarly to the new size requirements.

The program limits to two the number of units that can be recycled "per customer service location per program year." KEMA confirmed with Southern California Edison (SCE) program staff that the account number in the ARCA tracking database identifies a customer service location. Therefore, we used this variable to determine the number of units per location. The JACO data did not contain an account number, so for JACO, the address variable was used as a proxy for the account number. Given the difficulty of electronically matching an address field, this likely resulted in a slight undercounting of multiple units per service location.

Where a location recycled more than two units, the additional units were considered ineligible and are reported in Row 4 of Table 2–1. The two units per service location that may be recycled can be refrigerators, freezers, or one of each. To assign excess units to the refrigerator or freezer column, we did the following:

- If units were recycled on different dates, the units recycled on the later date were flagged as additional.
- Where more than two units were recycled and both types of units were present, units that appeared later in the database were counted as ineligible.

The total number of units in the tracking database minus ineligible units is the "Total Verified" units for each utility (Row 5). In Row 6, we report the percentage difference between Total Verified Units and Reported Units. Verified units are within 3 percent of the units claimed for all three utilities.

2.2.2 Response to Findings

The utilities and ARCA reviewed the initial findings (dated September 23, 2004) and provided responses. In this subsection, we provide those responses.

The slight difference in Table 2–1 between reported units (Row 1) and database units (Row 2) may be solely due to a difference in the definition of program year. KEMA defined the 2003 program year as including all units for which the request for a pick-up was made in calendar year

[1] JACO provided data subsequent to this analysis that included unit size. The data confirmed that the JACO percentages of ineligible units are roughly the same as those for ARCA. We used the ARCA-based estimates because size was missing for 65 cases in the JACO database and we could not get an exact count.

2003. This included some units that were picked-up in 2004, but did not include requests for units made in 2002, but completed in 2003. In their response ARCA reported using the pick-up date as the determination of the program year for the 2003 program. They started billing and reporting based on the request date in 2004.

Table 2–2 shows ARCA's response to the findings that some units less than 14 cubic feet were recycled by the program for requests made after April 18, 2003. In some cases they found that their database was in error compared to the paper copies of the transaction. In other words, the units were mistakenly listed in the database as less than 14 cubic feet. In other cases they confirmed that the unit was less than 14 cubic feet.

Table 2-2
Response to Findings of Units Less than 14 ft^3

	Number of Units		
	PG&E	**SDG&E**	**SCE**
KEMA – less than 14 ft^3	155	31	137
ARCA database error on size (i.e., unit is 14 ft^3 or greater)	29	7	65
ARCA confirmed less than 14 ft^3	53	24	72

Table 2–3 shows ARCA's response to the findings that more than two units were picked up at a single location in the program year. ARCA reported that 32 of the units identified as multiples in SCE's service territory were picked up from mobile home parks in which a master meter was used for multiple households. SCE was able to confirm that 45 "extra" units were from mobile home parks, reducing the number of extra units in SCE's service territory to 87 units.

Table 2-3
Response to Findings of More Than Two Units from a Location

	Number of Units		
	PG&E	**SDG&E**	**SCE**
KEMA – units in excess of two at a location	48	39	132
ARCA – excess units from mobile home park	0	2	32[a]
ARCA confirmed more than 2 at a location	48	37	100

[a] SCE checked the account numbers and confirmed that 26 locations were mobile home parks, accounting for 45 extra units.

KEMA used account number reported in the ARCA database tracking system to identify multiple units. During the review period for these findings we discovered that this field contained the utility account number only for SCE customers. For the other two utilities, the telephone number is entered into the account number field. Therefore, KEMA's use of the

account number field to identify duplicate cases may not result in a fully accurate accounting of multiple units for PG&E and SDG&E. We must also point out that in this analysis we inadvertently used three approaches to identify multiple accounts:

1. Utility account numbers (SCE),
2. Telephone numbers (SDG&E, PG&E pick-ups by ARCA), and
3. Address (PG&E pick-ups by JACO).

Each approach has limitations in accuracy. Even the use of account numbers proved to be unreliable in the case of master metered units. We believe that all three approaches provide a reasonable estimate of the magnitude of multiple pick-ups, but none provide an exact count.

The verification findings and subsequent response indicate that the program is operating within the established rules. Modifications to the tracking database would improve the accuracy of the reporting and modifications to intake and field operations would improve compliance with program rules.

2.2.3 Verified Savings

Utility savings estimates with respect to kW and net kWh are relatively consistent with the number of units they claim and the formulas they report using for calculating savings. There are, however, differences in the factors used to calculate these savings. Table 2–4 shows the factors used by each utility in their final filings.

Table 2-4
Factors Used to Determine Energy and Demand Savings

	PG&E		SDG&E		SCE	
	Refrigerators	**Freezers**	**Refrigerators**	**Freezers**	**Refrigerators**	**Freezers**
Usage (kWh)	2,148	2,058	2,148	2,058	2,148	2,058
Load (kW)	0.33	0.31	0.325	0.3125	0.33	0.31
Net-to-Gross	0.53	0.57	0.8	0.8	0.53	0.57

All three utilities use the same usage and load factors.[2] The SDG&E factor has an additional decimal place that results in minor differences.

SCE and PG&E used a net-to-gross ratio of 0.53 for refrigerators and 0.57 for freezers, the ratio reported in the 1998 impact evaluation report and approved by the CPUC. SDG&E mistakenly

[2] These factors are included in the "Impact Evaluation of the Spare Refrigerator Recycling Program," CEC Study #537, Final Report" (1998).

used a net-to-gross ratio of 0.8 for both refrigerators and freezers in the final filings with the commission. This is inconsistent with the final program plan approved by the Commission.[3]

In Table 2–5 below we report the program goals, reported, and verified activities. The program goals are from the plan approved by the CPUC. The reported activity is from the fourth-quarter final reports filed with the CPUC in May 2004. The verified activity is based on the total units verified by KEMA using the approved usage, load, and net-to-gross factors approved by the CPUC. We also provide net kWh savings using ex-post estimates resulting from the 2002 program evaluation.

Both SCE and SDG&E came within 1 percent of meeting the program goal for savings in 2003. PG&E exceeded the program savings goal by 8 percent. All of the utilities exceeded the goal for the number of recycled refrigerators, but none obtained the goal for recycling freezers.

Table 2-5
Factors Used to Determine Energy and Demand Savings

	Number of Units		Net kWh Savings	
	Refrigerator	Freezers	Planning Estimates	2002 ex-post estimates[a]
Southern California Edison				
goal	26,888	6,722	38,618,794	X
reported	31,051	3,092	38,976,802	X
verified	30,540	3,046	38,341,098	26,345,053
verified % of goal	114%	45%	99%	
San Diego Gas and Electric				
goal	4,180	1,045	6,044,371	X
reported[b]	4,681	614	9,052,602	X
verified	4,622	603	5,969,225	4,144,946
verified % of goal	111%	58%	99%	
Pacific Gas & Electric				
goal	8,954	2,238	12,880,360	X
reported	10,358	1,972	14,105,236	X
verified	10,204	1,918	13,866,214	9,802,526
verified % of goal	114%	86%	108%	

[a] Measurement and Evaluation Study of 2002 Statewide Residential Appliance Recycling Program prepared by KEMA-XENERGY, February 13, 2004.
[b] Fourth-quarter/year-end filing with .8 net-to-gross ratio.

[3] SDG&E indicated that they plan to file an errata with the commission.

2.2.4 Hard-to-Reach Customers

The final database task involved verifying the percentage of hard-to-reach (HTR) customers in the program, as reported by the utilities. HTR is determined by the customer's zip code. The utilities establish targets for HTR customers in the program filings (in terms of percentage of participants) and report the percentage served in their fourth-quarter/annual reports. KEMA used ARCA's list of HTR zip codes provided to them by SCE[4] to verify the reported HTR percentages. (HTR customer estimates were calculated based on the HTR customers included in the tracking database. In other words, we did not calculate it based on the verified customer base.) As Table 2–6 indicates, PG&E and SCE's verified percentages were within 1 percent of reported percentages. SDG&E verified percentages were 5 percent lower than reported.

Table 2-6
Reported versus Calculated Hard-to-Reach Customers

	PG&E	SDG&E	SCE
Target Filed for 2003	37.0%	53.0%	57.0%
Reported Units (Filed – May 2004)	42.0%	56.0%	56.4%
Percent in Tracking Database	41.6%	53.0%	56.0%
Percent Difference from Reported	-1.0%	-5.4%	-0.8%

2.3 PARTICIPANT SURVEY VERIFICATION

In addition to verifying the numbers filed with the CPUC, we conducted a short telephone survey[5] with a sample of 2003 RARP participants to verify that the participants listed in the subcontractor databases had a working unit picked up by the utility recycler and that they had received an incentive.

Participants randomly selected from the ARCA and JACO databases and interviewed recall participating in the RARP program. A great majority recall receiving a rebate, report recycling a working unit, and are satisfied with the program. Below we report these findings in more detail.

The sample was selected from participants that requested that a unit be picked up in calendar year 2003 (although some of the units were collected in early 2004). We selected a sample of 450 units each from ARCA and JACO to obtain 150 completed surveys from each, or 300 total responses. Response rates appear in Table 2–7. JACO households were over-represented in the sample since JACO was new to the program and verification surveys had not been conducted on households served by JACO. We did not find any significant differences between ARCA and JACO respondents, so we report the findings in total.[6]

[4] ARCA calculated the HTR percentage for the customers it served.
[5] The survey is attached in Appendix A.
[6] Responses are weighted to reflect the proportion of ARCA and JACO households in the participant population.

Table 2-7
Participant Survey Response Rate

	ARCA		JACO	
Complete	150	33%	150	35%
Refused	42	9%	31	7%
Other – Out	67	15%	36	8%
In Progress	190	42%	214	50%

All (100 percent) of the respondents recalled having a unit (refrigerator or freezer) picked up in 2003 or early 2004, and 98.5 percent reported that the unit that was picked up was in working condition.

When asked "Which of the following best describes what you did with the <unit>?"

- 81 percent chose "A utility recycling program picked it up,"
- 17 percent chose "Another recycling program picked it up," and
- 2 percent couldn't remember or did not respond.

All of those who chose "another recycling program" responded affirmatively when asked, "Is it possible that a recycling company working on behalf of <utility> came and picked up the <unit> in 2003?"

When asked how satisfied or dissatisfied they were with the recycling process, almost 99 percent of the respondents were either satisfied or very satisfied. Results appear in Table 2–8.

Table 2-8
Satisfaction with the Recycling Process

	Percentage of Respondents
Very dissatisfied	0.7%
Dissatisfied	0.6%
Satisfied	31.5%
Very satisfied	67.1%
Total	**100.0%**

For those who responded that they were dissatisfied, we asked why. Respondents reported either difficulty scheduling the pickup or said that the pickup was late. One respondent each said that the driver was "Not professional," "Didn't send the right amount of money," or "Didn't speak English."

Respondents were asked if they had any additional comments regarding the program. The majority of those who commented made positive remarks about the program. Several respondents did not like that the program seemed to start and stop and thought it should be year-round.

2.4 SUMMARY OF VERIFICATION FINDINGS

Overall, the 2003 Residential Appliance Recycling Program was operated as planned and achieved its goals for energy savings. The great majority of the units picked up by the program are eligible units, participants are satisfied with the program, and there is no evidence of fraud or intentional misreporting of the program activities.

In the course of conducting the evaluation we did note some minor issues with program implementation and reporting that should be addressed in future years. These are outlined below.

- An inconsistent definition of program year.
- Unclear definition of what is contained in the tracking database. Phone numbers should not be identified as "account numbers."
- Incomplete information in the JACO database.
- Inability to identify in tracking database master-metered units where more than two units may be recycled.
- Filing savings estimates are inconsistent with the CPUC approved program plan.
- Inability to correct erroneous data in tracking database.
- Reporting ineligible units in reports filed to the commission.

3 MARKET POTENTIAL

The purpose of this section is to report the results of our analysis to determine the market potential for the Residential Appliance Recycling Program. In this instance market potential is an estimate of the units available to the program. Results are provided in Table 3–1 for each utility, as well as a total across the three utilities. We calculated market potential for all units, regardless of manufacture date, and for units estimated to be manufactured prior to 1990. In both cases, units are limited to those 14 cubic feet and larger. In an additional table (Table 3–2), we provide a more detailed age breakdown of the various types of units.

Immediately following Table 3–1 we describe the data sources, adjustments to source data, and any assumptions related to the analysis. This is followed by a line-by-line description of Table 3–1.

Table 3-1
RARP Market Potential for Recycling Refrigerators and Freezers (14 cubic feet or larger)

	PG&E	SDG&E	SCE	Total
All Units				
Refrigerators transferred - 14 cubic feet or larger	153,525	48,754	149,287	351,566
Secondary refrigerators	697,118	177,581	637,487	1,512,186
Transferred freezers1	NA	NA	NA	24,772
Stand-alone freezers	817,187	185,053	588,293	1,590,533
Units Manufactured before 1990				
Refrigerators transferred - 14 cubic feet or larger	70,346	19,793	62,303	152,442
Primary Refrigerators	639,597	142,519	623,344	1,405,460
Secondary refrigerators	175,579	33,914	141,678	351,171
Transferred freezers1	NA	NA	NA	18,946
Stand-alone freezers	271,578	37,861	208,288	517,727

3.1 DATA SOURCES AND ADJUSTMENTS

The primary source for data was the 2002 California Statewide Residential Appliance Saturation Survey (RASS). The RASS data included, for each utility:

- Refrigerators and freezers discarded in the previous 12 months, including size and age.
- Number of working refrigerators and freezers in the home, including size and age.

We used several other data sources to provide information necessary to complete this analysis.

2002 Discarder Survey. A survey of households who had discarded a refrigerator in 2002 in SCE's service territory was used to estimate the percentage of discarded refrigerators that were not working when they were discarded. This estimate (22 percent) is based on 151 respondents.

The 2002 RARP evaluation prepared by KEMA-XENERGY provided estimates of the percentage of discarded working refrigerators that are transferred (sold, given away, picked up by dealer) versus destroyed (by being sent to the landfill or by being recycled).

2002 RARP participant data were used to make adjustments to the size and age data from the RASS survey. The smallest size category in the RASS survey was "under 13 cubic feet." The RARP program is limited to units 14 cubic feet or larger. We used the 2002 participant tracking data to determine the ratio of units less than 14 cubic feet that are 13 cubic feet. We used these estimates to rescale the RASS size categories and remove all units under 14 cubic feet.

The RASS equipment age categories included a category of units 11-20 years old. For this analysis we were interested in units that were manufactured before 1990. In 2004, units manufactured before 1990 would be 15 or more years old. We used the distribution of 2002 participant refrigerators between 11 and 20 years to determine the proportion of those 11-14 years old and the proportion 15-20 years. These proportions were then applied to the RASS data to split the larger group into two sub-groups and estimate the percentage of units manufactured before 1990.

There are implied relationships in our adjustments to age and size that we make explicit below.

1. That the age distribution of equipment remains relatively constant over time. For example, the percentage of units that is 15 years or older is the same in 2004 as it was in 2002 because of turnover of units.
2. That the size distribution of 2002 participant units less than 14 cubic feet is a reasonable estimate of the size distribution of all units less than 14 cubic feet.
3. That the age distribution of 2002 participant units between 11 and 20 years is a reasonable estimate of the size distribution of all units between 11 and 20 years. (We might expect participant units to be a bit older than all units.)

3.2 TRANSFERRED REFRIGERATORS

Transferred units are units that are in working condition but are transferred to another user as a sale, a gift, or through an appliance dealer. These are units that are being discarded without program influence—"natural discards"—and are adjusted to include non-working units and units less than 14 cubic feet.

The number of transferred units was based on the 2002 RASS. In the RASS respondents were asked if they had discarded a refrigerator in the past 12 months and to provide information, including size and age, of discarded units. The size and age were adjusted as discussed above.

We subtracted 22 percent of the units from the number of discards to account for the percent of discarded units that are not working, based on the discarder survey conducted in SCE service territory. We also subtracted discarded units less than 14 cubic feet.

The result of these calculations is the number of transferred units greater than or equal to 14 cubic feet. Transferred units manufactured before 1990 are eligible for the current program. The majority of the 2002 program participant refrigerator units were from this group.

3.3 SECONDARY REFRIGERATORS

Secondary refrigerators are all refrigerators beyond the primary refrigerator that are working, according to 2002 RASS estimates. Units that are less than 14 cubic feet were removed from this estimate. Spare refrigerators manufactured before 1990 represent a potential program unit if householders can be convinced to retire these secondary units.

According to the RASS data, approximately 17 percent of households in California have a secondary refrigerator.

3.4 TRANSFERRED FREEZERS

Transferred freezers are freezers that are in working condition but are transferred to another user as a sale, a gift, or through an appliance dealer. These are "natural discards" that are adjusted to include non-working units and units that are less than 14 cubic feet.

The number of transferred units was based on the 2002 RASS. The number of discarded freezers reported in the RASS was too low to make estimates by utility. We applied the estimate of 22 percent non-working units, from refrigerator data, because a freezer-specific number was unavailable.

The percentage of households that disposed of a freezer in 2002 was very low, and so the number of respondents per utility was often less than 25. We have less confidence in these estimates (compared to the others reported here). The numbers indicate that the 2002 program handled a much greater proportion of discarded freezers than refrigerators.

3.5 STAND-ALONE FREEZERS

This is the number of freezer-only units in households, with units less than 14 cubic feet removed. The RASS category of units less than 13 cubic feet was scaled based on the size distribution of freezers in the 2002 program participant database.

According to the RASS data approximately 18 percent of households in California have a stand-alone freezer.

3.6 PRIMARY REFRIGERATORS

Primary refrigerators are existing, working refrigerators 14 cubic feet or larger, as reported in the 2002 RASS. If the program were to target early replacement of units, the existing primary refrigerators manufactured before 1990 would be eligible for the program.

Table 3-2
RARP 2004 Market Potential for Recycling Refrigerators and Freezers (14 cubic feet or larger) – broken down by age of units

		PG&E	SDG&E	SCE	Total
Refrigerators	**Refrigerators, transferred – 14 cubic feet or larger**	153,525	48,755	149,287	351,567
	10 or less years	66,870	23,087	72,404	162,361
	11–14 years	16,309	5,875	14,580	36,764
	15–20 years	47,647	17,163	42,597	107,407
	21+ years	22,699	2,630	19,706	45,035
	Primary refrigerators	4,143,709	1,161,323	3,958,706	9,263,738
	10 or less years	3,325,024	976,866	3,166,253	7,468,143
	11–14 years	179,088	41,937	169,109	390,135
	15–20 years	535,836	125,476	505,977	1,167,290
	21+ years	103,760	17,043	117,367	238,170
	Secondary refrigerators	697,118	177,581	637,487	1,512,186
	10 or less years	476,655	135,748	461,288	1,073,691
	11–14 years	44,883	7,920	34,521	87,324
	15–20 years	134,290	23,696	103,288	261,274
	21+ years	41,289	10,218	38,390	89,897
Freezers	**Transferred freezers**	NA	NA	NA	24,772
	10 or less years	NA	NA	NA	4,721
	11–14 years	NA	NA	NA	1,105
	15–20 years	NA	NA	NA	3,658
	21+ years	NA	NA	NA	15,288
	Stand-alone freezers	817,187	185,053	588,293	1,590,533
	10 or less years	493,118	139,398	342,045	974,561
	11–14 years	52,491	7,794	37,960	98,245
	15–20 years	173,763	25,801	125,660	325,224
	21+ years	97,815	12,060	82,628	192,503

4 DEGRADATION ANALYSIS

4.1 INTRODUCTION

In this memo we provide results for the refrigerator degradation analysis. The objective of the degradation analysis was to determine the extent to which the unit energy consumption (UEC) of a given refrigerator or freezer model that is recycled under the Residential Appliance Recycling Program (RARP) increases (or decreases) with age and other physical conditions of importance compared to its UEC at birth or new. To address this issue, we compared the manufacturer-reported UEC of a given model ("new") to DOE test results for the same model ("old") that is recycled by the RARP. We also tested analytic models that would express degradation, in terms of increased UEC, as a function of age and other unit characteristics to attempt to quantify the effect of age on UEC for program participant units.

The analysis indicates that degradation has taken place over the lifespan of the recycled refrigerators and freezers considered for this study. It also shows that degradation is a function of other physical unit characteristics in addition to unit age. However, issues with the data and sample size make these findings tentative.

4.2 DATA

The refrigerator usage data used in this study came from multiple sources. A sample of refrigerators collected by the RARP in 1998 (SCE program) and 2003 (statewide program), and metered according to the DOE protocol and used to represent RARP units when "old."[1] To determine usage for the models represented in the RARP data when "new," we used manufacturer ratings, based on model number to provide estimates of consumption. Thus, we are comparing an estimate of energy consumption for new units of a particular model to metered consumption for an older unit of that model in the program. We did not observe the same unit when new and when old. Furthermore, we only considered units collected through the recycling program, hence this analysis only attempts to determine degradation rate for units recycled by the program and as such is not applicable to any average refrigerator or freezer unit in the general population.

This analysis relied on our ability to match metered model numbers from the "old" units to databases containing manufacturer estimates of "new" usage. "Old" unit model numbers were available for:

- 1998 SCE sample – (140 units); and
- 2003 statewide sample – (100 units).

[1] Code of Federal Regulations (CFR), Section 430.23 (a), (2001).

We used two sources for the manufacturer rating of "new" usage. The primary source was California Energy Commission (CEC) regulatory data made available in electronic form by the Weatherization Assistance Program Technical Assistance Center (WAPTAC). This data included refrigerator model numbers and usage for refrigerators sold in California. The Association of Household Appliance Manufacturers (AHAM) also maintains a database in support of its volume certification program. We used the AHAM data to extend and fill in the WAPTAC/CEC data. The two sources include data for units manufactured from 1975 through 1977 and 1979 through 1992. Thus, data were not available for units made before 1975 or after 1992, nor for those made in 1978.

There are several limitations to the data sources. All RARP sample brands are not represented in the available manufacturer's data. Manufacturers provide usage data to AHAM on a voluntary basis. AHAM indicates that one of the major manufacturers dropped out of the organization after 1992. Other smaller manufacturers are also not present. The CEC/WAPTAC data would not necessarily include units brought into California from other states. Since we use primarily WAPTAC/CEC and pre-1992 AHAM data, missing manufacturers were not a major issue.

The manufacturer's rated UEC for a given model number may not be based on the usage of the exactly same unit. We learned in a previous evaluation that the rated UEC is not necessarily based on metering units of that particular model number, but may be an extrapolated value based on metering of other models. Finally, metering results for individual units of the same model might vary. Therefore, the rating could be different from an individual unit's actual consumption. This is one source of variation in comparing the "old" RARP UEC with its "new" UECs.

4.2.1 Matching

Matching the RARP sample units to the manufacturer rating databases proved to be difficult. The model numbers for the RARP sample units were provided by SCE. Only model numbers were used in the matching process. The model numbers are long and contain a mix of letters and numbers. When model numbers are transcribed from nameplates, it is easy for an S to become a 5, or an O a 0. Furthermore, the manufacturer's data does not provide as many digits as many of the recorded model numbers for the metered units. Because of these and other irregularities, the matching was done manually and involved a degree of judgment.

The model number itself does not always provide sufficient information to determine the actual manufacture year of the unit and hence the manufacturer's UEC at birth. A single model number can be used for multiple years, with the UEC of the model varying over the period of production. For example, one model included in this analysis had a UEC that dropped 18 percent over the span of its production. Other units had the same estimated UEC over the period of production. We had age information for the metered units from the tracking database but since these data are estimated and found to be unreliable to be able to pinpoint the actual manufacture year of the unit.

To address the model age data issue, we determined a minimum and maximum age (and attendant UECs) based on the model number. We refer to these as the maximum and minimum production age as they represent the beginning and end of the production cycle in the manufacturers' ratings available to us. For the models produced over multiple years the UEC may or may not change. A model produced for only one year was given the same minimum and maximum production age and a single UEC.

We were successful in matching 136 of the 240 metered units to the databases containing "new" UECs. We did not expand the matching process to brand and serial name, so we do not know if the model match rate could have been better. Of the 136 matches, 96 model numbers were identical for the model number digits provided in the manufacturer information databases. We refer to these as "complete matches." The other 40 differed by one or two digits and appeared to be a reasonable match based on configuration and defrost information on the "old" metered unit. We refer to these as "close matches." We considered these two groupings as we looked at statistics and tested models.

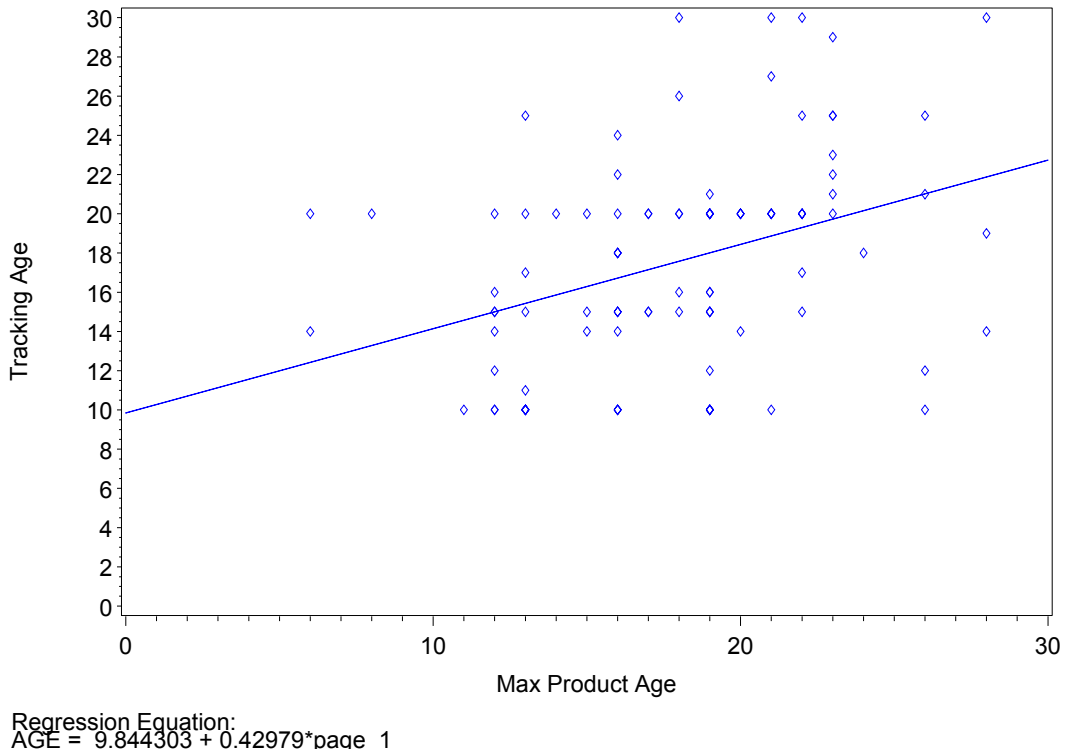
4.3 EXPLORATION OF THE AGE DATA

Before examining the relationship between age, other unit characteristics, and UEC degradation, we looked at the age data themselves. The model-based age is available only for the limited set of units for which we have model numbers, along with UEC measurements from the time the units were taken by the program. Age estimates based on customer reports and/or collection staff observations are in the tracking system for all units.

Figure 4–1 plots age reported in the program-tracking database by the maximum production age based on model number. The plot shows that all but three of the units available for this analysis are older than 10 years, using the model-based measure. Thus, these data will offer little information on degradation for units from new to age 10.

The regression line in the figure indicates a positive but weak relationship between the estimated age in the tracking database and the maximum model-based age. The considerable scatter exhibited shows a correlation between the two. Since there is little or no difference between the maximum and minimum production ages, this indicates that the tracking database estimate of age is not a reliable indicator of unit age.

Figure 4-1
Tracking Age Versus Maximum Production Age,
Complete Matches



4.4 CALCULATING DEGRADATION

For the 136 matches, we compared the old and new UEC in terms of both the difference in annual kWh and the ratio of old to new usage. The distribution provides the first clear indication that degradation does occur. Of the 136 units under consideration, only 7 percent or fewer had old UECs lower than the new UEC. The median difference between new UEC and old UEC was either 557 kWh or 591 kWh depending on whether the maximum or minimum production age was used. The corresponding median ratios were 1.46 and 1.47. Thus, the old units overwhelmingly used more energy than the estimated UEC when new.

Figure 4–2 shows the distribution of the UEC differences. The bins are 200 kWh wide (the label indicates the bin midpoint). These are the differences when using maximum production age.

Figure 4-2
Distribution of UEC differences Using Maximum Production Age
(Earliest Possible Match)

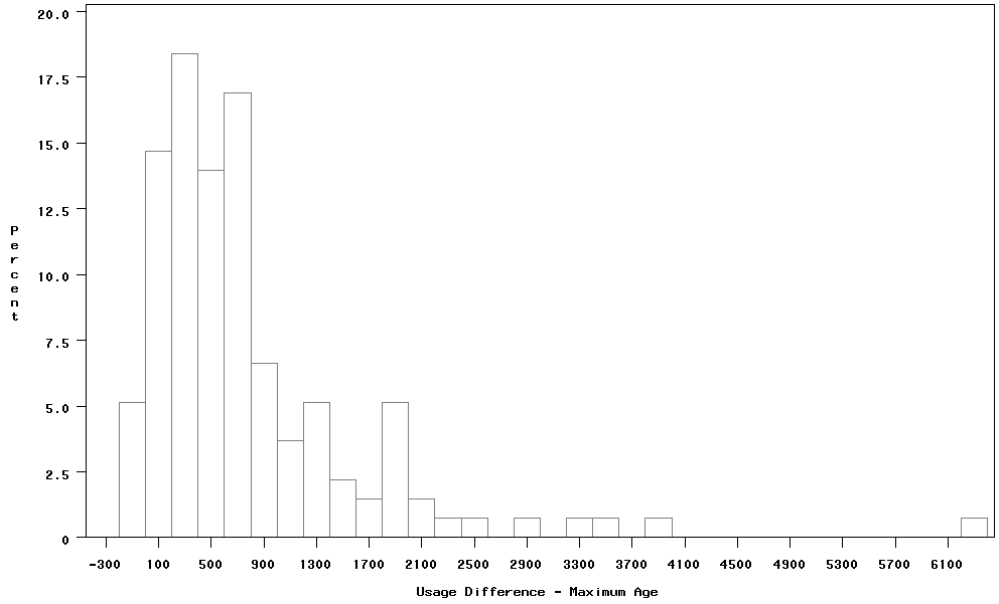
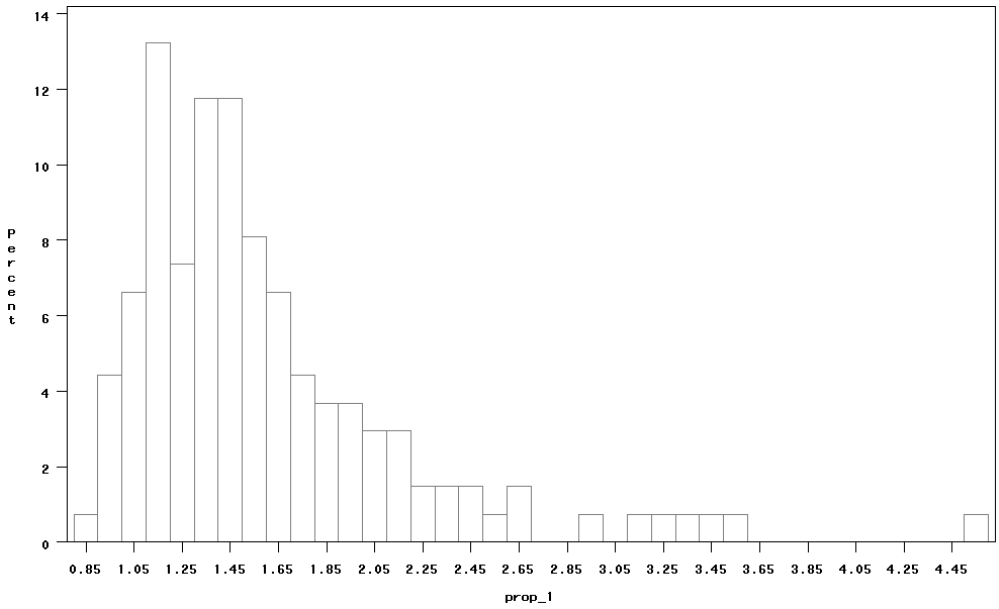


Figure 4–3 shows the UEC difference in proportional terms – old metered data as a proportion of the new usage. The bins are 0.1 wide.

Figure 4-3
Distribution of Proportions Using Maximum Production Age
(Earliest Possible Match)



4.5 REGRESSION ANALYSIS

A goal of the degradation analysis was to develop a model that expresses unit degradation as a function of age and other unit characteristics. A preliminary examination of plots generally provides a good indication of the likelihood of success with regression analysis. Figure 4–4 plots UEC difference by the maximum production age for the units with complete model number matches. The different symbols (and colors) represent the two different samples of metered units.

Figure 4-4
Usage Difference by Maximum Age, Complete Matches

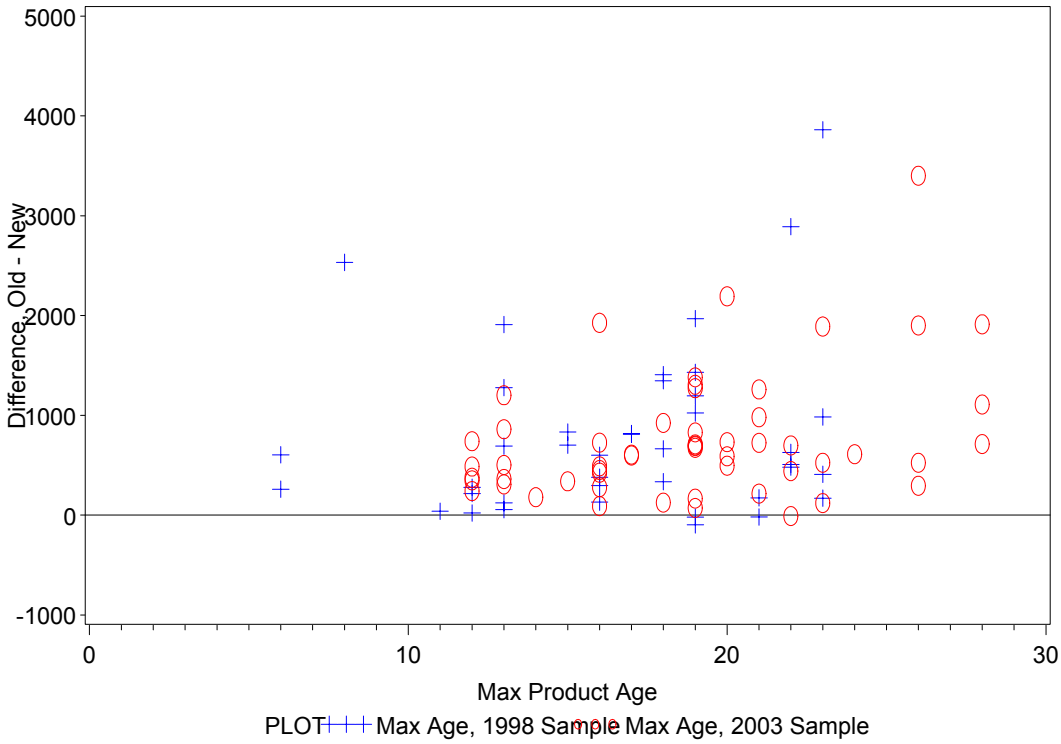


Figure 4–4 does not indicate a dramatic age-related trend either across all the data or within the different samples. It does indicate a slight upward trend (i.e., increasing UEC with age). This trend is more apparent with the complete matches alone (shown in Figure 4–4) than with the close matches included. Using regression analysis, we tested whether there was a statistically significant trend based on age and sample information alone. Regression analysis also allowed us to control for unit characteristics to examine the combined effect of age and unit characteristics on UEC degradation.

4.5.1 Basic Model forms

We tested the relationship between old and new UEC using three different functional forms. The basic functional form used for the regression analysis was:

$$\#1)\ \ln(\text{OLDUEC}_j) - \ln(\text{NEWUEC}_j) = a + b_1 t_j + b_2 c + e_j$$

where t is age and c is some set of unit characteristics. The difference of the logged old and new usage produces a dependent variable that approximates the percentage increase from new to old when proportions are closer to one but scales them down as the proportions increase.

Two variants were also tested:

$$\#2)\ \ln(\text{OLDUEC}) = a + b_1 t + b_2 c + b_3 \ln(\text{NEWUEC}) \text{ and}$$
$$\#3)\ \text{OLDUEC} - \text{NEWUEC} = a + b_1 t + b_2 c.$$

The first of these additional functional forms was essentially the same as model #1 above except that by moving the "new" UEC to the right-hand side, it allowed for an added linear relationship between the new and old UECs. The second additional functional form was also similar to the first but removed the logarithmic transformations. This dependent variable was the difference used in Figure 4–4 above.

All three functional forms were run for all possible combinations of complete and close matches and minimum and maximum production age. In all, for any set of explanatory variables, 12 models were run.

4.5.2 Effect of Age Alone

The first step was to check the visual observation from Figure 4–4 that there was no strong relationship between usage difference and age. We ran all 12 models including only the production age (minimum or maximum) and the sample indicator as explanatory variables. Production age was only statistically significant at a 90 percent confidence level for two of the 12 models: Model #3 used complete matches for both production ages. These models showed an increase of 38 kWh/year for minimum production age and 36 kWh/year for maximum production age. The models did not indicate a difference between the two meter samples. These results indicated that using the correct functional form and limiting the data to the complete matches there is in fact a discernible relationship between age and difference in old and new UEC. However, the R^2 of .06 indicated that very little of the variation in the data was being explained.

4.5.3 Effects of Age with Other Characteristics

We explored the possibility that the relationship between usage difference and age was informed by some combination of unit characteristics. Table 4–1 provides the list of characteristics we tested in the model.

Table 4-1
List of Variables include in the Degradation Regressions

Unit Configuration Binaries	Side by Side
	Single Door
	Top Freezer
	Upright Freezer
Other Characteristic Binaries	Frost Free Binary
	freezer binary
Continuous Characteristics	size
	Amps
	Age (Max or Min Production)
Sample Indicator	Sample Binary (1998 sample)
Amps Interactions	Freezer *Amps
	Below Freezer *Amps
	Side by Side *Amps
Age Interactions	Side by Side *Age
	Single Door *Age
	Top Freezer *Age
	Upright Freezer *Age
	Frost Free Binary *Age
	freezer binary *Age
	size *Age
	amps *Age

We included this list of variables in the models using a backwards elimination model selection procedure. In this procedure the variable contributing the least to the model is removed until all variables remaining are significant at the 10 percent level. We checked for influential observations and found none. The variables included in the final version of each of the 12 model permutations are indicated in Table 4–2.

Table 4-2
Variables Remaining and R^2 for All Model Permutations

Variable	Maximum Production Age						Minimum Production Age					
	Close Matches			Complete Matches			Close Matches			Complete Matches		
	#1	#2	#3	#1	#2	#3	#1	#2	#3	#1	#2	#3
Side by Side			X									
Single Door												X
Top Freezer										X		
Upright Freezer				X		X						
Frost Free Binary				X	X						X	X
freezer binary				X		X			X	X		
size				X	X	X			X			
Amps												
Age (Max or Min Production)	X	X	X	X	X	X	X	X		X	X	
Sample Binary (1998 sample)												
Freezer*Amps				X					X			X
Below Freezer*Amps	X	X	X	X	X	X				X	X	X
Side by Side*Amps												
Side by Side*Age	X	X		X	X	X				X	X	X
Single Door*Age	X	X	X	X	X	X	X	X		X	X	
Top Freezer*Age	X	X	X	X	X	X				X	X	X
Upright Freezer*Age						X						
Frost Free Binary*Age												
freezer binary*Age	X	X	X		X							
size*Age	X	X	X	X	X	X	X	X		X	X	X
amps*Age												X
R^2	.143	.568	.169	.295	.674	.337	.088	.546	.141	.232	.652	.321

While there was some variation with regards to which variables remained in the models, aspects of the results remained consistent across all the permutations. Age is significantly different from zero in 10 of the 12 permutations, only dropping out for the un-transformed difference models using minimum production age. Age in interaction with other unit characteristics enters into all of the models at least four times in most of the models. These results indicate that door configuration, size, and whether a unit is a freezer or not combine with age do explain unit degradation. Contrary to expectations, age is negative in all 10 instances where it is present. However, in all the models where age was retained, interactions between age and other variables were also retained, and with a positive sign. Thus, to determine the overall effect of age, the net effect in combination with other factors must be considered. The results for the best regression model are discussed below and Figure 4–5 shows that the net affect of age remains positive.

The results also highlight aspects of the different data we are using for different model permutations. Maximum age consistently outperforms minimum age with regards to R^2. Similarly, the data from complete matches consistently performs better than the full dataset. The best set of models, the three models using maximum production age and the complete matches yield similar results. Models #1, 2, and 3 have 11, 9, and 10 characteristic variables included and seven of them are in common. The two logged models (models #1 and 2), with variables in the same scale, have very similar magnitudes across like variables. The explanatory power of the models appears also to be similar. Model #2, which includes new usage as an explanatory

variable, has a much higher R^2 than would be expected. However, the similar coefficients for the two logged models, models #1 and #2, indicates that model #2 is similar to model #1 in explanatory power with regards to the relationship between old and new. Model #1's R^2 is just slightly less than model #3.

4.6 BEST MODEL

Parameter estimates for model #3 run with maximum production age and complete matches are reported in Table 4–3. This model is representative of the three best models with regards to the included age interaction variables. As this model is not log-transformed, the parameter estimates represent kilowatt hours and thus are more intuitive. The parameter estimate for maximum production age for model #3 is negative 455.0. All the age interaction/binary characteristic terms are positive but smaller than the non-interacted age variable. Age interacted with size is also positive indicating that as units get older and bigger their degradation increases. Side by side, single door or top freezer refrigerators, and upright freezers above modest sizes (17,14,16, and 6 cubic feet respectively) will have a positive net age effect, increasing with size. Upright freezers have the strongest age-related effect.

Table 4-3
Model #3 Parameter Estimates, Maximum Production Age, Complete Matches

	Parameter Estimate	Standard Error	P-value
Intercept	3,119.4	1,629.7	0.0590
Upright Freezer	-9,253.4	3,400.4	0.0079
freezer binary	6,944.6	2,497.1	0.0067
size	-168.9	82.7	0.0442
Below Freezer	698.4	213.7	0.0016
Side by Side * Age	232.9	86.7	0.0087
Single Door * Age	267.3	88.9	0.0035
Top Freezer * Age	245.1	87.0	0.0061
Upright Freezer * Age	381.9	138.2	0.0070
Size * Age	13.6	4.5	0.0033
Maximum Production Age	-455.0	123.8	0.0004

To assess the implications of these results for the units being collected by the program, we used model #3 to estimate the mean per unit increase in UEC for the mix of refrigerator models in the 2003 tracking. The characteristics reflect the 2003 tracking data, except for age. As tracking age was shown to be a poor estimator of production age we applied the model multiple times with all units assigned a single age, five years, ten years, etc. Thus, we effectively assume that the distribution of unit characteristics other than age is the same as observed for the population of units collected in the 2003 program, and look at the effect of age on such a mix of units. In reality, of course, the characteristics such as size and configuration vary with age due to changing production practices. However, this approach lets us see what the overall age effects

appear to be for the units observed. The same type of analysis could be done for any particular distribution of characteristics of interest.

Figure 4-5
Estimated kWh increase in UEC at Five Year Age Increments

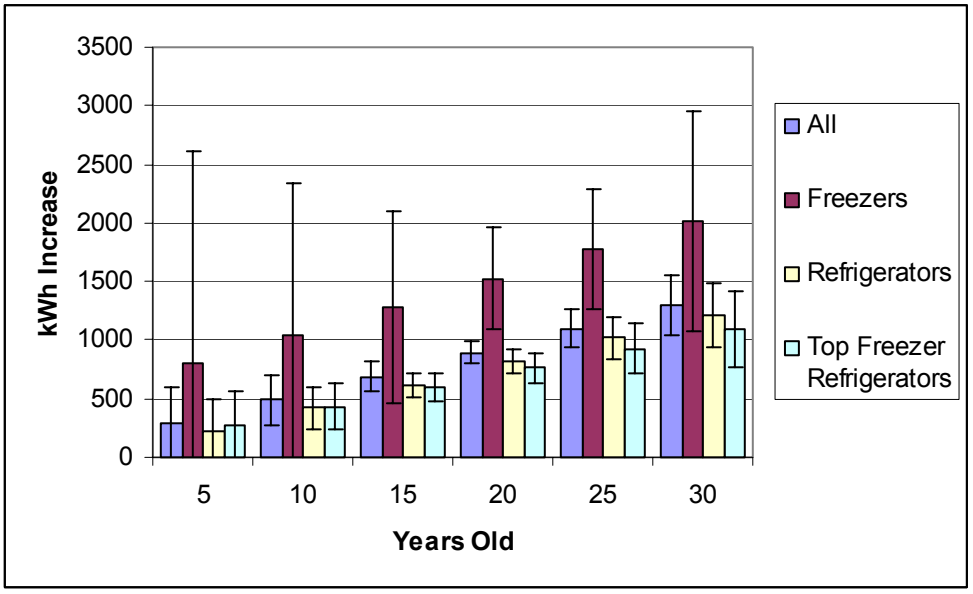


Figure 4–5 shows the results from model #3 for the full 2003 RARP tracking data and three different subgroups. The figure shows the estimated mean per unit increase in UEC as a function of age, with 80 percent confidence bands, for each of the four subgroups. The overall results show a slightly higher overall increase in UEC of 40 kWh/year with the inclusion of characteristics. The increased R^2 of .34 further indicates that inclusion of characteristics explains substantially more of the variability in the data. Given the lack of data with a production age of less than 10, the results for 5 years old are only included to illustrate the trend.

The importance of the inclusion of characteristics in the model is illustrated by the three sets of characteristic-specific results in Figure 4–5. Freezers clearly show a higher degree of degradation. Because the number of freezers in the analysis is small (7 of the 96 complete matches), the 80 percent confidence band is quite wide. Similarly, the most common refrigerator configuration, those with a top freezer, shows lower degradation than refrigerators as a whole.

4.7 CONCLUSION

This analysis clearly indicates that degradation, in terms of increased UEC, does take place in refrigerators and freezers over their lifespan. There are a number of issues with the data that make any conclusion tentative. These include:

- Manufacturer's data limited in years, varying over years and interpolated among models,
- Uncertainty regarding the exact age of the metered units.
- The imprecise nature of the matching of model numbers.

Despite these issues and the potential variation they represent, 93 percent of the metered units showed increased usage during their lifespan, compared to the as-new rating for units of the same model. The regression analysis further indicates that degradation existed and could be quantified. Finally, the analysis makes clear that degradation differs across units with different characteristics. Unfortunately, given the small size of our sample and relatively low explanatory power of the best models, these models are of limited use in providing firm quantitative estimates of potential degradation in specific units. A larger sample size, incorporating additional metering cases from studies currently planned, may provide more robust estimates.

A

VERIFICATION SURVEY INSTRUMENT

Notes to interviewers:
Except where indicated otherwise, record only one answer per question

I1. INTRO:

May I please speak with <CONT1>? Hello, my name is _____ calling on behalf of <utility>. We are contacting customers who might have gotten rid of a refrigerator or freezer in 2003.

Are you the person who would be able to answer questions about getting rid of a refrigerator or freezer sometime during 2003?

> IF NO: Then may I please speak to the person who would know the most about a removal?
> IF NEEDED: It will take less than 5 minutes.
> IF NEEDED: I'm calling from - Group, an independent research firm, who has been contracted to conduct the study.

[Spoke to contact]	1	
[Spoke to someone else]	2	
[No such person]	3	=> TERM
[Refused]	4	=> TERM

RIGHT PERSON: I have a few questions that will take less than five minutes about appliance pick up practices and would like to get your opinions.

A1:

First, to make sure I have the right telephone number, I'd like to confirm that you had an electric account at <address> in 2003?

Yes	1	
No	2	=> TERM
[Don't know/Not sure/Can't remember]	97	=> TERM
[Refused]	98	=> TERM

A2:

Did your household get rid of a <Unit> in 2003?

Yes	1	=> A4
No	2	
[Don't know/Not sure/Can't remember]	97	
[Refused]	98	

A3:

A recycling program's records indicate that a <unit> was picked up at this address in <month> 2003. Do you recall getting rid of a <unit> then?

Yes	1	
No	2	=> TERM
[Don't know/Not sure/Can't remember]	97	=> TERM
[Refused]	98	=> TERM

A4:

When you got rid of the <unit> was it in working condition?

Yes	1
No	2
[Don't know/Not sure/Can't remember]	97
[Refused]	98

A5: [if a3 ^ =1]

Which of the following best describes what you did with the <unit>. (Read list until they pick an option)

It was picked up by a utility recycling program	1	=>A7
It was picked up by a another recycling program	2	
A dealer took it away	3	
You sold it or gave it away to a private citizen	4	
Somebody else hauled it away	5	
You took it somewhere	6	
[Other](RECORD)	7	
[Don't know/Not sure/Can't remember]	97	
[Refused]	98	

A6: [if a3 ^ =1]

Is it possible that a recycling company working on behalf of <utility> came and picked up the <unit> in 2003?

Yes	1	
No	2	=> TERM
[Don't know/Not sure/Can't remember]	97	=> TERM
[Refused]	98	=> TERM

A7:

Did you receive any incentive for recycling the <unit>?

Yes	1	
No	2	=> A9
[Don't know/Not sure/Can't remember]	97	=> A9
[Refused]	98	=> A9

A8:

Did you receive a check for $35 or a five-pack of compact fluorescent light bulbs?

$35 rebate check	1
5 pack of CFLs	2
[Other incentive](RECORD)	3
[Don't know/Not sure/Can't remember]	97
[Refused]	98

A9:

Next, I'd like to know how satisfied or dissatisfied you were with the recycling process. Would you say you were very **dis**satisfied, **dis**satisfied, satisfied, or very satisfied?

Very dissatisfied	1	
Dissatisfied	2	
Satisfied	3	=> A11
Very satisfied	4	=> A11
[Don't know/Not sure/Can't remember]	97	=> A11
[Refused]	98	=> A11

A10:

What problems, if any, did you have with the recycling process? (CIRCLE ALL THAT APPLY)

[Pick up was late]	1
[Scheduling problems]	2
[Driver was not professional]	3
[Damaged the house]	4
[Other](RECORD)	5
[Don't know/Not sure/Can't remember]	97
[Refused]	98

A11:

That's all the questions I have for you today. Do you have any other comments regarding the utility recycling program that you would like us to pass on?

Yes (RECORD)	1	=> TERM
No	2	=> TERM

Thank you, that is all the questions we have for you today.