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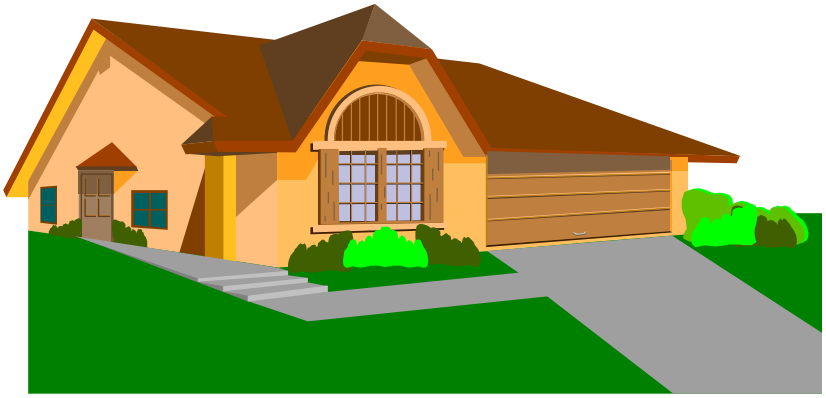
1994 & 1995 Residential New Construction Program

Fourth Year Retention Evaluation

March 1999



Study ID No. 933

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1994 & 1995 RESIDENTIAL NEW CONSTRUCTION INCENTIVES:

FOURTH YEAR RETENTION EVALUATION

STUDY ID NO. 933

Program Description

SDG&E's PY94 and PY95 Residential New Construction Program was designed to encourage new home builders to incorporate energy saving advanced building technologies and appliances that exceeded Title 24 State Building Energy Efficiency Standards. By so doing, developers were able to take advantage of conservation opportunities at the optimum time. All residential builders who exceeded the space cooling, space heating, or water heating standards of Title 24 by a minimum of five percent were eligible to participate in the program.

Financial incentives were provided to builders to help offset additional costs of installing the more energy-efficient measures of high performance glass, air conditioning, and R-19 wall insulation.

Sampling and Data Collection

Since incentives were provided to the new construction developers, actual residents in those homes may have been unaware of their program participation. In PY94 and PY95, SDG&E rebated 877 measures at 840 unique addresses. These addresses provided by the developer often were lot numbers without street numbers or street names. Since this was a new construction program, the homes were uninhabited at the time of participation so no customer name was provided.

Matching current residents with the data provided proved to be challenging. Several passes at the customer master file and looking up addresses in a "reverse" phone directory (sorted by street name, not customer name), created a database of 262 customers. These 262 customers became the retention sample for this study.

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. The three measures in the Residential New Construction Program were 1) air conditioners with a SEER rating of 11.0 or greater; 2) high performance glass (tinted or dual paned); and 3) R-19 wall insulation. All three measures were evaluated for estimating their Effective Useful Life (EUL).

SDG&E contracted with CIC Research, Inc. to conduct telephone surveys on all 262 identified participants in the program. CIC Research successfully completed 119 interviews, a 45% response rate. 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 and PY95 Residential New Construction Program, all three measures in the program were evaluated, so there are no "like" 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.

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

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:

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

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

PY94 THIRD EARNINGS CLAIM

FOR

RESIDENTIAL NEW CONSTRUCTION PROGRAM

FOURTH YEAR RETENTION EVALUATION

MARCH 1999

STUDY ID NO. 933

TABLE 6 for RETENTION STUDIES
PROGRAM: Residential New Construction
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
Space Cond.	A/C SEER 11.0	18	**	NA	18	NA	NA	NA	NA	1.00	none
Space Cond.	A/C SEER 11.1	18	**	NA	18	NA	NA	NA	NA	1.00	none
Space Cond.	High Performance Glass	20	***	12.0	20	18.1	2.2	21.7	50.7%	1.00	none
Space Cond.	R-19 Wall Insulation	20	***	NA	20	NA	NA	NA	NA	1.00	none

*M&E Protocols Appendix "F"

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

*** Custom Job: Engineering Judgement

Note: NA indicates that no failures were observed

M&E PROTOCOLS TABLE 7

DATA QUALITY AND PROCESSING

DOCUMENTATION

FOR

RESIDENTIAL NEW CONSTRUCTION PROGRAM

FOURTH YEAR RETENTION EVALUATION

MARCH 1999

STUDY ID NO. 933

M&E PROTOCOLS TABLE 7

DATA QUALITY AND PROCESSING DOCUMENTATION

For Residential New Construction Program

Fourth Year Retention Evaluation

March 1999

Study ID No. 933

1. OVERVIEW INFORMATION

a. **Study Title and Study ID:** 1994 and 1995 Residential New Construction Program – Fourth Year Retention Evaluation, March 1999, Study ID No. 933.

b. **Program, Program Year(s), and Program Description (Design):** Residential New Construction Program for the 1994 and 1995 program years. The Program was designed to encourage new homebuilders to incorporate energy saving advanced building technologies and appliances that exceeded Title 24 State Building Energy Efficiency.

c. **End Uses and Measures Covered:** Space Conditioning; three measures: high performance glass, air conditioners, and R-19 wall 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
94&95	A/C SEER 11	87	87	87	39	July-98
94&95	A/C SEER 12	274	274	274	62	July-98
94&95	A/C SEER 13	1	1	1	0	July-98
94&95	Hi Perf Glass	94	94	94	10	July-98
94&95	R-19 wall ins	421	421	421	8	July-98

2. DATABASE MANAGEMENT

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

- Lot number, installed measures, and participation date from the program tracking database
- Customer name, address, phone number, from master file and "reverse" phone directory
- Measures 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:** 877 measures were installed at 840 unique addresses (lot numbers) in the program. Matching lot numbers to current residents produced a database of 262. Multiple attempts were made to contact the 262 by phone; 119 interviews were completed.

SDG&E New Construction Study
Final Dialing Results
July 1998

Call Result	No.	%
Number not in service	47	17.9
Business number	28	10.7
Wrong number	21	8.0
Refusal	15	5.7
Answering machine	14	5.3
No answer	7	2.7
Other language	5	1.9
Respondent never available	2	0.8
Callback	2	0.8
Busy Number	2	0.8
Completed interviews	119	45.4
TOTAL	262	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 census of PY94 and PY95 was attempted. Because the program participants were developers and builders, participating units were identified by lot numbers, not street addresses and before occupancy took place. Attempting to identify current occupants in those dwellings without street addresses proved challenging. See the section of the report entitled Sampling and Data Collection and 2b above for a detailed description.

b. **Survey information:** A copy of the SDG&E New Construction Survey is attached at the end of the report. The survey completed response rate was 45.4%; see 2.b. above for reasons for non-completed surveys.

c. **Statistical Descriptions:** See Failure Distribution Table 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 table,

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 TABLE

DATUM	DESCRIPTOR	AGE (MONTHS)
10	NN94	NA
1	NF94	40
1	NF94	5
8	ND94	45
rnc-win.xls		

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
RNC	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 NEW CONSTRUCTION PROGRAM

FOURTH YEAR RETENTION EVALUATION

MARCH 1999

STUDY ID NO. 933

SDG&E Residential New Construction - #408
July 1998

Merge #_____ _____

Hello. This is _____ calling on behalf of SDG&E. We're conducting a brief survey to determine if energy efficiency measures placed in newly built homes are still in place. Have I reached the residence at (address)? According to SDG&E records, you moved into a home that was built in 1994 or 1995. Is that correct? (IF YES, CONTINUE. IF NO, PROBE TO BE CERTAIN YOU DON'T HAVE THE RIGHT HOUSEHOLD.)

As you may or may not know, the contractor who built your home participated in an SDG&E energy efficiency program which included . . . (READ ITEMS CHECKED BELOW)

1 dual-paned or tinted windows — a_____
2 wall insulation — b_____
3 energy-efficient central air conditioning — c_____

The California PUC requires that SDG&E contact customers who have participated in their energy efficiency programs to see if the items are still in place. Therefore, I have just a couple of quick questions to ask you. (ASK FOR ITEMS CHECKED ABOVE)

1. First, have you replaced any of the windows that were originally installed in the house?

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

   1a. Did you replace them with windows which were tinted or double paned, or just ordinary glass?

   1 tinted or double paned 2 ordinary glass 9 DK — 2_____

   1b. When did you replace them? month & year __/_____ — 3_____

2. Is the wall insulation that was originally installed still in place, or has some remodeling or construction taken place which removed some of that original insulation? — 4_____

   1 yes, all insulation is still in place (SKIP TO Q3)
   2 no (EXPLAIN) _____

   _____

   2a. When did that construction take place? month & year __/_____ — 5_____

3. Is the central air conditioning that was installed when the house was new still in place and operable?

_1_ yes, in place and operable (SKIP TO CLOSING)
_2_ yes, in place but not operable (CONTINUE)
_3_ no, not in place (CONTINUE)

6____

3a. When was it removed or when did it become inoperable?

month & year /_____

7____

Those are all my questions. Thanks so much for your cooperation.