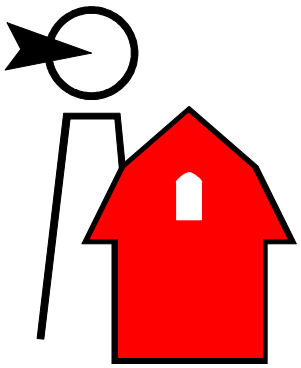
San Diego Gas & Electric
Marketing Programs & Planning
8335 Century Park Court
San Diego, California 92123

# 1996 & 1997 Agricultural Energy Efficiency Incentives

## Sixth Year Retention Evaluation

***March 2003***



Study ID Nos. 1000 & 1024

## Table of Contents

# 1996 & 1997 AGRICULTURAL ENERGY EFFICIENCY INCENTIVES:

# SIXTH YEAR RETENTION EVALUATION

# STUDY ID NOS. 1000 & 1024

## Program Description

SDG&E's PY96 & PY97 Agricultural Energy Efficiency Incentives Program was designed to help customers reduce energy costs and increase energy efficiency at their facilities while providing positive resource value to society.

A customer who participated in SDG&E's Agricultural Energy Efficiency Incentives Program received a rebate upon completed installation of the equipment. Information regarding customer name, address, phone number, installed measures, measure costs, energy savings and participation date were kept in SDG&E's project tracking system. 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, excluding miscellaneous measures. In PY96, four measures in the Agricultural Energy Efficiency Incentives Program accounted for 51% of program TRC and thus require a retention study. For PY97, three measures accounted for 56% of program TRC. These seven measures were evaluated for retention.

SDG&E contracted with Xenergy, Inc. to conduct an on-site survey of the participating customers to verify that the measures were still in place and operable – the definition of effective useful life 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, M&E Protocols require that the utility identify any "like" measures within the program. For SDG&E's PY96 & PY97 Agricultural Energy Efficiency Incentives Program, the "like" measures are in the lighting and

pumping end uses. M&E Protocol Table 6 in this report identifies those measures that are determined to be "like" measures (those measures that were not studied but have similar characteristics to measures that were evaluated in this retention study).

## 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]

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

**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)**

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

### *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 $\omega$ 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 $\beta$, the median lifetime can be estimated using Equation 3.

The estimated variance of $\beta$, 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 $\beta$; 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*

# *PY96 & PY97 FOURTH EARNINGS CLAIM*

# *FOR*

# *AGRICULTURAL ENERGY EFFICIENCY INCENTIVES PROGRAM*

# *SIXTH YEAR RETENTION EVALUATION*

# *MARCH 2003*

# *STUDY ID NOS. 1000 & 1024*

**TABLE 6 for RETENTION STUDIES**
**PROGRAM: AgEEI**
**YEAR(S):** PY96 & PY97

| | 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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PY96 | LIGHTING | 5-10W CFL | 10 | ** | 29.3 | 10.0 | 37.9 | (19.3) | 77.9 | 61.1% | 1.00 | 1 |
| PY96 | LIGHTING | CF-7 Hardwire Fxtr | 16 | ** | NA | 16.0 | NA | NA | NA | NA | 1.00 | 2 |
| PY96 | LIGHTING | CF-9 Hardwire Fxtr | 16 | ** | NA | 16.0 | NA | NA | NA | NA | 1.00 | 3 |
| PY96 | PUMPING | VFD for High Lift Sewer Pump | 15 | **** | NA | 15.0 | NA | NA | NA | NA | 1.00 | 4 |
| PY97 | PUMPING | Redesign Booster Pump, Pumping Efficiency 86% | 15 | **** | NA | 15.0 | NA | NA | NA | NA | 1.00 | 5 |
| PY97 | PUMPING | Efficient Pump | 15 | *** | NA | 15.0 | NA | NA | NA | NA | 1.00 | 6 |
| PY97 | PROCESS | Ultrafine Aeration Diffusers Panel | 15 | **** | NA | 15.0 | NA | NA | NA | NA | 1.00 | 7 |

| # above | 9. "Like" Measures to be Adjusted | |
|---|---|---|
| 1 | 11-15W CFL | PY96 |
| 4 | VFD for Low Lift Sewage Pumps | PY96 |

*M&E Protocols Appendix "F"

**Advice Letter filing 957-E-A/986-G-A: Feb 1, 1996

***Advice Letter filing 1001-E/1030-G: Oct 1, 1996

**** Custom Job: Engineering Judgement

Note: NA indicates that no failures were observed

# *M&E PROTOCOLS TABLE 7*

# *DATA QUALITY AND PROCESSING*

# *DOCUMENTATION*

# *FOR*

# *AGRICULTURAL ENERGY EFFICIENCY INCENTIVES PROGRAM*

# *SIXTH YEAR RETENTION EVALUATION*

# *MARCH 2003*

# *STUDY ID NOS. 1000 & 1024*

**M&E PROTOCOLS TABLE 7**

**DATA QUALITY AND PROCESSING DOCUMENTATION**

**For Agricultural Energy Efficiency Incentives Program**

**Sixth Year Retention Evaluation**

**March 2003**

**Study ID Nos. 1000 & 1024**

## B. Retention Studies

## 1. OVERVIEW INFORMATION

### a. Study Title and Study ID:

1996 & 1997 Agricultural Energy Efficiency Incentives Program – Sixth Year Retention Evaluation, March 2003, Study ID Nos. 1000 & 1024.

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

Agricultural Energy Efficiency Incentives Program for the 1996 and 1997 program years. The Program was designed to help customers reduce energy costs and increase energy efficiency at their facilities while at the same time providing positive resource value to society.

### c. End Uses and Measures Covered:

Lighting, pumping, and process end uses. The measures are identified in Table 6.

### 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 |
|---|---|---|---|---|---|---|
| 1996 | 5-10W CFL | 4 | 7,048 | 7,048 | 7,048 | Aug-Oct '99<br>May-Aug '00<br>June ’01<br>June ‘02 |
| 1996 | CF-7 Hardwire Fxtr | 1 | 2,050 | 2,050 | 2,050 | Oct '99<br>May '00<br>June ’01<br>June ‘02 |
| 1996 | CF-9 Hardwire Fxtr | 2 | 1,105 | 1,105 | 1,105 | Oct-Dec '99<br>May '00<br>June ’01<br>June ‘02 |
| 1996 | VFD for High Lift Sewer Pump | 1 | 1 | 1 | 1 | Aug '99<br>May '00<br>July ’01<br>June ‘02 |
| 1997 | Redesign Booster Pump, Pumping Efficiency 86% | 1 | 1 | 1 | 1 | Oct '99<br>Aug '00<br>July ’01<br>June ‘02 |
| 1997 | Efficient Pump | 1 | 2 | 2 | 2 | Sep '99<br>Apr '00<br>July ’01<br>June ‘02 |
| 1997 | Ultrafine Aeration Diffusers Panel | 1 | 1 | 1 | 1 | Aug '99<br>May '00<br>July ’01<br>June ‘02 |

## 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 on-site 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 analysis leading to the estimated Effective Useful Life

**b. Data Attrition:**

There was no data attrition. On-site audits were successfully conducted on all program participants in 1999, 2000, 2001 and 2002.

**c. Data Quality Checks:**

The data sets for the 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. Data collected**

All data for this analysis was utilized.

**3. SAMPLING**

**a. Sampling procedures and protocols:**

A census was attempted and successfully completed.

**b. Survey information:**

A copy of the Survey is attached at the end of the report. The survey completed response rate was 100%.

**c. Statistical Descriptions:**

| Measure | Independent or dependent failure analysis (see report) | Variable Designation (see report) | Sample Size (observations or failures) | Age of failure (months) |
|---|---|---|---|---|
| 5-10W CFL | Dependent* | n | 7 | Not applicable |
| | | $n^Q$ | 1 | 77 |
| *A group of measures is said to have undergone "dependent failure" if the number of failures is more than 40% of the group. A typical set of dependent failures is 100% of the group. For dependent failures, n is the number of groups, not the number of measures in the group. | | | | |

# 4. DATA SCREENING AND ANALYSIS

## a. Outliers and Missing Data Points:

No outliers and no missing data.

## b. Background Variables:

NA

## c. Screened Data:

None.

## d. Model statistics:

See M&E Protocol Table 6.

## e. Specification:

| Specification for dependent failures | Specification for independent failures | Mixed estimation |
|---|---|---|
| Exponential | NA | 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:

The single estimate for CFLs is based in a single dependent 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*

# *AGRICULTURAL ENERGY EFFICIENCY INCENTIVES PROGRAM*

# *SIXTH YEAR RETENTION EVALUATION*

# *MARCH 2003*

# *STUDY ID NOS. 1000 & 1024*

## *SDG&E AgEEI Survey*

Aug-Oct 1999

May-Aug 2000

June-July 2001

June 2002

**SDG&E PY96 & PY97 Agricultural EEI Program**
**Measure Retention Survey**

**Site nbr:** **Site sec:** **PART:**

**Site nm:**

Rank: **Address:**

**Site Ctv:**

**Bldg sz:** **Bldg lgt:**

**ENDUSE:**

Site Contact (DB):
Contact Ph:

Alternate contact name:
Alternate contact phone:

Surveyor:
Suvey Date:

| Contract | MSR # | NEW DESC | kWh Sav. | kW Red. | Th. Sav. | MSR LOC | Ins. Qty | Run Hrs | Ver. Schedule (incl.date of change in schedule) |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | |

**SDG&E PY96 & PY97 Agricultural EEI Program**
**Measure Retention Survey**

**Site_nbr:** **Site_sec:** **PART:**
Site Contact (DB):
Contact Ph:

**Site_nm:**

Rank: **Address:**
Alternate contact name:
**Site_Cty:**
Alternate contact phone:

**Bldg_sz:** **Bldg_lgt:**
Surveyor:

**ENDUSE:**
Suvey Date:

**SURVEY DISPOSITION**

Audit Completed?: [ ]Yes [ ]No (check

Reason for not completed: [ ]
1 = Unable to reach/contact.
2 = Changed mind about participation in study.
3 = Premise closed/not operating.
4 = Site/contact info incorrect and could not find alternate contact.
5 = Requested to call back, could not complete call.
6 = Rescheduled upon arrival at site.
7 = Other: Describe:

**DISCREPANCIES**

Reason for discrepance in counts (check one and describe if necessary)
[ ]=Removed, not replaced (include date of
[ ]=Never installed
[ ]=Exceeds tracking system counts (describe reasons for additional eqmt, eg, retrofits part of SDG&E Program in
[ ]=Removed, replace with more efficient
[ ]=other, describe situation fully

Description/Comments:

**SDG&E PY96 & PY97 Agricultural EEI Program**
**Measure Retention Survey**

**Site_nbr:** **Site_sec:** **PART:**
Site Contact (DB):
Contact Ph:

**Site_nm:**

Rank: **Address:**
**Site_Cty:**

Alternate contact name:
Alternate contact phone:

**Bldg_sz:** **Bldg_lgt:**

Surveyor:
Suvey Date:

## Facility Tenancy/Ownership:

Have Tenant and Owner remained the same? [ ] Yes [ ] No (check one)
If NO, what best describes the situation [ ] (select one, describe below)

1. New tenant-same owner.
2. Same tenant-New owner
3. New tenant-New owner
4. Premise closed.

Description/Comments:

## Building/Facility Configuration:

Check one box that represents the facility layout (check all that apply, describe below):
[ ] Same as time of installation.
[ ] Same tenant, had tenant improvements
[ ] Same tenant, increased floorspace
[ ] Same tenant, decreased floorspace
[ ] New tenant, no tenant improvements
[ ] New tenant, and had tenant improvements
[ ] New tenant, increased floorspace
[ ] New tenant, decreased floorspace, ie, there is empty floorspace.

Description/Comments: