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1995 Residential Weatherization Retrofit Incentives

Ninth Year Retention Evaluation

March 2004

Study ID No. 958

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1995 RESIDENTIAL WETHERIZATION RETROFIT INCENTIVES PROGRAM:

NINTH YEAR RETENTION EVALUATION

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Program Description

San Diego Gas & Electric's PY95 Residential Weatherization Retrofit Incentive Program (RWRI) was part of their DSM Replacement Bid Pilot. To meet the California Public Utility Commission's goal for DSM bidding, SDG&E contracted with SESCO to operate the RWRI program. As part of the program, SESCO offered free conservation improvements to selected homes. The program operated as approved by the CPUC on February 8, 1995 in Application 94-08-038. SESCO targeted customers based upon customer consumption history. The conservation measures installed included: attic and ceiling insulation, weatherstripping, caulking, outlet insulation, sealing by-passes, low-flow showerheads, water heater and pipe wraps, and compact fluorescent lights. The intent of the program was to reduce heating and cooling losses, resulting in energy savings for customers and the utility.

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, excluding miscellaneous measures. For PY95, two different measures, Infiltration and Attic Insulation constitute 62% of resource value. These measures were evaluated for measure retention.

The M&E Protocols require that PY94 and PY95 program years be combined for retention studies to increase sample sizes for retention measures. SDG&E did not have a program in PY94; therefore there are no measures to combine across program years.

1,995 customers installed participated in the PY95 RWRI program. All participants had infiltration measures installed and 1,285 also added attic insulation. In March 1999, SDG&E (Study ID. No. 957) filed a joint study with PG&E (Study ID. No. 332R1) conducted by Megdal

& Associates. That first retention study of PY95 RWRI entailed 90 on-sites audits in the SDG&E service territory.

In 2003, SDG&E contracted with CIC Research, Inc. to conduct telephone surveys of 350 residential customers in the PY95 RWRI program. The objective of the surveys was to verify the number of measures that were still in place and operable – the definition of effective useful life (EUL) per the M&E Protocols. A copy of the survey is provided at the end of this study.

Measures/"Like" Measures

In order to apply any changes in EUL to measures not studied, the M&E Protocols require that the utility identify any "like" measures within the program. For SDG&E's PY95 RWRI Program, the "like" measures are included in the Infiltration and Attic Insulation primary measures.

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 $S(0) = 1$:

Equation 2 (The survivor function)

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

The median lifetime

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

Equation 3 (Definition of the median m)

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

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)

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

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

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:

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

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

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):

$$h(j) = h_{ind}(j) + h_{dep}(j)$$

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

$$h_{ind}(j) = b_0^{ind} + b_1 j + b_2 j^2$$

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,

$$h_{dep}(j) = b_0^{dep}$$

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

PY95 FOURTH EARNINGS CLAIM

FOR

RESIDENTIAL WEATHERIZATION RETROFIT INCENTIVES PROGRAM

NINTH YEAR RETENTION EVALUATION

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TABLE 6 for RETENTION STUDIES
PROGRAM: RWRI
YEAR(S): 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 Per Protocols	*4. ACTUAL* EUL for 4th claim	5. Standard Error	6. Upper & lower bounds @ 80% Conf Int		7. P Value	8. Realization Rate	9. "Like" Measures to be Adjusted
PY95	HVAC	Attic Insulation	20	***	85.5	85.5	20	18.0	62.4	108.5	0.0%	4.27	1
PY95	HVAC	Infiltration	15	***	11.2	11	11	1.0	9.8	12.5	0.0	0.74	2

*** Engineering Judgement

Note: NA indicates that no failures were observed

M&E PROTOCOLS TABLE 7

DATA QUALITY AND PROCESSING

DOCUMENTATION

FOR

RESIDENTIAL WEATHERIZATION RETROFIT INCENTIVES PROGRAM

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M&E PROTOCOLS TABLE 7

DATA QUALITY AND PROCESSING DOCUMENTATION

For Residential Weatherization Retrofit Incentives Program

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B. RETENTION STUDIES

1. OVERVIEW INFORMATION

a. **Study Title and Study ID:** 1995 Residential Weatherization Retrofit Incentives Program – Ninth Year Retention Evaluation, March 2004, Study ID No. 958.

b. **Program, Program Year(s), and Program Description (Design):** Residential Weatherization Retrofit Incentives Program for the 1995 program year. The intent of the program was to reduce heating and cooling losses, resulting in energy savings for customers and the utility

c. **End Uses and Measures Covered:** HVAC end uses. The measures are Infiltration and Attic Insulation

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
PY95	Infiltration	1,995	1,995	1,995	1998: 89 On-sites 2003: 350 phone	Oct-Dec ‘98 May-June '03
PY95	Attic Insulation	1,285	1,285	1,285	1998: 63 On-sites 2003: 350 phone	Oct-Dec ‘98 May-June '03

2. 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

- Measures were determined to be in place and operable by the data collection 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:** None

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

Unused collected data: None.

3. SAMPLING

a. **Sampling procedures and protocols:** Refer to the Sampling and Data Collection section of the report. Section 1.e. above shows how the sample covered the participant population.

b. **Survey information:** A copy of the survey and a call disposition record are attached at the end of the report.

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 DISTRIBTION TABLES PER MEASURE

DATUM	DESCRIPTOR	AGE (MONTHS)
339	NN95	NA
11	NQ95	94
328	ND95	94
62	NN95	NA
12	NQ95	41
50	ND95	41
25_RWRI 95_IND_Attic Insulation.xls--independent failures		

DATUM	DESCRIPTOR	AGE (MONTHS)
262	NN95	NA
88	NQ95	94
174	ND95	94
176	NN95	NA
55	NQ95	41
121	ND95	41
25_RWRI 95_IND_Weatherization.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
CEEI	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 SURVEYS

FOR

RESIDENTIAL WEATHERIZATION RETROFIT INCENTIVES PROGRAM

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1998 Site Visit Survey for the Retention Study of the RWRI Program -- SDG&E

(90 On-Sites Were Completed in SDG&E Service Territory Oct - Dec 1998)

Utility_____ ASW Tracking #__ Surveyor Initials __ Survey ID Date ____

Customer Name
Contact for Visit
Street Address
City
Zip
Phone number(s)
Account #
Schedule Date & Time
Other Scheduling

From sample database (1=Yes, 0=No)
SDG&E
Infiltration – cooling _____
Attic Insulation _____
Infiltration – heating _____

Q1 Were you the owner in 1994? Yes ___ No ____

Attic Insulation

[AS A RETENTION STUDY, WE ARE ONLY INTERESTED IN THE PROPORTION REMAINING IN PLACE. NOT THE PROPORTION COVERED INITIALLY]

Q2 What proportion of the **attic insulation** is still in place (of that you can tell was originally there)? **[If "All" skip Q3 & Q4]**

All _____ Most ____Half ____Less than half___ None____
Q3 When was the attic insulation removed? [ASK CUSTOMER]
Month ____ Year ___

Q4 Why was it removed?

_____
[ASK CUSTOMER]

Infiltration

Q15 What proportion of **window caulking** is still in place (of that you can tell was originally there)?

All _____ Most ____ Half _____ Less than Half ____ None ___ Never Installed ____

Q16 What proportion of **weatherstripping on exterior doors** is still in place (of that you can tell was originally there)?

All _____ Most ____ Half _____ Less than Half ____ None ___ Never Installed ____

Q17 What proportion of **electrical outlet insulation (switches and receptacles)** are still in place (of that you can tell was originally there)?

All _____ Most ____ Half _____ Less than Half ____ None ___ Never Installed ____

Q18 What proportion of **sealing on bypass** (sealing on plumbing accesses & special openings) are still in place (of that you can tell was originally there)?

All _____ Most ____ Half _____ Less than Half ____ None ___ Never Installed ____

NOTES:

Homeowner Insulation and Infiltration Study
May - June 2003

Hello. This is _____, I am calling on behalf of San Diego Gas & Electric Company. They want to know if the energy-efficiency measures installed in your home a few years ago are still in place. Have I reached the residence at (address)?

(**If no, terminate the survey and thank customer**).

A. Am I speaking to the person in your household who is most knowledge about the energy-efficiency measures that were installed?

1 yes (CONTINUE)
2 no (ASK TO SPEAK TO THAT PERSON, RESCHEDULE IF NECESSARY)

1. (**ATTIC INSULATION**:) Thinking about your home's attic insulation. Has any remodeling, new construction, or major damage caused any of the insulation to be removed?
FROM CONTACT SHEET

1 yes (CONTINUE)
2 no (SKIP TO Q2)

1a. Approximately what percentage would you say was removed? _____ %

1b. When was the attic insulation removed? _____ (**MONTH**) & _____ (**YEAR**).

2. (**INFILTRATION**:) Thinking about the weatherstripping, caulking, and insulation around your doors, windows, and plumbing. Does any of it currently need to be replaced?
FROM CONTACT SHEET

1 yes (CONTINUE)
2 no (TERMINATE SURVEY AND THANK CUSTOMER)

2a. Approximately what percentage needs to be replaced? _____ %

2b. When did you notice it needed replacement? _____ (**MONTH**) & _____ (**YEAR**).

(TERMINATION MESSAGE)

"Thank you very much for your time and cooperation."

Call Disposition

Call Result	**Number**	**Percent**
Completed interviews	***350***	***27.2%***
Answering machine	106	8.2%
Refusals	80	6.2%
Callbacks	19	1.5%
No answer	167	13.0%
Number not in service	197	15.3%
Wrong number	82	6.4%
Business number	60	4.7%
Other language	6	0.5%
Busy number	40	3.1%
Most knowledgeable resident never available	16	1.2%
Blocked number	50	3.9%
Wrong address	112	8.7%
Total	**1,285**	**100.0%**