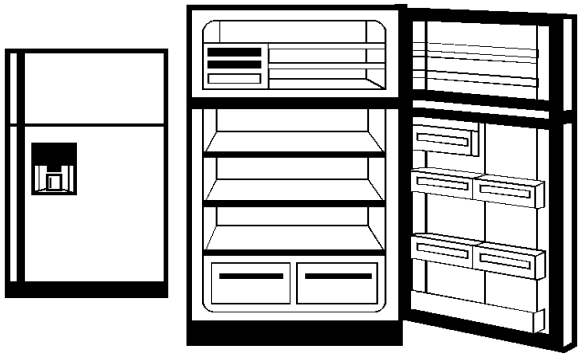
San Diego Gas & Electric
Marketing Programs & Planning
8306 Century Park Court
San Diego, California 92123

1994 & 1995 Residential Appliance Efficiency Incentives: Refrigerators

Fourth Year Retention Evaluation

March 1999



Study ID No. 915

Table of Contents

Program Description *1*
Sampling and Data Collection *1*
Measures/"Like" Measures *2*
Econometric Framework *2*
Table 6 ..... *7*
Table 7 ..... *9*
Measure Retention Survey *14*
Retroactive Waiver *16*

1994 & 1995 RESIDENTIAL APPLIANCE EFFICIENCY INCENTIVES:

REFRIGERATORS

FOURTH YEAR RETENTION EVALUATION

STUDY ID NO. 915

Program Description

SDG&E's PY94 & PY95 Residential Appliance Efficiency Incentives (RAEI) – High Efficiency Refrigerator Program was designed to capture potential lost opportunities by encouraging residential customers to purchase higher efficiency units when replacing current refrigerators. The strategy for this program was to (1) offer discounts to customers purchasing refrigerators exceeding federal standards of appliance efficiency and (2) encourage manufacturers to produce higher efficiency units. The program also included freezers.

A customer who participated in SDG&E's RAEI High Efficiency Refrigerator Program received a rebate at the time of purchase. SDG&E's rebates where on a sliding scale, with higher rebates for higher efficiency units. The dealer was required to collect the name, address, telephone number, and refrigerator model, and then submit this documentation to SDG&E for reimbursement. The retention sample for this study was drawn from this database.

Sampling and Data Collection

The M&E Protocols require that retention studies evaluate the top 10 measures or 50% of the estimated resource value, whichever number of measures is less. For the RAEI High-Efficiency Refrigerator Program, one measure, refrigerators exceeding federal standards by more than 20% and less than 25% constitutes 52% of program gross kWh savings for PY94. (This identification of PY94 measures is in accordance with the retroactive waiver attached to the end of this report). For PY95, two measures constitute the top 50% of resource value. The first are those refrigerators exceeding federal efficiency standards by more than 20% and less than 25% (39% of program TRC). The second measure are those refrigerators greater than 25% and less than 30% above federal efficiency standards (32% of program TRC; a cumulative total of 70%

of TRC for PY95). These three groups of customers are the basis for estimating the Effective Useful Life (EUL) for refrigerators.

SDG&E contracted with CIC Research, Inc. to conduct telephone surveys on the participants who purchased refrigerators within the three groups. The customers in each of the three groups were provided to CIC Research in random order. SDG&E requested that CIC Research conduct surveys with 450 customers in each group to determine if the refrigerators were still in place and operable – the definition of effective useful life per the M&E Protocols. CIC Research actually performed a few more surveys than were required:

- Group 1, PY94 20-25% above federal standards – 451 surveys;
- Group 2, PY95 20-25% above federal standards - 456 surveys;
- Group 3, PY95 25-30% above federal standards – 450 surveys.

A copy of the survey and tally sheet is provided at the end of this study.

Measures/"Like" Measures

In order to apply any changes in EUL to measures not studied, M&E Protocols require that the utility identify any "like" measures within the program. For SDG&E's PY94 & PY95 RAEI High-Efficiency Refrigerator Program, all refrigerators are identified as "like" measures. The *ex ante* estimated EUL for all refrigerators in the program is 18 years.

The only measures excluded as "like" measures are freezers, although the *ex ante* EUL is also 18 years. Freezers were excluded for the following reasons: (1) most freezers would be kept in the garage as opposed to the house, (2) freezers wouldn't be opened as often as in-house refrigerators, and (3) in both PY94 and PY95, freezers accounted for less than 1% of the program.

Econometric Framework

Retention model for estimating median lifetime

The model for lifetime estimation involves the key concepts of the survivor function, the hazard function, and median lifetime. Once these concepts are established, they will be applied to the

data and a maximum-likelihood framework (which brings the concepts and the data together) to produce estimated median lifetime.

The survivor function

For the lifetime of the equipment in question, the survivor function is,

$$S(j) = \text{prob}(\text{lifetime} \geq j)$$

It is the estimated survivor function that allows the formation of an expected median lifetime. Of course, the survivor function must be specified. This is done through a related function: the hazard function.

The hazard function

The hazard function $h(j)$ is the probability of equipment failure (removal, retirement, etc.) in the next unit of time, conditioned on having reached age j. It bears the following relationship to the survivor function.

$$h(j) = -\frac{dS(j)/dj}{S(j)}$$

The hazard function is generally the "intuitive starting point" of any lifetime analysis, since it is structured to reflect the general pattern of equipment failures. The quadratic hazard function allows for U-shaped and linear hazard curves ($b_2 = 0$, below), as well as an exponential survivor function ($b_1 = b_2 = 0$, below) as special cases:[1]

Equation 1 (The quadratic hazard function)

$$-\frac{dS(j)/dj}{S(j)} = h(j) = b_0 + b_1 j + b_2 j^2$$

Note that the hazard function is actually a differential equation in the survivor curve.

Getting the survivor function from the hazard function

The exact structure of the survivor function can be obtained by solving the hazard function (a differential equation in the survivor function) for $S(j)$, imposing the constraint $S(0) = 1$:

[1] Lawless, J.F. (1982). *Statistical Models and Methods for Lifetime Data*. New York: Wiley. 252-253.

Equation 2 (The survivor function)

$$S(j) = e^{-(\beta_1 j + \beta_2 j^2 + \beta_3 j^3)} \quad (\beta_1 = b_0, \quad \beta_2 = \frac{b_1}{2}, \quad \beta_3 = \frac{b_2}{3})$$

The median lifetime

The median age at failure m is then given by the implicit expression,

Equation 3 (Definition of the median m)

$$S(m) = e^{-(\beta_1 m + \beta_2 m^2 + \beta_3 m^3)} = \frac{1}{2}$$

We now show the steps necessary to estimate the median lifetime from actual data, by defining the "discrete failure function" and the likelihood function.

The discrete failure function

For uniform periods of time (months), the likelihood of failure at age j (before age j+1) is,

Equation 4 (The discrete failure function)

$$F(j) = S(j) - S(j+1)$$

The data, the likelihood function, and estimation

Consider an equipment sample of size n. Let n_j^F be the number of known failures at age j, and let n^Q be the number of known failures whose age at failure is unknown; then the number of survivors by observation at age J is $n - n^Q - \sum_{j=0}^{J} n_j^F$. Furthermore, let ω be the likelihood that the age at failure is unknown, given failure. The log-likelihood function (the log of the likelihood of observing the data) is then,

$$L(\beta, \omega) = \sum_{j=0}^{J} n_j^F \log[(1-\omega)F(j)] + n^Q \log\{\omega[1 - S(J+1)]\} + \left(n - n^Q - \sum_{j=0}^{J} n_j^F \right) \log S(J+1).$$

The log-likelihood function can be maximized with respect to its arguments just as a sum-of-squares function can be minimized in a standard regression problem. Standard numerical and grid-search methods can be used to maximize the log-likelihood function. Once estimates are obtained for the vector of coefficients β, the median lifetime can be estimated using Equation 3.

The estimated variance of β, on which the standard errors of its elements are based, is a fairly complex calculation and one which will not be expressly derived here, although the calculation is based on the expectation of the second-derivative matrix for the log-likelihood function:

$$\mathrm{VAR}(\beta)=\left(\mathrm{E}\frac{\partial^2 \mathrm{L}}{\partial\beta\partial\beta'}\right)^{-1}$$

The estimated median is a nonlinear function of β; as such, its standard error can be estimated dependably for large samples, based on $\mathrm{VAR}(\beta)$.

Solving data problems--developing independent and dependent failures

Lifetime estimation using maximum likelihood requires the statistical independence of failures. Sometimes equipment failures are indeed independent, as when failures occur due to age or manufacturing weaknesses. However, in many cases failures are not independent--that is, they are "dependent"--as when, for example, a "cluster" or "bank" of lighting measures are jointly removed during a remodeling.

Independent failures can easily be handled using the maximum likelihood framework described above. Fortunately, dependent failures can also be handled in a similar fashion. A cluster of dependent failures can be viewed as an independent failure in its own right, one of numerous observed clusters, each of which is subject to the possibility of independent failure. The maximum likelihood framework can simply be applied to the clustered data.

Modeling and estimating with independent and dependent failures

When any one piece of equipment is subject to both independent and dependent failure, the hazard function can be modified accordingly (ignoring the event of both types of failures occurring jointly):

$$\mathrm{h}(\mathrm{j})=\mathrm{h}_{\mathrm{ind}}(\mathrm{j})+\mathrm{h}_{\mathrm{dep}}(\mathrm{j})$$

Independent failures are bound to be age-dependent, so that,

$$\mathrm{h}_{\mathrm{ind}}(\mathrm{j})=\mathrm{b}_0^{\mathrm{ind}}+\mathrm{b}_1\mathrm{j}+\mathrm{b}_2\mathrm{j}^2$$

Dependent failures are mostly likely age-independent (with respect to the building-remodeling effect, we expect the age of the equipment to be irrelevant), so that,

$$\mathrm{h}_{\mathrm{dep}}(\mathrm{j})=\mathrm{b}_0^{\mathrm{dep}}$$

This yields a new survivor function (and, implicitly, a new median life that can be estimated based on the joint use of independent and dependent failure data):

$$S(j) = e^{-\left[\left(\beta_1^{ind} + \beta_1^{dep}\right)j + \beta_2 j^2 + \beta_3 j^3\right]}$$

The variance matrix for the joint estimation problem can be constructed, as can the standard error for the jointly estimated median lifetime, represented by the expression,

$$S(m) = e^{-\left[\left(\beta_1^{ind} + \beta_1^{dep}\right)j + \beta_2 m^2 + \beta_3 m^3\right]} = \frac{1}{2}$$

M&E PROTOCOLS TABLE 6

RESULTS USED TO SUPPORT

PY94 THIRD EARNINGS CLAIM

FOR

RESIDENTIAL APPLIANCE EFFICIENCY INCENTIVES PROGRAM: REFRIGERATORS

FOURTH YEAR RETENTION EVALUATION

MARCH 1999

STUDY ID NO. 915

TABLE 6 for RETENTION STUDIES
PROGRAM: RAEI-Refrigerators
YEAR(S): PY94 & PY95

1. Enduse	1. Measure	*2. ex-ante* EUL	*2. ex-ante* EUL Source	*3. ex-post* EUL from Study	*4. ex-post* EUL for 3rd & 4th claim	5. Standard Error	6. Upper & lower bounds @ 80% Conf Int		7. P Value	8. Realization Rate	9. "Like" Measures to be Adjusted
Refrig	>=20 AND <25 % EFF REF	18	**	27.5	18	43.8	3.9	51.2	82.8%	1.00	see below
Refrig	>=25 AND <30 % EFF REF	18	**	26.5	18	57.0	(4.3)	57.2	88.1%	1.00	see below

9. "Like" Measures to be Adjusted
>=10 AND <15 % EFF REF
>=15 AND <20 % EFF REF
>=30 AND <35 % EFF REF
>=35 AND <40 % EFF REF
>=40 AND <45 % EFF REF

**Advice Letter filing 926-E-A/934-G-A: March 23, 1995

M&E PROTOCOLS TABLE 7

DATA QUALITY AND PROCESSING

DOCUMENTATION

FOR

RESIDENTIAL APPLIANCE EFFICIENCY INCENTIVES PROGRAM: REFRIGERATORS

FOURTH YEAR RETENTION EVALUATION

MARCH 1999

STUDY ID NO. 915

M&E PROTOCOLS TABLE 7

DATA QUALITY AND PROCESSING DOCUMENTATION

For RAEI-Refrigeration Program

Fourth Year Retention Evaluation

March 1999

Study ID No. 915

B. RETENTION STUDIES

1. OVERVIEW INFORMATION

a. **Study Title and Study ID:** 1994 & 1995 Residential Appliance Efficiency Incentives: Refrigerators – Fourth Year Retention Evaluation, March 1999, Study ID No. 915

b. **Program, Program Year(s), and Program Description (Design):** RAEI Refrigeration Program for the 1994 and 1995 program years. The Program is designed to encourage residential customers to purchase higher efficiency units when replacing current refrigerators.

c. **End Uses and Measures Covered:** Refrigeration; two measures: refrigerators 20-25% and 25-30% above federal standards.

d. **Methods and Models Used:** See the section of the report entitled Econometric Framework for a complete description of the final model specifications.

e. **Analysis sample size:**

Program Year	Measure	# of Customers in Program	# of Installations in Program	# of Measures Installed in Program	# of Measures in Sample Frame	Date of Retention Studies
94	20 - 25 %	18,491	18,491	18,491	451	Apr-98
95	20 - 25 %	16,389	16,389	16,389	456	Apr-98
95	25 - 30 %	7,650	7,650	7,650	450	Apr-98

1. DATABASE MANAGEMENT

a. **Data sources:** the data came from the following sources:

- Customer name, address, phone number, installed measures, and participation date from the program tracking database
- Refrigerators were determined to be in place and operable by the phone survey described in the section of the report entitled Sampling and Data Collection.

The data were merged together to form the dataset for the econometric analysis leading to the estimated Effective Useful Life

b. **Data Attrition:** The goal was to achieve a sample of 1,350 completed surveys - 450 for each of the different levels of efficiency for each program year (see 1.e. above).

SDG&E Refrigerator Study
Final Dialing Results
April 1998

Call Result	No.	%
Number not in service	366	8.0
Wrong number	538	11.8
Other language	62	1.4
Business number/fax/modem/cell phone	343	7.5
Refusal	305	6.7
Didn't buy refrigerator in '94/95	213	4.7
Busy number	55	1.2
No answer	358	7.9
Answering machine	802	17.7
Callback	128	2.8
Respondent never available	16	0.4
Completed interviews	1,357	29.9
TOTAL	4,543	100.0

c. **Data Quality Checks:** The data sets for the regression analysis were merged in SAS by the appropriate key variables. Counts of the data sets before and after the merges were verified to ensure accurate merging.

d. **All data collected** for this analysis was utilized.

3. SAMPLING

a. **Sampling procedures and protocols:** A goal of 450 participants per efficiency level per program year (3 groups of customers) was established. Each of the three groups of customers was provided to CIC Research in random order. CIC Research was instructed to start at the top of each list and get the first 450 customers they could to respond. See the section of the report entitled Sampling and Data Collection and 2.b. above for a detailed description.

b. **Survey information:** A copy of the SDG&E Refrigerator Survey is attached at the end of the report. The survey completed response rate was 29.9%; see 2.b. above for reasons for non-completed surveys.

c. **Statistical Descriptions:** See Failure Distribution Tables provided in Section 4.c.

4. DATA SCREENING AND ANALYSIS

a. **Outliers and Missing Data Points:** No outliers and no missing data.

b. **Background Variables:** NA

c. **Screened Data:** In the following failure distribution tables,

NN = the quantity of the measure studied

NQ = the number of observed failures whose age at failure is unknown

NF = the number of observed failures whose age at failure is known

ND = the number of measures still in place and operable

FAILURE DISTRIBUTION TABLES PER MEASURE

DATUM	DESCRIPTOR	AGE (MONTHS)
450	NN95	NA
1	NQ95	39
1	NF95	24
1	NF95	38
1	NF95	39
1	NF95	32
445	ND95	39
refrigerator study no. 2.xls--independent failures		

DATUM	DESCRIPTOR	AGE (MONTHS)
451	NN94	NA
4	NQ94	51
1	NF94	0
1	NF94	12
2	NF94	39
1	NF94	40
1	NF94	48
458	NN95	NA
2	NQ95	39
1	NF95	36
2	NF95	38
1	NF95	4
1	NF95	29
2	NF95	20
1	NF95	32
1	NF95	21
441	ND94	51
447	ND95	39
refrigerator study no. 1.xls--independent failures		

d. **Model statistics:** See M&E Protocol Table 6.

e. **Specification:**

	Type of Data Used		Type of Specification Used		
Study	Independent Failures	Dependent Failures	Exponential Specification	Linear Specification	Combination Linear/Exponential Specification
RAEI-REF	x			x	

1) **Heterogeneity:** See section of the report entitled “Econometric Framework.”

2) **Omitted Factors:** None omitted.

f. **Error in Measuring Variables:** NA.

g. **Influential Data Points:** None.

h. **Missing Data:** None.

i. **Precision:** The calculation for the standard error is based on the expectation of the second-derivative matrix for the log-likelihood function.

MEASURE RETENTION SURVEY

FOR

RESIDENTIAL APPLIANCE EFFICIENCY INCENTIVES PROGRAM – REFRIGERATORS

FOURTH YEAR RETENTION EVALUATION

MARCH 1999

STUDY ID NO. 915

SDG&E Refrigerator Survey

April 1998

Hello. Have I reached the _____ household? (CONTINUE) I'm calling from CIC Research for San Diego Gas & Electric Company. We're conducting a very brief survey on refrigerators. The survey only takes a few minutes. May I speak with a person who was involved in the purchase of your last refrigerator? (REPEAT INTRO IF NECESSARY.)

1. According to our records, you purchased a new refrigerator in (1994/95). Is that correct?
   1 yes (CONTINUE) 2 no (THANK & TERMINATE)

2. Do you still have that refrigerator?

   1 yes, in my own home (CONTINUE)
   2 yes, in my rental or other property (CONTINUE)
   3 no, got rid of it (SKIP TO Q5)

3. And is it still plugged in and being used?

   1 yes (THANK & TERMINATE; COUNT AS COMPLETE)
   2 no (CONTINUE)
   9 DK (THANK & TERMINATE; COUNT AS COMPLETE)

4. Why not?

   1 plan to get rid of it but haven't yet
   2 seasonal use only
   3 other (SPECIFY) _____

(THANK & TERMINATE; COUNT AS COMPLETE)

5. When did you get rid of it? Month & Year _____

6. Where did it go?

   1 SDG&E territory (San Diego County & southern Orange County)
   2 outside SDG&E's territory
   3 other (SPECIFY) _____
   9 DK

Those are all my questions. Thank you very much for your time and cooperation.

RETROACTIVE WAIVER

FOR

RESIDENTIAL APPLIANCE EFFICIENCY INCENTIVES PROGRAM – REFRIGERATORS

FOURTH YEAR RETENTION EVALUATION

MARCH 1999

STUDY ID NO. 915

SAN DIEGO GAS & ELECTRIC
RETROACTIVE WAIVER FOR
1994 RAEI-REFRIGERATOR, CEEI, IEEI, and NRNC PROGRAMS
(Study ID Nos. 915, 924/960, 927/963, and 936/972)

Approved by CADMAC on February 17, 1999

REQUEST

SDG&E is requesting a waiver for the PY94 RAEI-Refrigerator, CEEI, IEEI, and NRNC Programs identification of fourth year retention measure studies required by Table 9A of the Protocols. Protocol Table 9A defines retention study measures as "the top ten measures, excluding measures that have been identified as miscellaneous (per Table C-9), ranked by net resource value or the number of measures that constitutes the first 50% of resource value, whichever number of measures is less." SDG&E is requesting that (1) commercial measures for PY94 be identified by the top 50% of the "incentive basis" (IB) as defined in the shareholder mechanism in place at that time; and (2) that residential refrigerator measures be identified as the top 50% of gross kWh savings.

BACKGROUND

For PY94, SDG&E's project tracking system did not carry resource values (and could not be constructed due to changes in data systems), but rather the "incentive basis" (IB) as defined in the shareholder mechanism in place at that time. IB was a calculated as follows: IB = Benefits – (Administrative Costs + (.25 * Incentive Costs) + (.5 * Equipment Costs)). SDG&E ranked the PY94 measures by descending IB. PY94 residential programs did not carry the IB value; the refrigerators were ranked by percent of program gross kWh savings. SDG&E believes that the measures required to be included for the fourth year retention studies are most likely identified by the substitute criteria. By identifying the top 50% of IB, the measures constituting the greatest shareholder earnings are being evaluated. The number of measures, percentage of non-miscellaneous program IB/kWh savings, and program earnings are presented in the following table.

Program	Number of Retention Study Measures	Percent of Non-Miscellaneous IB	Program Earnings (Millions of $$)
CEEI	8	51.4%	3.413
NRNC	6	54%	1.110
IEEI	11	69%	1.707
RAEI-Refrigerators	1	52%of kWh	.65

CONCLUSION

SDG&E believes that it is reasonable to assume that the identified measures constitute the top 50% of program net resource value. This is a one-time request, has no effect on earnings, and does not affect future earnings claims. Therefore, SDG&E is requesting that it be granted this waiver to identify retention measures for the PY94 CEEI, NRNC, IEEI and RAEI-Refrigerator Programs as described above.