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1996 Residential New Construction *Program*

Ninth Year Retention Evaluation

March 2006



Study ID No. 1003

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**1996 RESIDENTIAL NEW CONSTRUCTION INCENTIVES:
NINTH YEAR RETENTION EVALUATION
STUDY ID NO. 1003**

Program Description

SDG&E's PY96 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 PY96, SDG&E rebated 194 measures at 191 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 68 customers in the 1999 sample. Additional research increased the numbers over the years, culminating with 110 names in 2005. These 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 identified participants in the program. CIC Research attempted up to 10 phone calls to complete the survey with participants. The survey completed response rate ranged from a 53.7% to 85.3%. A copy of the SDG&E New Construction 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 PY96 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)

$$-\frac{dS(j)/dj}{S(j)} = h(j) = b_0 + b_1j + b_2j^2$$

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)

$$S(j) = e^{-(\beta_1j + \beta_2j^2 + \beta_3j^3)} \quad (\beta_1 = b_0, \quad \beta_2 = \frac{b_1}{2}, \quad \beta_3 = \frac{b_2}{3})$$

The median lifetime

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

Equation 3 (Definition of the median m)

$$S(m) = e^{-(\beta_1m + \beta_2m^2 + \beta_3m^3)} = \frac{1}{2}$$

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,

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

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:

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

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

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):

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

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

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

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,

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

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):

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

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,

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

M&E PROTOCOLS TABLE 6
RESULTS USED TO SUPPORT
PY96 FOURTH EARNINGS CLAIM
FOR
RESIDENTIAL NEW CONSTRUCTION PROGRAM
NINTH YEAR RETENTION EVALUATION
MARCH 2006
STUDY ID NO. 1003

TABLE 6 for RETENTION STUDIES
PROGRAM: Residential New Construction
YEAR: PY96

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	**	239.1	18	166.0	26.4	451.9	18.3%	13.29	none
Space Cond.	High Performance Glass	20	***	173.4	20	134.2	1.3	345.4	25.3%	1.00	none
Space Cond.	R-19 Wall Insulation	20	***	291.1	20	168.0	75.8	506.4	10.7%	14.56	none

*M&E Protocols Appendix "F"

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

*** Custom Job: Engineering Judgement

M&E PROTOCOLS TABLE 7

DATA QUALITY AND PROCESSING DOCUMENTATION

FOR

RESIDENTIAL NEW CONSTRUCTION PROGRAM

NINTH YEAR RETENTION EVALUATION

MARCH 2006

STUDY ID NO. 1003

M&E PROTOCOLS TABLE 7
DATA QUALITY AND PROCESSING DOCUMENTATION
For Residential New Construction Program--Ninth Year Retention Evaluation
March 2006
Study ID No. 1003

B. Retention Studies

1. OVERVIEW INFORMATION

a. Study Title and Study ID:

1996 Residential New Construction Program – Ninth Year Retention Evaluation, March 2006, Study ID No. 1003.

b. Program, Program Year(s), and Program Description (Design):

Residential New Construction Program for the 1996 program year. 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 overview 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
96	A/C SEER > 11	108	108	108	26 31 21 27 22 23 46	Nov-Dec 1999/ Aug 2000 Aug-Sep 2001 May-June 2002 May-Aug 2003 Aug-Sep 2004 Aug 2005
96	Hi Perf Glass	40	40	40	9 7 4 4 3 1 16	Nov-Dec 1999/ Aug 2000 Aug-Sep 2001 May-June 2002 May-Aug 2003 Aug-Sep 2004 Aug 2005
96	R-19 wall ins	46	46	46	23 23 19 16 18 25 21	Nov-Dec 1999/ Aug 2000 Aug-Sep 2001 May-June 2002 May-Aug 2003 Aug-Sep 2004 Aug 2005

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:

194 measures were installed at 191 unique addresses (lot numbers) in the program. Matching lot numbers to current residents produced an initial database of 68 in 1999. Additional research increased the numbers over the years, culminating with 110 names in 2005. Multiple attempts (up to 10 calls per residence) were made to contact the all the participants by phone with the tallies presented in the table below.

SDG&E 1996 New Construction Study
Final Dialing Results

Call Result	1999 Results		2000 Results		2001 Results		2002 Results	
	No.	%	No.	%	No.	%	No.	%
Number not in service	1	1.5	5	6.3	10	13.2	10	11.9
Business number	4	5.9	3	3.8	1	1.3	5	5.9
Other language	2	2.9	--	--	2	2.6	3	3.6
Wrong number	2	2.9	4	5.0	5	6.6	11	13.1
Refusals	--	--	2	2.5	5	6.6	4	4.8
Answering Machine	1	1.5	1	1.3	6	7.9	3	3.6
No answer	--	--	1	1.3	1	1.3	2	2.4
Callbacks	--	--	1	1.3	1	1.3	0	0
Busy line	--	--	1	1.3	-	--	0	0
Completed interviews	58	85.3	61	77.2	45	59.2	46	54.8
Total	68	100.0	79	100.0	76	100.0	84	100.0

Call Result	2003 Results		2004 Results		2005 Results	
	No.	%	No.	%	No.	%
Number not in service	7	8.8	9	11.3%	7	6.4
Business number	1	1.3	2	2.5%	7	6.4
Other language	2	2.5	0	0.0%	0	--
Wrong number	7	8.8	8	10.0%	0	--
Refusals	4	5.0	2	2.5%	6	5.4
Answering Machine	8	10.0	6	7.5%	3	2.7
No answer	5	6.2	5	6.3%	2	1.8
Callbacks	3	3.7	0	0.0%	3	2.7
Busy line	0	0	0	0.0%	1	1.0
Completed interviews	43	53.7	48	60.0%	81	73.6
Total	80	100.0	80	100.0%	110	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. Summary of data

Given the small number of PY96 RNC participants and the difficulty in identifying who the participants were from developer lot numbers, CIC Research attempted a census of identified participants each year. CIC Research attempted to reach each identified participant with a minimum of 10 call attempts before labeling the call as incomplete.

3. SAMPLING

a. Sampling procedures and protocols:

A census of PY96 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 ranged from a 53.7% to 85.3%; see 2.b. above for reasons for non-completed surveys.

c. Statistical Descriptions:

Measure	Independent or dependent failure analysis (see report)	Variable Designation (see report)	Sample Size (observations or failures)	Age of failure (months)
Wall insulation	Independent	n	132	Not applicable
		n ^Q	3	115
Air conditioning	Independent	n	181	Not applicable
		n ^Q	2	115
		n _j ^F	1	17
		n _j ^F	1	63
		n _j ^F	1	89
Windows	Independent	n	44	Not applicable
		n ^Q	1	68

4. DATA SCREENING AND ANALYSIS

a. Outliers and Missing Data Points:

No outliers and no missing data.

b. Background Variables:

Age is the only variable in the life analysis.

c. Screened Data:

Through the multiple years of surveying, several households (fifteen) were surveyed more than once. This multiple-surveying was accounted for in estimating results and determining sample size.

d. Model statistics:

See M&E Protocol Table 6.

e. Specification:

Measure	Specification for dependent failures	Specification for independent failures	Mixed estimation
Wall insulation	Not applicable	Exponential	None
Air conditioning	Not applicable	Exponential	None
Windows	Not applicable	Exponential	None

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:

For windows, the estimate was based on a single failure.

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
NINTH YEAR RETENTION EVALUATION
MARCH 2006
STUDY ID NO. 1003***

SDG&E Residential New Construction

Annual Survey from 1999 - 2005

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 1996. 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
- 2 wall insulation
- 3 energy-efficient central air conditioning

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)

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

1b. When did you replace them? month & year ____/____

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?

1 yes, all insulation is still in place (SKIP TO Q3)

2 no (EXPLAIN) _____

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

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)

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

month & year / _____

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