6TH YEAR RETENTION STUDY OF PACIFIC GAS & ELECTRIC COMPANY'S 1996 AND 1997 ENERGY EFFICIENCY INCENTIVES PROGRAM, AGRICULTURAL SECTOR MEASURES:

PG&E Study ID number: 354R2, 385R2, 335AR2, 335BR2, 335CR2

March 1, 2003

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Sixth Year Measure Retention Study of Pacific Gas & Electric Company's Agricultural Sector
1996 and 1997 Nonresidential Energy Efficiency Incentives Programs
Study IDs: 354R2, 385R2, 335AR2, 335BR2, & 335CR2

Purpose of Study

The purpose of the attached study is to document the level of measure retention in the sixth year after installation and to estimate the ex post effective useful life (EUL) values for PG&E's 1996 and 1997 Agricultural Energy Efficiency Incentives (AEEI) Programs. As required, the study was conducted in compliance with the requirements specified in "Protocols and Procedures for the Verification of Costs, Benefits, and Shareholders Earnings from Demand-Side Management Programs" (Protocols), as adopted by California Public Utilities Commission Decision 93-05-063, revised March, 1998, pursuant to Decisions 94-05-063, 94-10-059, 94-12-021, 95-12-054, 96-12-079, 98-03-063, and 99-06-052. The study covers measures representing the top 66% of the estimate resource value, which exceeds the Protocol requirements. These measures include pump repair, micro irrigation conversion, and high intensity discharge lighting measures. The AEEI Program promoted the purchase of energy efficient technologies to the agricultural sector through financial incentives paid to agricultural participants.

Methodology

When PG&E conducted the 1996 and 1997 impact studies, it created retention panels documenting the equipment type and location for approximately 150 sites per program year. These sites were revisited in 1999 and 2000 (three years after installation) and again in 2002 (six years after installation) to assess whether the measures were still "in place and operable", as required by the Protocols. The resultant data was then analyzed using three basic approaches to estimating EULs. These were the classic survival analysis, the standard ordinary least squares, and the assumed functional form approach.

Study Results

1) HID Measures – HID measures had only a 1% failure rate. An analysis was attempted and produced an implausibly large EUL. Thus the ex ante EUL of 16 years will be retained
2) Micro Irrigation – There were no failures to date for the micro irrigation measure, it was impossible to perform an EUL analysis. Thus the ex ante EUL of 20 years will be retained
3) Pump Repair – Of the measures studied, pump retrofit was the only measure that had enough installed measures identified as not "in place and operable" to proceed with statistically valid analysis. This analysis produced an EUL estimate that was statistically indistinguishable from the ex ante EUL estimate.

Thus, as is shown below, the EUL values for the sixth year earnings claim for all studied measures will be the same as the ex ante estimated EULs.

Regulatory Waivers and Filing Variances

A waiver concerning earnings calculation methodology is included for completeness. There were no variances from the E-Tables.

PG&E's 1996 Agricultural Sector Energy Efficiency Incentive Programs
Summary of Ex Post Effective Useful Life Estimates from 6th Year Retention Study

		EUL		Upper 80% CL	Lower 80% CL	EUL for Claim
Measure Description	**Code**	**Ex Ante**	**Ex Post**	**Ex Post**	**Ex Post**	**-**
Pump Retrofit	A1	9.0	10.5	13.7	7.3	9.0
Sprinkler to Micro, Valley/Well/Field Vegetables (1)	A44	20.0	NA	NA	NA	20.0
HID Fixture: Interior, 251-400 Watt Lamp (2, 3)	L81	16.0	358	433	305	16.0

(1) Impossible to do the analyses because there were no failures.
(2) Results are implausibly large
(3) These results also apply to measures L26, L27, and L37 which are different wattage versions of interior HID fixtures.

PG&E's 1997 Agricultural Sector Energy Efficiency Incentive Programs
Summary of Ex Post Effective Useful Life Estimates from 6th Year Retention Study

		EUL		Upper 80% CL	Lower 80% CL	EUL for Claim
Measure Description	**Code**	**Ex Ante**	**Ex Post**	**Ex Post**	**Ex Post**	**-**
Pump Retrofit	A1	9.0	10.5	13.7	7.3	9.0
Sprinkler to Micro, Valley/Well/Field Vegetables (1)	A44	20.0	NA	NA	NA	20.0
Sprinkler to Micro, Valley/No Well/ Deciduous (1, 2)	A49	20.0	NA	NA	NA	20.0

(1) Impossible to do the analyses because there were no failures.
(2) These results also apply to measures A45, A47, A51, and A55, which are "like" measure A49

If the measure shows NA for the Ex Post EUL, it is because there were no failures observed and therefore, could not be analyzed.

Equipoise Consulting, Inc.

Energy Analysis

Project Management

Training

Final Report for

Pacific Gas & Electric Company's 1996 and 1997 6th Year Agricultural EEI Program Retention Study

Submitted by:

Equipoise Consulting Incorporated

in association with

California AgQuest Consulting and

Ridge & Associates

March 1, 2003

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1. EXECUTIVE SUMMARY

This report presents the results of the 6th year retention study of Pacific Gas and Electric Company's (PG&E) Paid Year (PY) 1996 and PY 1997 Agricultural Programs. The *Protocols and Procedures for the Verification of Costs, Benefits, and Shareholder Earnings from Demand-Side Management Programs* (Protocols)[1] call for a retention study of the Effective Useful Life (EUL) for the agricultural sector three and six years after the measures are installed. The 3rd year retention study was completed March 1, 2001 and filed with the California Public Utilities Commission.

According to the Protocols, a measure retention study is "to collect data on the fraction of measures or practice remaining in a given year that will be used to produce a revised estimate of its effective useful life."[2] This study uses, where possible, classic survival, ordinary least squares, and assumed functional form analyses of the retention data to assess whether the ex post estimates should replace the ex ante value of EUL. The studies assessed EULs for measures representing 66% of the avoided cost for measures installed in the 1996 and 67% of the avoided cost for measures installed in 1997 in the Agricultural Sector.

Exhibit 1.1 shows the ex ante EULs for the measures assessed, the recommended ex post EUL, and the best estimate of ex post EUL with its 80% confidence interval, for all measures assessed.

Exhibit 1.1
Ex Ante and Ex Post EUL Estimates for PY 1996 and PY1997

Measure	Ex Ante Value	Ex Post Recommended	Best Ex Post Model with 80% Confidence Interval
HID Lighting	16	16	358 (305 to 433) Model provided implausible results.
Micro Irrigation Conversion	20	20	No failures to analyze
Pump Repair	9	9	10.5 (7.3 to 13.7)

HID lighting and micro irrigation conversion measures, with 1.1% and 0% failure rates respectively, could not be meaningfully analyzed using existing techniques. Therefore, the ex ante values are retained.

The pump repair measure had sufficient failures (27% overall) for assessment. All of the analysis results supported a minimum EUL of nine years and almost all analyses supported retention of the ex ante EUL of nine years.

[1] D.93-05-063 as adopted by California Public Utilities Commission Decision 93-05-063, revised June, 1999, pursuant to Decisions 94-05-063, 94-10-059, 94-12-021, 95-12-054, 96-12-079, 98-03-063, and 99-06-052.

[2] Protocols, Table 8A, footnote 2.

2. OVERVIEW

Energy-efficiency measures installed by Demand-Side Management programs all have a predicted time period over which the measures are expected to provide energy savings. This period of time, called the engineering useful life in the Protocols, is the engineering estimate of the number of years that a piece of equipment will operate if maintained properly. However, equipment can be removed from operation for a myriad of reasons. When the engineering useful life is adjusted for early removal, the effective useful life (EUL) is determined.

The Protocol definition of EUL is "An estimate of the median number of years that the measures installed under the program are still in place and operable." The EUL is, then, the median period of time between installation and the point at which 50% of the installed measures remain "in place and operable". According to the Protocols, a measure retention study is "to collect data on the fraction of measures or practice remaining in a given year that will be used to produce a revised estimate of its effective useful life."[3]

The Protocols call for a retention study of the EULs for the agricultural sector three and six years after the measures are installed. The 3rd year retention study of the 1996 and 1997 Agricultural Programs was completed March 1, 2001 and filed with the CPUC. This report covers the 6th year retention study of the same agricultural programs.

For each planned retention study, there are specific measures from each year for which EULs were, if possible, to be updated. These planned measures are shown in Exhibit 2.1 for PY1996 and PY1997 Agricultural measures.

[3] Protocols, Table 8A, footnote 2.

Exhibit 2.1
Planned Measures for Retention Study

Program Year	Measure Code	Measure Description	# of Paid Units	Life Cycle Avoided Cost	Project Life	% of Total Avoided Cost
1996	A1	Pump Repair	68	$ 598,123	9	16%
1996	A44	Sprinkler to Micro, Valley, Well, Field/Veg (acres)	1285	$ 603,712	20	16%
1996	L81	HID Fixture: Interior, Standard, 251-400 Watt Lamp (unique apps)	57	$ 1,193,328	16	31%
Total % of Avoided Cost for 1996 Program Year						63%
1997	A1	Pump Repair	111	$ 1,051,755	9	14%
1997	A44	Sprinkler to Micro, Valley, Well, Field/Veg (acres)	1840	$ 1,097,802	20	15%
1997	A49	Sprinkler to Micro, Valley, No Well, Deciduous (acres)	3660	$ 2,225,953	20	31%
Total % of Avoided Cost for 1997 Program Year						60%

There were seven non-studied, or "like," measures associated with these studied measures. These measure associations are shown in Exhibit 2.2.

Exhibit 2.2
Non-studied Measures Associated to Studied Measures

Studied Measures		**Non-Studied Measures**		**Rationale**
PG&E Measure Code	**Measure Description**	**PG&E Measure Code**	**Measure Description**	**Reason Measures are Comparable**
L81	HID Fixture: Interior, 251-400 Watts Lamp	L26	HID Fixture: Interior, 101-175 Watts Lamp	All HID interior applications are similar. The participant to participant (or application) variation is accounted for in the range of applications studied in the retention study.
		L27	HID Fixture: Interior, 176-250 Watts Lamp	
		L37	HID Fixture: Interior, >=176 Watts Lamp	
A49	Sprinkler to Micro, Valley, No Well, Deciduous	A45	Sprinkler to Micro, Valley, Well, Deciduous	Micro irrigation systems are similar in type for perennial crops such as orchards and vineyards. They are used similarly and should have similar effective useful lives.
		A51	Sprinkler to Micro, Valley, No Well, Vineyard	
		A55	Sprinkler to Micro, Coast, Well, Vineyard	
		A47	Sprinkler to Micro, Valley, Well, Vineyard	

When the avoided costs for these "like measures" are added to the values in Exhibit 2.1, 66% of the avoided cost for 1996 and 67% of the avoided cost for 1997 were assessed.

The data collection process, analysis methodology, and analysis results for the 6th year retention of the 1996 and 1997 Agricultural Program measures are presented next.

3. DATA COLLECTION

The 1996 and 1997 Agricultural Programs first year impact studies created retention databases (also called retention panels) specific to each year. These databases, assembled in the fall of 1997 and 1998, respectively, collected information on measures so that they could be located later and the extent to which they were "in place and operable" could be assessed. As required by the Protocols, the retention database measures were selected to represent "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 the estimated resource value, whichever number of measures is less."

All data collected for this study was for the measures in the existing retention panels. There was no sample frame as the Equipoise/AgQuest team performed a census of the sites via either on-site or telephone surveys. The sample list for the 6th year study came from the 3rd year retention study, from which a few of the original retention panel points had been dropped due to failures by the third year. Exhibit 3.1 shows the original population, retention panel size, and 6th year sample size for the study of those measures in Exhibit 2.1.

Exhibit 3.1
Sample Size

Measure	*Measure Code*	*Original Program Population*	*Original Retention Database*	*3rd Year Evaluation - In Place and Operable*	*6th Year Evaluation - Sample Size*
Program Year 1996					
Pump Repair	A1	67	46	43	43
Micro Irrigation (sites)	A44	11	10	10	10
Indoor Lighting (unique applications)	L26 / L27 / L37 / L81	57	47	47	47
Total for PY1996		***135***	***103***	***100***	***100***
Program Year 1997					
Pump Repair*	A1	111	102	82	83
Micro Irrigation (sites)	A44, A49	17	17	17	17
Total for PY1997		***128***	***119***	***99***	***100***

*There is one pump that was a failure in the 3rd year evaluation because it had converted to diesel. It was audited.

The study audited one site that was previously considered as a failure (during the 3rd year retention study) because they had switched to a diesel fueled generator. The auditors checked to see if the site had reconnected to the electrical grid or continued to use diesel fuel (they continued to use diesel).

Each measure's retention data collection was conducted as follows:

- The pump repair sites had a census performed with at least 90% visited on-site, while the remaining had information collected over the telephone. Each pump was considered a single data point for analysis.
- The HID lights had the count and percentage of fixtures still in place and operable collected. A census was audited on-site.

- The micro irrigation conversion sites had the acres continuing to have micro irrigation in place collected. A census was audited on-site.

Once contacted by telephone or in person, the customer was asked a series of questions to determine if the measure was still in place and operable. (See Appendix C) If the measure was no longer in place or was not operable, the customers were asked why not and when the measure had been removed from service. Pump repair sites were queried to determine if another pump repair had occurred since the last retention study. There were 13 sites where the pump was visually inspected to be in place and operable, but the grower was unable to be contacted to determine if there had been another pump repair since the last audit. Therefore these sites were not included in the analyses. For the micro irrigation conversion sites, the number of acres still in use was determined.

As shown in Exhibit 3.2 all sites except one were audited. There was one refusal for a 1996 lighting measure.

Exhibit 3.2
Completed Audits

Measure	*Measure Code*	*Original Program Population*	*Original Retention Database*	*3rd Year Evaluation - In Place and Operable*	*6th Year Evaluation - Sample Size*	*6th Year Evaluation - Completed Audits*
Program Year 1996						
Pump Repair	A1	67	46	43	43	43
Micro Irrigation (sites)	A44	11	10	10	10	10
Indoor Lighting (unique applications)	L26 / L27 / L37 / L81	57	47	47	47	46
Total for PY1996		***135***	***103***	***100***	***100***	***99***
Program Year 1997						
Pump Repair*	A1	111	102	82	83	83
Micro Irrigation (sites)	A44, A49	17	17	17	17	17
Total for PY1997		***128***	***119***	***99***	***100***	***100***

*There is one pump that was a failure in the 3rd year evaluation because it had converted to diesel. It was audited.

4. EVALUATION METHODOLOGY

This section provides an overview of the measures being analyzed for retention and methodology used to obtain the results presented in Section 5.

4.1 Overview of Measures Assessed

There were three measures assessed in this retention evaluation. It is helpful to understand each measure and how it was determined to be "in place and operable".

Pump Repair - Participants with the pump repair measure originally were paid an incentive to "repair" their deep well pumps. This type of pump has the motor above ground that rotates a shaft reaching to the bottom of a well where it spins an impeller. The spinning impeller fits precisely into a set of bowls, creating the pressure required to lift the water up the well shaft to the ground surface. In some situations, sand or other debris can move with the water through the impeller/bowl assembly. When the quantity of sand is sufficient, it can result in an erosion of the impeller and bowl assembly. When this occurs, the pressure drops, less water is pumped for the same energy input, and the efficiency decreases. The incentive helped defray the cost to remove the impeller/bowl system and replace the impeller or bowls to reinstate the pressure and increase the efficiency of the overall pumping system. As this explanation indicates, the actual equipment changed is at the bottom of a well and was not actually viewable during a retention audit. The auditors visually inspected the motor and well system that was above ground to determine: 1) if the motor was connected to the well and 2) that the well appeared to be intact and functioning (i.e., is not caved in). The auditor then discussed the particular well with the grower and determined, by self-report, whether the pump continued to be operable and if it had had an additional pump repair performed since the repair associated with PG&E incentive. It was considered a failure if an additional pump repair had been performed or it failed the visual inspection.

Micro-Irrigation Conversion – This measure consisted of a structural change in the type of irrigation system being used. The grower moved to a micro-irrigation system from a less efficient system (e.g. high-pressure sprinklers). This change created savings at the pump through a reduction in the operating pressure and an increase in overall irrigation efficiency. Micro-irrigation systems can utilize micro-jets, which spray the water in a small diameter, or drippers, which slowly drip the water out of small holes. Micro-irrigation systems require the addition of sophisticated filtration equipment to prevent debris from entering the system and potentially clogging the micro-jets or drip emitters. The filtration equipment represents a large capital investment on the part of the grower. An on-site audit of the acres where the system was installed determined visually if the filter system was in place and that the micro-jets or drippers were in place. Further, conversation with the grower helped to determine if the system continued to be operable if it was not clear during a visual inspection. It was considered a failure if the micro system has been removed and replaced by another type of irrigation. In addition to inspecting for large changes in the irrigation type, the field auditors determined whether micro-jets had been replaced with drip emitters or vice versa through questioning the grower.

HID Lighting – This measure installed 400-watt high intensity discharge (HID) fixtures in barns and greenhouses. The auditor verified operability by turning on the lights. A burnt out lamp was not considered a failure as the fixture continues to remain. It was considered a failure when the entire fixture has been removed or replaced with a less efficient fixture.

4.2 EUL Analysis Approach

This study was an equipment survival rate study, and did not attempt to update the estimates of the energy or demand savings represented by the equipment. The resulting equipment survival rates from the 1996/97 program years were used to estimate the measure EULs, as prescribed by Tables 9 and 10 of the Protocols.

For this evaluation, three basic approaches to estimating EULs were used. The first approach used was a *classic survival analysis* of the data collected in this study. This approach involves the analysis of data that correspond to time from a well-defined time origin until the occurrence of some particular event or end-point (Collett, 1994). It is considered to be the most accurate of the three methods used since formal survival models can adjust for right, left, and interval censoring. The other two approaches cannot make any such adjustments and are used (1) when a classic survival model *cannot* be estimated, or (2) as a reality check, if the classic survival model *can* be estimated. The second approach was the standard *ordinary least squares* (OLS) (Maddala, 1992). This involved regressing the percentage of measures still in place and operable against time (i.e., months since the installation). The third approach was the *assumed functional form* (AFF) approach (Wright, 1999). The AFF assumes a functional form and involves conducting a survey at a given point in time after the installation. The collected data are then used in conjunction with the functional form to estimate the EUL.

Below is a description of the details of the most statistically rigorous approach, classic survival analysis, followed by a brief description of the OLS and the AFF.

4.3 Classic Survival Analysis

The first part of this section describes the appropriate unit of analysis. This is followed by a description of various issues surrounding survival analysis in the context of this study, including left versus right censoring, the hazard function, precision, covariates, hypothesis testing, and required failures.

4.3.1 Units of Analysis

The unit of analysis for the survival estimation is the survival unit being studied, such as patients or light bulbs. The unit of analysis is always a binary outcome - survival versus failure. For this study, the units of analysis are pumps, HID fixtures, and acres of micro irrigation conversion that are no longer in place and operable.

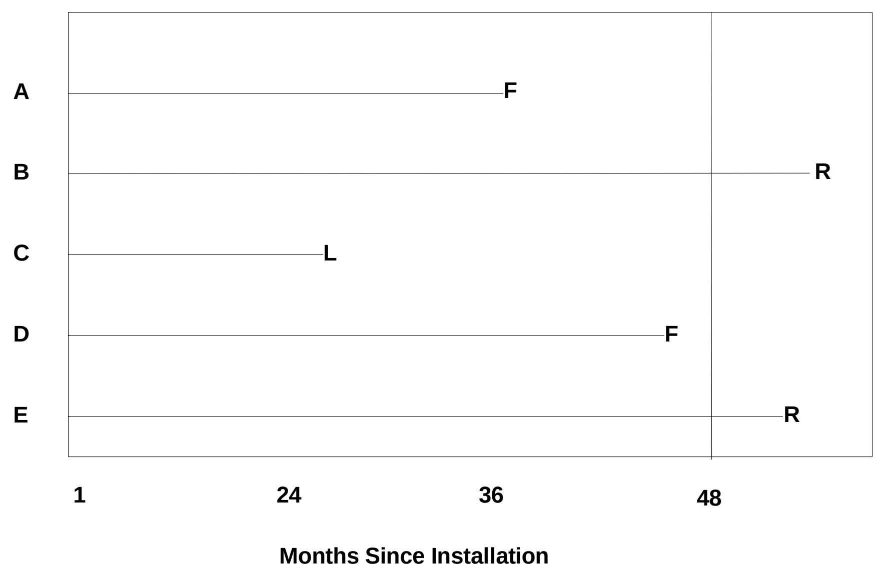
4.3.2 Left Censoring versus Right Censoring

In this survival analysis, a failure event is defined as a point in time at which a particular measure is no longer "in place and operable," hereafter referred to as a "failure." This implies the need to know not only that a given measure has failed but also when it failed.

Two concepts critical to this method are the right censoring and left censoring of the data. Right censoring of the data occurs when a measure is observed before the failure event occurs, i.e., the measure is still "in place and operable." Left censoring occurs when the actual installation or failure date for a measure is unknown. Exhibit 4.1 illustrates the distinction between right and left censoring. The observation followed by an "L" is a case in which the measure did not survive until the 48th month, the month of observation, but the time of failure is still unknown. This is a case of "left" censoring. The observations by an "F" represent those cases in which the measure did not survive until the 48th month but for which the time of failure *is* known. These represent cases of "no" censoring. The observations marked by an "R" represent those cases in which the measure survived until the 48th month and will not fail until some time beyond the 48th month. These represent cases of "right" censoring. Both right censoring and left censoring can have significant impacts on the precision of any survival analysis.

Right censoring is inevitable when one conducts a three- or six-year follow-up on kWh savings associated with measures that have expected useful lives of 15 to 18 years. For example, in a six-year retention study, very few micro irrigation measures (long life measures) in a small sample are expected to have experienced failure. The problem with right censoring is that more measures that have experienced failure must be brought into the sample in order to produce a robust estimate of the EUL. Of course, right censoring is expected to be somewhat less of a problem in the case of measures that have a shorter EUL.

Exhibit 4.1.
Left Censoring versus Right Censoring



The problem of left censoring can be somewhat more easily mitigated by asking participants to report the time of failure. When a site was inspected, the evaluation team asked the customer when the measure failures occurred. The failures were defined as failures at that date. In using such an approach, analysis efforts must guard against the threat of measurement error since customers may not be able to remember the true failure date accurately. This can be handled through use of a hazard function.

4.3.3 Functional Forms of Hazard Function

Initially the following general form of the constant hazard function was assumed:

$$h(t) = \lambda \qquad (1.)$$

The corresponding survivor function is:

$$S(t) = e^{-\lambda t} \qquad (2.)$$

This constant hazard implies an exponential distribution for the time until an event occurs.

However, because it was also realized that the probability of a measure not surviving increases with time (i.e., the hazard is not constant over time), the following four accelerated failure time (AFT) models were also explored:

1. Weibull:

$$S(t) = e^{\left[-(\lambda t)^K\right]}$$

where

λ = $\exp\{-[\beta_0 + \beta_1 x_1 + . . . + \beta_k x_k]\}$

K = A constant whose value is greater than 0

Note that when K = 1 (a constant), the exponential model is specified.

2. Gamma

$$S(t) = \frac{\lambda(\lambda t)^{K-1} e^{-\lambda t}}{\Gamma(K)}$$

where

λ = $\exp\{-[\beta_0 + \beta_1 x_1 + . . . + \beta_k x_k]\}$

Γ = The gamma function

K = $1/\delta^2$ (the shape parameter)

3. Log-logistic

$$S(t) = \frac{1}{1 + (\lambda t)^{\gamma}}$$

where

λ = $\exp\{-[\beta_0 + \beta_1 x_1 + . . . + \beta_k x_k]\}$

$1/\sigma$

σ = Scale parameter

4. Log-normal

Since the log-normal cannot be expressed in closed form, it is presented as a regression model in which the dependent variable is the logarithm of the hazard:

$$\log h(t) = \log h_0(te^{-\beta x}) - \beta x$$

where

h_0 (.)= The hazard function for an individual with x = 0

For each of these models, the parameters were estimated to maximize the likelihood of observing the data in the sample. When comparing the results of different models, larger values of the *Log Likelihood Statistic* indicate superior model performance. However, even if all the models agree on the coefficient estimates, they still have markedly different implications for the shape of the hazard function. The question is how to select the best model. When comparing nested models[4] one can use the Likelihood Ratio statistic to answer this question, so that was what was applied here. This statistic is calculated by taking the difference in the Likelihood Ratios between two nested models and multiplying this difference by 2. This yields a Likelihood-Ratio Chi-Square statistic.

The first thing to note is that because the generalized gamma has one more parameter than any of the other models being considered, its hazard function can take on a wide variety of shapes. The exponential, the Weibull, and log-normal models (but not the log-logistic) are all special cases of the generalized gamma model. In addition, the generalized gamma can also take on shapes that are unlike any of these special cases. It also has hazard functions with a U or *bathtub* shape in which the hazard function declines, reaches a minimum, and then increases. Given the richness of the generalized gamma model, why not always use it instead of the other models? The main reason is that the formula for the generalized gamma model is rather complicated, involving the gamma function and the incomplete gamma function. Consequently, it is often difficult to judge the shape of the hazard function from the estimated parameters. By contrast, the hazard functions for the specific submodels can be rather easily described.

As a result, a number of models that are nested within the generalized gamma were estimated. This allowed for any number of formal hypotheses tests to be conducted by comparing the performance of each model to the generalized gamma. If the likelihood-ratio chi-square statistic suggests that the difference is not statistically significant, then the model using the more easily interpretable hazard function is adopted. Also note that the exponential is nested in the Weibull, which can serve as another way of testing whether the hazard is constant or accelerated. Finally, recall that the log-logistic, because it is not nested within any other model, does not fit into the formal test of significance. It must be compared with the other models on the basis of the likelihood ratios alone and not on the basis of the likelihood-ratios chi square statistics.

[4] A model is said to be nested within another if the first model is a special case of the second

4.3.4 Statistical Power

The statistical power of a test is defined as the probability of rejecting the null hypothesis when it is in fact false. The power that one can achieve is in large part a function of the number of failures that one can expect to see in a study. The number of failures that one can expect to see is largely a function of the expected EULs. For example, in the hazard function (Equation 1), the median survival time is given by

$$\hat{t}(50) = \hat{\lambda}^{-1} \log 2 \qquad (3.)$$

with a standard error (s.e.) of

$$\text{s.e.}\{\hat{t}(50)\} = \frac{\hat{t}(50)}{\sqrt{r}} \qquad (4.)$$

where r is the number of failures within a sample. The more failures there are, the smaller the standard error and the greater the precision of the estimate. That is, the number of failures is directly related to the power of any survival analysis to determine whether any differences between re-estimated EULs and the ex ante EULs are statistically different at some predetermined level of confidence (in our case 80%). Of course, in a third year or sixth year retention study, the number of failures for longer-EUL measures will be very small, while the numbers of failures associated with shorter-EUL measures will be more numerous. While the problem of right censoring may be somewhat serious for all measures, it may be particularly acute for the measures with longer EULs.

Normally, for a classic survival analysis, one must attempt to estimate the number of failures needed to achieve the required level of power and then determine the required sample size to produce the number of required failures. Prior to conducting any analysis of any particular measure, one should estimate the number of failures needed to achieve the required level of power. This estimate requires that one make a number of other assumptions in addition to the confidence level. For example, how big a difference between the ex ante EUL and the ex post EUL (the so-called effect size) should the statistical test be able to detect as significant? This is a particularly critical factor since the sample size is, to a large extent, a function of the effect size. As the expected size of the effect increases, the required size of the sample decreases.

Having said this, it is noted that the sizes of the samples for this retention study were not designed with the statistical power and expected number of required failures in mind. Also note that because PG&E's approach relies on retention panel data collected during the first-year impact evaluation, there is no possibility of increasing the sample sizes in the event that the number of failures is insufficient. As a result, we must accept the statistical power and precision that the sample size for this study provides. In subsequent retention studies, it is recommended that, whenever possible, a power analysis be conducted so that the required number of failures and the sample size needed to obtain these failures can be determined.

4.3.5 Covariates

In some retention studies, other factors that may affect the life distribution have been investigated. In such a study, one can attempt to control for the heterogeneity of the determinants of measure survival. However, for this study, it was not possible to collect information on such variables.

4.3.6 Software

The Statistical Analysis System (SAS) software was used to estimate all survival functions. The SAS procedure, LIFEREG, which can handle right censoring and provide standard errors for each point on the survival curve, including the median, was used.

4.3.7 Hypothesis Testing

The Protocols consider effective useful life to be that median number of years in which half of the units associated with a given measure (e.g., HID fixtures) installed in a given program year are still in place and operable. It turns out that in survival analysis, the median value is of greatest importance because the mean value is biased downward when there is right censoring, as may be the case in this study. Thus, the evaluation team's hypothesis test focused on the sixth year and ex post median values.

The null hypothesis established for this phase of the analysis is that the measure-level EUL (a median value) estimated as a part of this research project is not statistically different from the sixth year EUL (a median value) at the 80% percent level of confidence[5], i.e.,

$$\text{EUL}_{\textit{ex post}} = \text{EUL}_{\textit{sixth year}}$$

For measures with relatively long expected useful lives, the hypothesis test is perhaps the most difficult task, since the model will be extrapolated to times that are beyond those that are actually observed. In such cases, the standard errors of the estimated medians will be substantial.

Along with the predicted medians, the standard errors of the medians were also produced. The 80% confidence interval was calculated by multiplying 1.28 (the t value associated with the 80% level of confidence) times the standard error. If the 80% confidence interval *did not* include the ex ante EUL, then the newly estimated ex post EUL was adopted. If the interval *did* include the ex ante EUL, then the ex ante EUL was retained.

4.4 Ordinary Least Squares

The next approach used for those measures with enough failures was the familiar ordinary least squares (OLS) regression that estimates the relationship between time and the percentage of measures remaining that are still present and operable (Maddala, 1992). The following model was estimated for each measure where there were an adequate number of observations.

$$\text{PR} = \alpha + \beta t + e \qquad (5.)$$

where

[5] Protocols, Table 6.B.6

PR = Percentage remaining

β = The change in the Percentage Remaining due to a one unit change in t (months)

α = A constant that captures the Percentage Remaining through an unspecified set of variables

ε = The error term that capture changes in Percentage Remaining that are not explained by the model

Once this model was estimated, it was evaluated at values of t until the percentage remaining equaled 50%. The value of t that produced 50% was the chosen estimate of the EUL.

4.5 Assumed Functional Form

The assumed functional form (AFF) approach was explored next. The AFF first assumes a functional form, such as the logistic or exponential. Next, a survey is conducted at a given point in time after the installation. The results of the survey are entered into an equation that describes the functional form that has been manipulated algebraically to derive the EUL associated with 50% survival. This method has most recently been developed by Wright (1999). Wright begins with the exponential survival function:

$$S(t) = e^{-\lambda t} \qquad (6.)$$

Here the mean survival time is equal to $1/\lambda$. The EUL is defined as the value of t that satisfies the equation $S(t) = e^{-\lambda t}$ = 0.5. Solving for t=EUL, one obtains

$$EUL = -\frac{\ln(0.5)}{\lambda} \qquad (7.)$$

If one observes $\hat{S}$ in a sample with average measure age t, then one can solve the survival function for

$$\hat{\lambda} = -\frac{\ln(\hat{S})}{t} \qquad (8.)$$

If one substitutes this equation in the preceding one, one obtains

$$E\hat{U}L = \frac{t\ln(0.5)}{\ln(\hat{S})} \qquad (9.)$$

Thus, for example, if one finds that, in a sample of 100, 90% survive and that the average age of the surviving units is three years, then the estimated EUL is 19.7 years.

4.6 Confidence Intervals

4.6.1 Classic Survival Analysis

Standard errors around the estimated median EUL are automatically produced by SAS for a classic survival analysis. These standard errors were multiplied by 1.28, the critical value of the 80 percent level of confidence. This product was then added to the estimated EUL to create the upper bound and then subtracted from the EUL to create the lower bound.

4.6.2 Ordinary Least Squares

The pump repair measure was the only measure found to have enough failures for this type of analysis. The 80% confidence intervals shown in the tables in section 5 were calculated using the approach shown below.

The variance of the model error (the residuals) is first estimated using Equation 10 (Pindyck and Rubinfeld, 1981).

$$s^2 = \frac{1}{T-2} \Sigma(Y_t - \hat{Y}_t)^2 \qquad (10.)$$

The variance of the forecast error is then estimated using Equation 11.

$$s_f^2 = s^2\left[1 + \frac{1}{T} + \frac{\left(X_{T+1} - \overline{X}\right)^2}{\sum\left(X_t - \overline{X}\right)^2}\right] \qquad (11.)$$

Finally, the calculation of the confidence interval around each forecasted point is then done using Equation 12.

$$\hat{Y}_{T+1} \ +/- \ t_{.20} s_f \qquad (12.)$$

The 80% confidence interval for the percentage of pump repairs surviving is very small. There are two primary reasons for this. First, the pump forecast is unconditional, since the explanatory variable, time, is known with certainty for the entire forecast period. This absence of error around future explanatory values removes a large source of forecasting error. Second, the model has a very high R^2 of 0.891, leading to a very small model error using Equation 12.

However, the percentage of pump repairs surviving is not an EUL. The EUL is derived as follows. First the estimated model is evaluated at future values of time to determine when the forecasted percentage reaches 50%. The number of months associated with this 50% value are then divided by 12 to derive the EUL. To calculate the 80% confidence interval around this EUL, the upper and lower bounds surrounding the forecasted value of 50% were first determined. Then, forecasted values that are near to the upper and lower bounds are identified. The number of months associated with the upper and lower bounds are then divided by 12 to derive the upper and lower bounds of the EUL.

4.6.3 Assumed Functional Form

Once the EUL is estimated using Equation 9, the standard error for $\hat{S}$, the estimated proportion of the measures surviving is calculated. The upper and lower bounds of the estimated proportion at the 80% confidence level are then calculated. These upper and lower bounds are then used in Equation 9 to calculate the upper and lower bounds of the EUL.

5. RESULTS

5.1 Survival of Measures

Exhibit 5.1 shows those measures for the PY1996 program that are still in place and operable as of 2002. The exhibit indicates the number of sites with unknown data. These were treated as missing and not included in the analysis for the pumping measure.

Exhibit 5.1
1996 Program Measures In Place and Operable as of 2002

Measure	Measure Code	In Place and Operable			Total	% in Place and Operable*
		Yes	No	Unknown		
Pump Repair	A1	35	7	4	46	83.3%
Micro Irrigation (acres)	A44	1,638	0	0	1,638	100.0%
Indoor Lighting (fixtures)	L26 / L27 / L37 / L81	4,848	55	0	4,903	98.9%

*Unknown points treated as missing. Not included in calculation of % in Place and Operable

As shown above, approximately 17% of the 1996 retention panel pump repair measures have been removed. There were no removals of the micro irrigation conversion sites. The failures for the HID lighting represented 1.1% of the installed HID fixtures and took place at 4 sites.

Exhibit 5.2 shows the measures audited during the evaluation of the 1997 program. Just over 32% of the pump repair measure are known to not be in place and operable. Again, there were no removals of the micro irrigation conversion sites.

Exhibit 5.2
1997 Program Measures In Place and Operable as of 2002

Measure	Measure Code	In Place and Operable			Total	% in Place and Operable*
		Yes	No	Unknown		
Pump Repair	A1	61	29	9	99	67.8%
Micro Irrigation (acres)	A44, A49	5,500	0	0	5,500	100.0%

*Unknown points treated as missing. Not included in calculation of % in Place and Operable

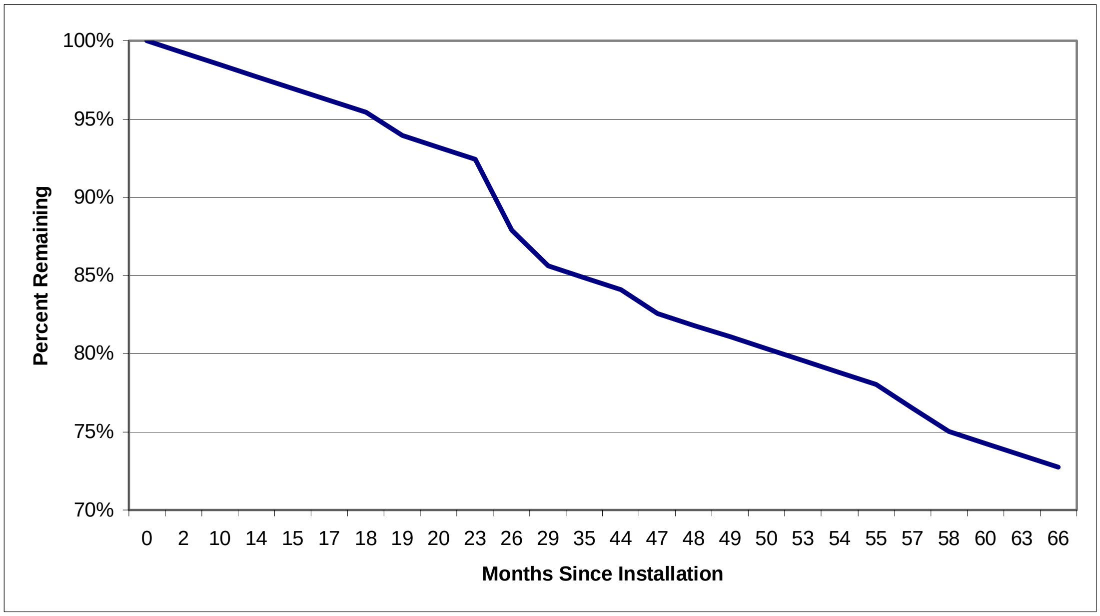
As the EUL approach used data from both PY1996 and PY1997, the percent in place and operable for the pump repair analysis was 73% (i.e., 96/132). Since PY1996 and PY1997 were analyzed together to increase the power of the analysis, 73% was used for both years.

5.2 Effective Useful Life of Measures

5.2.1 Pump Repairs

First, Exhibit 5.3 presents a simple empirical plot of failures against time.

Exhibit 5.3
Empirical Survival Function For PY 96/97 Pump Repairs



To begin, it is necessary to calculate the average hazard rate. The average hazard rate is simply defined as the total number of failures (36) divided by the total number of observations (132). The average hazard rate is 0.273. The percent of observations that are right censored is 0.727 (i.e., 1 - 0.273). Each technique will now be explored, beginning with the classic survival analysis.

Classic Survival Analysis

The exponential functional form, which assumes that hazard is constant, was tried first. Then four other functional forms that assumed that the probability of failure increased over time were tried. These so-called accelerated failure time (AFT) models include the Weibull, the log logistic, the log normal, the gamma, and the exponential. The results of these analyses are presented in Exhibit 5.4.

Exhibit 5.4
Estimated Pump Repair EULs and 80 Percent Confidence Interval, by Functional Form

Functional Forms	EUL	80% Confidence Interval: Lower Bound	80% Confidence Interval: Upper Bound	Log Likelihood
Log Logistic	10.2	8.0	12.4	-102.9
Weibull	9.4	7.6	11.2	-103.1
Log Normal	11.7	8.6	14.8	-103.0
Generalized Gamma	10.5	7.3	13.7	-102.8
Exponential	16.0	13.2	18.8	-156.5

Of the five models estimated, four have 80 percent confidence intervals that include the ex ante value of 9 years. The exponential model does not include the ex ante value and also has the poorest fit as measured by the Log Likelihood statistic.

Formal hypotheses tests were then conducted by comparing nested models[6]. In order to compare the different models, the Likelihood Ratio Chi-Square statistic was used. This statistic is calculated by first calculating the Log Likelihood for each of the two models being compared. For each comparison, the difference in the Log Likelihoods was multiplied by 2. This yields a Likelihood-Ratio Chi-Square statistic. Exhibit 5.5 presents these results.

Exhibit 5.5
Model Comparisons

Comparisons	Likelihood-Ratio Chi-Square
Exponential vs. Weibull	106.9*
Exponential vs. Generalized Gamma	107.4*
Weibull vs. Generalized Gamma	0.5
Log-normal vs. Generalized Gamma	0.38

* Difference is statistically significant at least the 0.05 significance level or better.

That the exponential model should be eliminated seems clear, given that it produces an implausibly high EUL estimate (16 years) and very large likelihood-ratio chi-squares when compared to the Weibull and the generalized gamma.[7] Thus, of the remaining models, all four have 80 percent confidence intervals that include the ex ante EUL value of nine years. As expected the generalized gamma model has the best model fit with the largest log

[6] A model is said to be nested within another if the first model is a special case of the second
[7] Large chi-squares indicate a significant difference.

likelihood. Moreover, neither the Weibull nor the log-normal are significantly different from the generalized gamma and the log-logistic model actually has a better fit than the Weibull and nearly identical to the log normal.

Except for the exponential model, these results strongly support the conclusion to accept the ex ante value of 9 years. For reporting purposes, we recommend the results from the Generalized Gamma Model since this model has the best fit.

Thirteen observations, nearly 9 percent, were not included in the above analysis. These pumps were observed as being in place by the field investigators, however, they were not able to speak with the owner. Therefore, they could not determine whether these pumps had been repaired again since the original repair provided by the Program. Because they could not determine whether these pumps were failures or not, these observations were treated as missing values in the analysis.

Ordinary Least Squares

Next, a linear and exponential trend lines were fitted to the empirical survival function. The fitted line is presented in Exhibit 5.6. Exhibit 5.7 presents the regression results.

Exhibit 5.6
Empirical Survival Function Versus Fitted Trend Line

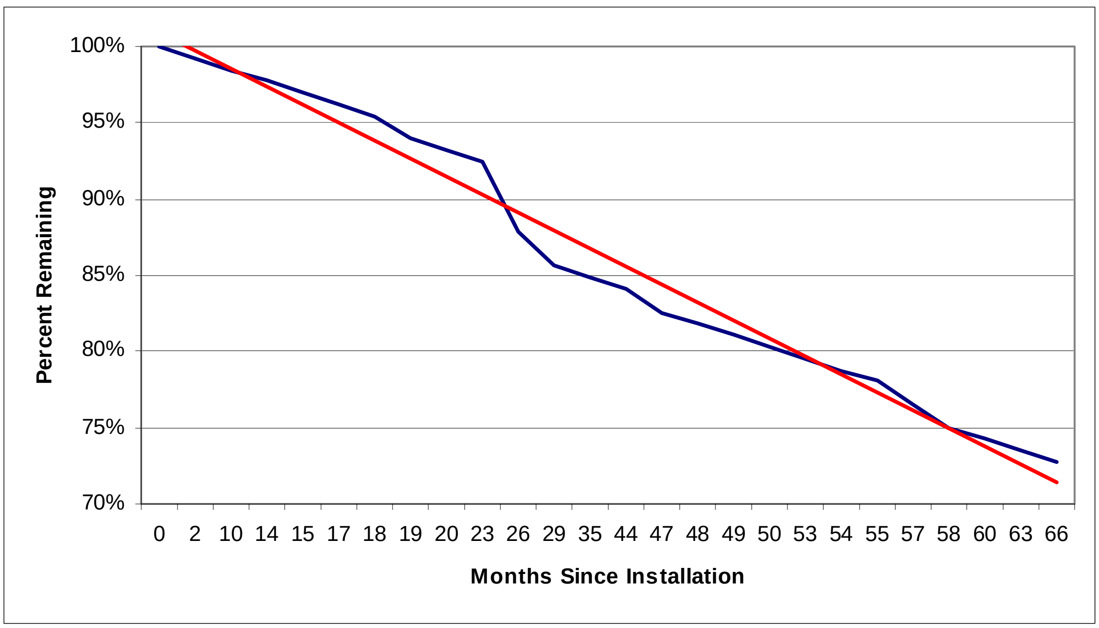


Exhibit 5.7
Regression Results for Pump Repairs

Variable	Coefficients	Standard Error	t Statistic[1]
Intercept	1.0227	0.0064	158.9
Months	-0.0045	0.0002	-29.1

[1] The t statistics for both variables are highly significant.

Using the estimated parameters from this regression, we then forecasted the percent remaining until the median, 50 percent, was reached. The forecast error surrounding the 50 percent was four percentage points at the 80 percent level of confidence.

The 80% confidence interval for the percentage of pump repairs surviving is very small. There are two primary reasons for this. First, the pump forecast is unconditional, since the explanatory variable, *time*, is known with certainty for the entire forecast period. This absence of error around future explanatory values removes a large source of forecasting error. Second, the model has a very high R^2 of 0.974, leading to a very small model error, which has a direct effect on the forecast error.

However, the percentage of pump repairs surviving is not an EUL. The EUL is derived as follows. First, the estimated model is evaluated at future values of time to determine when the forecasted percentage reaches 50%. The number of months associated with this 50% value is then divided by 12 to derive the EUL. To calculate the 80% confidence interval around this EUL, the upper and lower bounds surrounding the forecasted value of 50% are first determined. Then, forecasted values that are near to the upper and lower bounds are identified and the number of months associated with each are divided by 12 to derive the upper and lower bounds of the EUL.

Thus, estimate of the EUL is 9.75 years, with an 80 percent confidence level of 9.3 to 10.3 years. Because this confidence interval does not include 9, we would reject the ex ante EUL of 9 years using this model.

Assumed Function Form

Next, the assumed functional form approach was used to estimate the EUL for pump repairs. The resulting EUL was 10.6 years. The 80 percent confidence interval was 8.7 to 13.2 years. Because this interval includes the ex ante value of 9 years, the ex ante value is accepted.

Conclusions

Based on the more robust classic survival analysis, the main conclusion is that the ex ante value of 9 years should be accepted. The estimate is further supported by the results of the AFF model, which is also consistent with the ex ante value. Even the regression model estimate of 9.75 years is reasonably consistent with the estimate from the classic survival analysis of 10.5 years, assuming the Generalized Gamma functional form.

5.2.2 HID Lighting

Classic Survival Analysis

Since there were only 1.1% failures observed in the 1996-97 data, the confidence interval surrounding the estimated EUL would be enormous. Put another way, the statistical power of such a test is far too small. Such a wide confidence interval guarantees acceptance of the ex ante EUL of 16 years.

Ordinary Least Squares

With only four observations with failures, a regression analysis produced implausibly large estimates of the EUL and was rejected.

Assumed Function Form

Next, the assumed functional form approach was used to estimate the EUL for HID fixtures. The resulting EUL was 358 years. The 80 percent confidence interval was 305 to 433 years. Because this value is implausibly large, the ex ante value was retained.

Conclusions

The sixth-year HID measure EUL of 16 years (Exhibit 2.1) should be retained as the best estimate of effective useful life for 1996

5.2.3 Micro Irrigation

The field inspection showed that 100% of the installed acreage is still in place and operable. Given these results it is impossible to do any analysis to estimate effective useful life at this time. The ex ante EUL of 20 years is retained as the best estimate of EUL for this measure.

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6. CONCLUSIONS

The overall conclusions evolving from this study is that the ex ante EULs should be retained for all measure groups assessed in PG&E's 1996 and 1997 Agricultural sector programs.

Exhibit 6.1 shows the ex ante EULs for the measures assessed, the recommended ex post EUL, and the best estimate of ex post EUL with its 80% confidence interval, for all measures assessed.

Exhibit 6.1
Ex Ante and Ex Post EUL Estimates for PY 1996 and PY1997

Measure	Ex Ante Value	Ex Post Recommended	Best Ex Post Model with 80% Confidence Interval
HID Lighting	16	16	358 (305 to 433) Model provided implausible results
Micro Irrigation Conversion	20	20	No failures to analyze
Pump Repair	9	9	10.5 (7.3 to 13.7)

HID lighting and micro irrigation conversion measures, with 1.1% and 0% failure rates respectively, could not be meaningfully analyzed using existing techniques. Therefore, the ex ante values are retained.

The pump repair measure had sufficient failures (27% overall) for assessment. All of the analysis results supported a minimum EUL of nine years and almost all analyses supported retention of the ex ante EUL of nine years.

7. PROTOCOL TABLES 6.B AND 7

7.1 Protocol Table 6.B – 1996 Agricultural Sector

Refer to Section 4.6 for the method used to determine the confidence intervals shown in this table.

Results of 6th Year Retention Study
PG&E 1996 Agricultural Sector
Study ID 354R2 and 385R2

Item 1			Item 2		Item 3	Item 4	Item 5	Item 6		Item 7	Item 8	Item 9
PG&E Measure Code	Studied Measure Description	End Use	Ex Ante EUL	Source of Ex Ante EUL (ref. Ftnote)	Ex post EUL from Study	Ex Post EUL to be used in Claim	Ex Post EUL Standard Error	80% Conf. Interval Lower Bound	80% Conf. Interval Upper Bound	p-Value for Ex Post EUL	EUL Realizat'n Rate (ex post/ex ante)	"Like" Measures Associated with Studied Measure (by measure code)
A1	Pump Repair	Pumping and Related	9.0	1	10.5	9.0	2.52	7.3	13.7	0.80	1.00	-
A44	Sprinkler to Micro, Valley, Well, Field/Veg	Pumping and Related	20	1	NA*	20.0	NA	NA	NA	NA	NA	-
L81	HID Fixture: Interior, Standard, 251-400 Watts Lamp	Ag Indoor Lighting	16.0	1	365.3	16.0	NA	311.1	442	0.80	22.8	L26, L27, L37

*No failures were found during the retention study. No EUL can be calculated

Ex Ante Source References: 1 PG&E Advice Filing 1921-G-A/1540-E October 1995

7.2 Protocol Table 6.B – 1997 Agricultural Sector

Refer to Section 4.6 for the method used to determine the confidence intervals shown in this table.

Results of 6th Year Retention Study
PG&E 1996 Agricultural Sector
Study ID 354R2 and 385R2

Item 1			Item 2		Item 3	Item 4	Item 5	Item 6		Item 7	Item 8	Item 9
PG&E Measure Code	Studied Measure Description	End Use	Ex Ante EUL	Source of Ex Ante EUL (ref. Ftnote)	Ex post EUL from Study	Ex Post EUL to be used in Claim	Ex Post EUL Standard Error	80% Conf. Interval Lower Bound	80% Conf. Interval Upper Bound	p-Value for Ex Post EUL	EUL Realizat'n Rate (ex post/ex ante)	"Like" Measures Associated with Studied Measure (by measure code)
A1	Pump Repair	Pumping and Related	9.0	1	10.5	9.0	2.52	7.3	13.7	0.80	1.00	-
A44	Sprinkler to Micro, Valley, Well, Field/Veg	Pumping and Related	20	1	NA*	20.0	NA	NA	NA	NA	NA	-
L81	HID Fixture: Interior, Standard, 251-400 Watts Lamp	Ag Indoor Lighting	16.0	1	358	16.0	NA**	305	433	0.80	22.4	L26, L27, L37

*No failures were found during the retention study. No EUL can be calculated

**The AFF model does not include a reliable approach to calculate the standard error around the EUL. Confidence intervals calculated using SE of the propotion surviving (SE=0.0015).

Ex Ante Source References: 1 PG&E Advice Filing 1921-G-A/1540-E October 1995

7.3 Protocol Table 7 – 1996 Retention Study (Study # 354R2 and 385R2)

1996 Agricultural EEI Program
6th Year Retention Study
PG&E Study ID #354R2 and 385R2

The purpose of this section is to provide the documentation for data quality and processing as required in Table 7 of the California Public Utility Commission (CPUC) Evaluation and Measurement Protocols (the Protocols). Major topics are organized and presented in the same order as they are listed in Table 7 for ease of reference and review. When responses to the items are discussed in detail elsewhere in the report, only a brief summary will be given in this section to avoid redundancy.

7.3.1 Overview Information

7.3.1.1 Study Title and Study ID Number

Study Title:	6th Year Evaluation of Retention in Pacific Gas &Electric Company's 1996 Agricultural Energy Efficiency Incentives (AEEI) Program
Study ID Number:	354R2 and 385R2

7.3.1.2 Program, Program Year and Program Description

Program:	PG&E EEI Program, Agricultural Sector
Program Year:	Rebates Received in the 1996 Calendar Year.
Program Description:	The 1996 Agricultural Program rebated technologies covered by the Retrofit Express (RE), Retrofit Efficiency Options (REO), Customized Incentives (CI) Programs, and Advanced Performance Options (APO).

7.3.1.3 End Uses and/or Measures Covered

End Uses Covered:	Agricultural Pumping and Related Technologies Agricultural Indoor Lighting Technologies
Measures Covered:	Pump Repair Micro Irrigation Conversion HID Interior 251-400 W Lamps

7.3.1.4 Methods and Models Use

The PG&E AEEI Program retention study evaluated three methods: 1) classic survival analysis 2) ordinary least squares (OLS), and 3) assumed functional form (AFF).

Classic Survival Analysis: Pump Repair

In additional to the exponential model, which assumes a constant hazard, also estimated were a number of accelerated time failure (AFT) models, including:

1. Weibull:

$$S(t) = e^{\left[-(\lambda t)^{K}\right]}$$

where

λ = $\exp\{-[\beta_0 + \beta_1 x_1 + \ldots + \beta_k x_k]\}$

K = A constant whose value is greater than 0

Note that when K = 1 (a constant), the exponential model is specified.

2. Gamma

$$f(t) = \frac{\lambda(\lambda t)^{K-1} e^{-\lambda t}}{\Gamma(K)}$$

where

λ = $\exp\{-[\beta_0 + \beta_1 x_1 + \ldots + \beta_k x_k]\}$

Γ = The gamma function

K = $1/\delta^2$ (the shape parameter)

3. Log-logistic

$$S(t) = \frac{1}{1 + (\lambda t)^{\gamma}}$$

where

λ = $\exp\{-[\beta_0 + \beta_1 x_1 + \ldots + \beta_k x_k]\}$

γ = $1/\sigma$

σ = Scale parameter

4. Log-normal

Since the log-normal cannot be expressed in closed form, it is presented as a regression model in which the dependent variable is the logarithm of the hazard:

$$\log h(t) = \log h_0(te^{-\beta x}) - \beta x$$

where

h_0 (.)= The hazard function for an individual with x = 0

Ordinary Least Squares: Pump Repair

The next approach used was the familiar ordinary least squares (OLS) regression that estimates the relationship between time and the percentage of measures remaining that are still present and operable (Maddala, 1992). The following model was estimated for each measure where there were an adequate number of observations.

$$PR = \alpha + \beta t + e$$

where

PR = Percentage remaining

β = The change in the Percentage Remaining due to a one unit change in t (months)

α = A constant that captures the Percentage Remaining through an unspecified set of variables

ε = The error term that capture changes in Percentage Remaining that are not explained by the model

Once this model was estimated, it was evaluated at values of t until the percentage remaining equaled 50%. The value of t that produced 50% was the estimate of the EUL.

Assumed Functional Form: Pump Repairs & HID Lighting

$$E\hat{U}L = \frac{t \ln(0.5)}{\ln(\hat{S})}$$

where $\hat{S}$ = equal to survey-based estimate of the proportion of measures surviving

t = average measure age in the survey

The key inputs come from the site survey that provides the percentage surviving ($\hat{S}$) and the average age of the measure (t). These two values are inserted into the equation above to derive the estimated EUL.

7.3.1.5 Analysis Sample Size

The analysis sample size is shown below in Exhibit 7.1.

Exhibit 7.1
Sample Summary – 1996 Agricultural Sector

Measure	***Measure Code***	***Analysis Sample Size***
Program Year 1996		
Pump Repair	A1	43
Micro Irrigation (sites)	A44	10
Indoor Lighting (unique applications)	L26 / L27 / L37 / L81	46
Total for PY1996		***99***

7.3.2 Database Management

7.3.2.1 Specific Data Sources

On-site survey data were collected for a census of specific measures from the 1996 retention panel. All data came directly from the retention panel.

7.3.2.2 Data Attrition

All data elements mentioned above were first validated and then merged together to form the final analysis data set. All data points collected during the on-site audits were kept.

7.3.2.3 Internal Data Quality Procedures

The data quality procedures are consistent with PG&E's internal guidelines and the guidelines established in the Protocols. The on-site audits were validated by an agricultural engineer prior to data entry.

7.3.2.4 Unused Data Elements

All data collected specifically for the Evaluation were utilized.

7.3.3 Sampling

7.3.3.1 Sampling Procedures and Protocols

The limited participant population necessitated an attempted census of retention panel participants. The number of completed participant surveys as mentioned above in Section 3, reflects such an attempted census.

7.3.3.2 Survey Information

On-site audit instruments are presented in Appendix C.

7.3.3.3 Statistical Descriptions

The only variables in the model were whether the measure had failed and time. No covariates were available. Descriptive statistics for variables in the models are shown in Exhibit 7.2.

Exhibit 7.2
Descriptive Statistics

End Use	Average Age (Years)	Standard Deviation	Percent Surviving
Pumping	4.8	1.36	0.73
Lighting	5.8	0.67	0.989

7.3.4 Data Screening and Analysis

7.3.4.1 Outliers and Missing Data

When the failure date was unavailable, the date of removal was set for 1.5 years before the 6th year retention evaluation completed its on-site audits. Thirteen observations were not included in the above analysis. These pumps were observed as being in place by the field investigators, however, they were not able to speak with the owner. Therefore, they could not determine whether these pumps had been repaired again since the original repair provided by the Program. Because they could not determine whether these pumps were failures or not, these observations were treated as missing values in the analysis.

There were no outliers in the analysis.

7.3.4.2 Background Variables

There were no background variables modeled.

7.3.4.3 Data Screening Process

No data were screened from the retention analysis.

7.3.4.4 Model Statistics

Classic Survival Analysis: Pump Repairs

The following tables provide the basic model results for pump repairs using classic survival analysis.

Exhibit 7.3
Estimated Pump Repair EULs and 80 Percent Confidence Interval, by Functional Form

Functional Forms	EUL	80% Confidence Interval: Lower Bound	80% Confidence Interval: Upper Bound	Log Likelihood
Log Logistic	10.2	8.0	12.4	-102.9
Weibull	9.4	7.6	11.2	-103.1
Log Normal	11.7	8.6	14.8	-103.0
Generalized Gamma	10.5	7.3	13.7	-102.8
Exponential	16.0	13.2	18.8	-156.5

Of the five models estimated, four have 80 percent confidence intervals that include the ex ante value of 9 years. The exponential is more than seven years greater with a lower bound that is more than four years greater.

Formal hypotheses tests were then conducted by comparing nested models. Exhibit 7.4 presents these results.

Exhibit 7.4
Model Comparisons

Comparisons	Likelihood-Ratio Chi-Square
Exponential vs. Weibull	106.9*
Exponential vs. Generalized Gamma	107.4*

Weibull vs. Generalized Gamma	0.5
Log-normal vs. Generalized Gamma	0.38

* Difference is statistically significant at least the 0.05 level of significance.

That the exponential model should be eliminated seems clear cut given that it produces an implausibly high EUL estimate (16 years) and very large chi-squares when compared to the Weibull and the generalized gamma. Thus, of the remaining models, all four have 80 percent confidence intervals that include the ex ante value of nine years. As expected the generalized gamma model has the best model fit with the largest log likelihood. Moreover, neither the Weibull nor the log-normal are significantly different from the generalized gamma and the log-logistic model actually has a better fit than the Weibull and nearly identical to the log normal.

Except for the exponential model, these results strongly support the conclusion to accept the ex ante value of 9 years. For reporting purposes, the results from the Generalized Gamma Model are recommended since this model supplies the best fit.

Thirteen observations, nearly 9 percent, were not included in the above analysis. These pumps were observed as being in place by the field investigators, however, they were not able to speak with the owner. Therefore, they could not determine whether these pumps had been repaired again since the original repair provided by the Program. Because they could not determine whether these pumps were failures or not, these observations were treated as missing values in the analysis.

Ordinary Least Squares (OLS): Pump Repairs

The final model used for the pump repair measure only was an OLS model with time as the independent variable and percentage surviving as the dependent variable. The final model equation was:

$$Y = 1.0227 - .0045X$$

where:

Y = percentage surviving

X = months

The equation had an R^2 of 0.974.

Assumed Functional Form: Pump Repair

The key inputs come from the site survey that provides the percentage surviving ($\hat{S}$) and the average age of the pumps (t).

Percentage Surviving	73%
Average Age of Pumps	4.8 years

These two values are inserted into the equation below to derive the estimated EUL.

$$\hat{EUL} = \frac{t \ln(0.5)}{\ln(\hat{S})}$$

Assumed Functional Form: HID Lighting

The key inputs come from the site survey that provides the percentage surviving ($\hat{S}$) and the average age of the lights (t).

Percentage Surviving	98.9%
Average Age of Lights	5.8 years

These two values are inserted into the equation below to derive the estimated EUL.

$$\hat{EUL} = \frac{t \ln(0.5)}{\ln(\hat{S})}$$

7.3.4.5 Model Specification

Classical Survival Analysis – Specification was not an issue since there were no other variables other than whether the measure had survived up to the time of the field survey and the date of installation. There were no covariates.

OLS Analysis – Specification is not an issue since there was only one independent variable available, time. There were no covariates. The chosen model had the highest R^2 and, therefore, the best predictive power.

Assumed Functional Form Analysis – Specification is not an issue since the functional form is assumed.

7.3.4.6 Measurement Errors

The main source of measurement errors is the on-site survey. Our approach has been to proactively stop the problem before it happens so that statistical corrections are kept to a minimum.

Measurement errors are a combination of random and non-random error components that plague all survey data. The non-random error frequently takes the form of systematic bias, which includes, but is not limited to, ill-formed or misleading questions and miscoded study variables. In this project, controls were implemented to reduce the systematic bias in the data.

The random measurement error, such as data entry error, has no impact on estimating mean values because the errors are typically unbiased.

7.3.4.7 Influential Data Points

Since the analysis consisted of a simple regression of the percentage of surviving pumps by time, there were no influential data points in the OLS analysis. There were no outliers in the analysis.

7.3.4.8 Missing Data

When the failure date was unavailable, the date of removal was set for 1.5 years before the 6th year retention evaluation completed its on-site audits. Thirteen pump repair observations were not included in the analysis. These pumps were observed as being in place by the field investigators, however, they were not able to speak with the owner. Therefore, they could not determine whether these pumps had been repaired again since the original repair provided by the Program. Because they could not determine whether these pumps were failures or not, these observations were treated as missing values in the analysis.

7.3.4.9 Precision

The precision was determined as specified in Section 4.6.

7.4 Protocol Table 7 – 1997 Retention Study (Study # 335AR2, 335BR2, 335CR2)

1997 Agricultural EEI Program
6th Year Retention Study
PG&E Study ID #335AR2, 335BR2, 335CR2

The purpose of this section is to provide the documentation for data quality and processing as required in Table 7 of the California Public Utility Commission (CPUC) Evaluation and Measurement Protocols (the Protocols). Major topics are organized and presented in the same order as they are listed in Table 7 for ease of reference and review. When responses to the items are discussed in detail elsewhere in the report, only a brief summary will be given in this section to avoid redundancy.

7.4.1 Overview Information

7.4.1.1 Study Title and Study ID Number

Study Title: 6th Year Evaluation of Retention in Pacific Gas &Electric Company's 1997 Agricultural Energy Efficiency Incentives (AEEI) Program

Study ID Number: 335AR2, 335BR2, 335CR2

7.4.1.2 Program, Program Year and Program Description

Program: PG&E EEI Program, Agricultural Sector

Program Year: Rebates Received in the 1997 Calendar Year.

Program Description: The 1997 Agricultural Program rebated technologies covered by the Retrofit Express (RE) and Retrofit Efficiency Options (REO) Programs

7.4.1.3 End Uses and/or Measures Covered

End Uses Covered: Agricultural Pumping and Related Technologies

Measures Covered: Pump Repair
Micro Irrigation Conversion

7.4.1.4 Methods and Models Use

The PG&E AEEI Program retention study evaluated three methods: 1) classic survival analysis 2) ordinary least squares (OLS), and 3) assumed functional form (AFF).

Classic Survival Analysis: Pump Repair

In additional to the exponential model, which assumes a constant hazard, also estimated were a number of accelerated time failure (AFT) models, including:

1. Weibull:

$$S(t) = e^{\left[-(\lambda t)^{\kappa}\right]}$$

where

λ = exp{-[$\beta_0 + \beta_1 x_1 + . . . + \beta_k x_k$]}

K = A constant whose value is greater than 0

Note that when K = 1 (a constant), the exponential model is specified.

2. Gamma

$$f(t) = \frac{\lambda(\lambda t)^{K-1} e^{-\lambda t}}{\Gamma(K)}$$

where

λ = exp{-[$\beta_0 + \beta_1 x_1 + . . . + \beta_k x_k$]}

Γ = The gamma function

K = $1/\delta^2$ (the shape parameter)

3. Log-logistic

$$S(t) = \frac{1}{1 + (\lambda t)^{\gamma}}$$

where

λ = exp{-[$\beta_0 + \beta_1 x_1 + . . . + \beta_k x_k$]}

γ = $1/\sigma$

σ = Scale parameter

4. Log-normal

Since the log-normal cannot be expressed in closed form, we present it as a regression model in which the dependent variable is the logarithm of the hazard:

$$\log h(t) = \log h_0(te^{-\beta x}) - \beta x$$

where

h_0 (.)= The hazard function for an individual with x = 0

Ordinary Least Squares: Pump Repair

The first alternative approach used was the familiar ordinary least squares (OLS) regression that estimates the relationship between time and the percentage of measures remaining that are still present and operable (Maddala, 1992). The following model was estimated for each measure where there were an adequate number of observations.

$$PR = \alpha + \beta t + e$$

where

PR = Percentage remaining

β = The change in the Percentage Remaining due to a one unit change in t (months)

α = A constant that captures the Percentage Remaining through an unspecified set of variables

ε = The error term that capture changes in Percentage Remaining that are not explained by the model

Once this model was estimated, it was evaluated at values of t until the percentage remaining equaled 50%. The value of t that produced 50% was the chosen estimate of the EUL.

Assumed Functional Form: Pump Repairs

$$E\hat{U}L = \frac{t \ln(0.5)}{\ln(\hat{S})}$$

where $\hat{S}$ = equal to survey-based estimate of the proportion of measures surviving

t = average measure age in the survey

The key inputs come from the site survey which provides the percentage surviving ($\hat{S}$) and the average age of the pumps (t). These two values are inserted into the equation above to derive the estimated EUL.

7.4.1.5 Analysis Sample Size

The analysis sample size is shown below in Exhibit 7.5.

Exhibit 7.5
Sample Summary – 1997 Agricultural Sector

Measure	***Measure Code***	***Analysis Sample Size***
Program Year 1997		
Pump Repair*	A1	83
Micro Irrigation (sites)	A44, A49	17
Total for PY1997		***100***

7.4.2 Database Management

7.4.2.1 Specific Data Sources

On-site survey data were collected for a census of specific measures from the 1997 retention panel. All data came directly from the retention panel.

7.4.2.2 Data Attrition

All data elements mentioned above were first validated and then merged together to form the final analysis data set.

7.4.2.3 Internal Data Quality Procedures

The data quality procedures are consistent with PG&E's internal guidelines and the guidelines established in the Protocols. The on-site audits were validated by an agricultural engineer prior to data entry.

7.4.2.4 Unused Data Elements

All data collected specifically for the Evaluation were utilized.

7.4.3 Sampling

7.4.3.1 Sampling Procedures and Protocols

The limited participant population necessitated an attempted census of retention panel participants. The number of completed participant surveys, as mentioned above in Section 3, reflects that a census was audited.

7.4.3.2 Survey Information

On-site audit instruments are presented in Appendix C.

7.4.3.3 Statistical Descriptions

The only variables in the model were whether the measure had failed and time. No covariates were available. Descriptive statistics for variables in the models are shown in Exhibit 7.6

Exhibit 7.6
Descriptive Statistics

End Use	Average Age (Years)	Standard Deviation	Percent Surviving
Pumping	4.8	1.36	0.73

7.4.4 Data Screening and Analysis

7.4.4.1 Outliers and Missing Data

When the failure date was unavailable, the date of removal was set for 1.5 years before the 6th retention evaluation completed its on-site audits. Thirteen observations were not included in the analysis. These pumps were observed as being in place by the field investigators, however, they were not able to speak with the owner. Therefore, they could not determine whether these pumps had been repaired again since the original repair provided by the Program. Because they could not determine whether these pumps were failures or not, these observations were treated as missing values in the analysis.

There were no outliers in the analysis.

7.4.4.2 Background Variables

There were no background variables modeled.

7.4.4.3 Data Screening Process

No data were screened from the retention analysis.

7.4.4.4 Model Statistics

Classic Survival Analysis: Pump Repairs

The following tables provide the basic model results for pump repairs using classic survival analysis.

Exhibit 7.7
Estimated Pump Repair EULs and 80 Percent Confidence Interval, by Functional Form

Functional Forms	EUL	80% Confidence Interval: Lower Bound	80% Confidence Interval: Upper Bound	Log Likelihood
Log Logistic	10.2	8.0	12.4	-102.9
Weibull	9.4	7.6	11.2	-103.1
Log Normal	11.7	8.6	14.8	-103.0
Generalized Gamma	10.5	7.3	13.7	-102.8
Exponential	16.0	13.2	18.8	-156.5

Of the five models estimated, four have 80 percent confidence intervals that include the ex ante value of 9 years. The exponential is more than seven years greater with a lower bound that is more than four years greater.

Formal hypotheses tests were then conducted by comparing nested models. Exhibit 7.8 presents these results.

Exhibit 7.8
Model Comparisons

Comparisons	Likelihood-Ratio Chi-Square
Exponential vs. Weibull	106.9*
Exponential vs. Generalized Gamma	107.4*
Weibull vs. Generalized Gamma	0.5
Log-normal vs. Generalized Gamma	0.38

* Difference is statistically significant at least the 0.05 level of significance.

That the exponential model should be eliminated seems clear cut given that it produces an implausibly high EUL estimate (16 years) and very large chi-squares when compared to the

Weibull and the generalized gamma. Thus, of the remaining models, all four have 80 percent confidence intervals that include the ex ante value of nine years. As expected the generalized gamma model has the best model fit with the largest log likelihood. Moreover, neither the Weibull nor the log-normal are significantly different from the generalized gamma and the log-logistic model actually has a better fit than the Weibull and nearly identical to the log normal.

Except for the exponential model, these results strongly support the conclusion to accept the ex ante value of 9 years. For reporting purposes, the results from the Generalized Gamma Model are recommended since this model supplies the best fit.

Thirteen observations, nearly 9 percent, were not included in the above analysis. These pumps were observed as being in place by the field investigators, however, they were not able to speak with the owner. Therefore, they could not determine whether these pumps had been repaired again since the original repair provided by the Program. Because they could not determine whether these pumps were failures or not, these observations were treated as missing values in the analysis.

Ordinary Least Squares (OLS): Pump Repairs

The final model used for the pump repair measure only was an OLS model with time as the independent variable and percentage surviving as the dependent variable. The final model equation was:

$$Y = 1.0227 - .0045X$$

where:

Y = percentage surviving

X = months

The equation had an R^2 of 0.974.

Assumed Functional Form: Pump Repair

The key inputs come from the site survey that provides the percentage surviving ($\hat{S}$) and the average age of the pumps (t).

Percentage Surviving	73%
Average Age of Pumps	4.8 years

These two values are inserted into the equation below to derive the estimated EUL.

$$E\hat{U}L = \frac{t \ln(0.5)}{\ln(\hat{S})}$$

7.4.4.5 Model Specification

Classical Survival Analysis – Specification was not an issue since there were no other variables other than whether the measure had survived up to the time of the field survey and the date of installation. There were no covariates.

OLS Analysis – Specification is not an issue since there was only one independent variable available, time. There were no covariates. The chosen model had the highest R^2 and, therefore, the best predictive power.

Assumed Functional Form Analysis – Specification is not an issue since the functional form is assumed.

7.4.4.6 Measurement Errors

The main source of measurement errors is the on-site survey. Our approach has been to proactively stop the problem before it happens so that statistical corrections are kept to a minimum.

Measurement errors are a combination of random and non-random error components that plague all survey data. The non-random error frequently takes the form of systematic bias, which includes, but is not limited to, ill-formed or misleading questions and miscoded study variables. In this project, controls were implemented to reduce the systematic bias in the data. These steps included auditor training and instrument pre-test.

The random measurement error, such as data entry error, has no impact on estimating mean values because the errors are typically unbiased.

7.4.4.7 Influential Data Points

Since the analysis consisted of a simple regression of the percentage of surviving pumps by time, there were no influential data points in the OLS analysis. There were no outliers in the analysis.

7.4.4.8 Missing Data

When data were unavailable, the date of removal was set for 1.5 years before the 6th year retention evaluation completed its on-site audits. Thirteen observations were not included in the above analysis. These pumps were observed as being in place by the field investigators, however, they were not able to speak with the owner . Therefore, they could not determine whether these pumps had been repaired again since the original repair provided by the Program. Because they could not determine whether these pumps were failures or not, these observations were treated as missing values in the analysis.

7.4.4.9 Precision

The precision was determined as specified in Section 4.6.

Appendix A: References

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Appendix B: CADMAC Waiver

PACIFIC GAS & ELECTRIC COMPANY
REQUEST FOR RETROACTIVE WAIVER FOR
COMPANY WIDE MODIFICATION TO THIRD AND FOURTH EARNINGS
CLAIM CALCULATION METHODOLOGY
Study ID: All study IDs for all PG&E programs.
Date Approved: February 17, 1999

Summary of PG&E Request

This waiver requests deviations from, or clarifications of, the Protocols[8] by PG&E for the third earnings claim methodology for PG&E's 1994 programs and for all future third and fourth earnings claims. The Protocols, as written, require that all third and fourth earnings claim impacts be calculated as the sum of the measure level AEAP values as adjusted by appropriate ex post Technical Degradation Factors (TDF) and Effective Useful Life (EUL) values. Since all PG&E second earnings claim AEAP amounts are agreed at the end use level, PG&E does not have the measure level AEAP values. PG&E seeks approval to use the first year ex post evaluation measure level findings to allocate the AEAP end use values into estimates of individual measure savings. These measure level estimates will then be combined, as specified in the Protocols, with the measure level ex post EUL and TDF values to calculate the third and fourth earnings claims.

Proposed Waiver (see Table A for Summary)

PG&E seeks CADMAC approval to:

Use the first year ex post evaluation measure level findings to allocate the AEAP end use values into estimates of individual measure savings. These measure level estimates will then be combined, as specified in the Protocols, with the measure level ex post EUL and TDF values to calculate the Resource Benefit, Net for the third and fourth earnings claims.

Parameters and Protocol Requirements

Table 10, item A.3.b.1 and 2, and A.4.a. and b., require the Resource Benefits, Net to be calculated at the measure level, then summed, using the net load impacts as "determined in the second earnings claim AEAP."

Rationale

The Protocols, as written, require that all third and fourth earnings claim impacts are calculated as the sum of the measure level second earnings claims AEAP values as adjusted by appropriate ex post TDFs and EULs. Since all PG&E second earnings claim AEAP amounts are agreed at the end use level, PG&E does not have the measure level second earnings claim AEAP values required by the methodology. PG&E cannot "back calculate" measure specific level AEAP values since there is no clear information on how to "allocate" the end use level AEAP values to the individual measures. PG&E can, however, use the measure level information from the first year evaluations to proportionally allocate or prorate the end use level AEAP values into estimates of the measure level AEAP values. These measure level estimates will then be combined, as specified in the Protocols, with the measure level ex post EUL and TDF values to calculate the Resource Benefit, Net, for the third and fourth earnings claims.

Conclusion

[8] Protocols and Procedures for the Verification of Costs, Benefits, and Shareholder Earnings for Demand-Side Management Programs.

PG&E is seeking a retroactive waiver to clearly define, in advance, acceptable methods for calculating third and fourth earnings claims. The AEAP process results in AEAP values which cannot be used to estimate the third and fourth earnings claims as required by the Protocols. PG&E's waiver proposes a straightforward alternative that fulfills the spirit of the Protocols.

TABLE A

TABLE 10, EARNINGS DISTRIBUTION SCHEDULE			
Parameters	**Protocol Requirements**	**Waiver Alternative**	**Rationale**
Calculation Methodology for Third and Fourth Earnings Claim.	Sum the product of measure level second earnings claim AEAP, ex post TDF, and ex post EULs.	Allow the use of the first year ex post evaluation measure level findings to allocate the AEAP end use values into estimates of individual measure savings. These measure level estimates will then be multiplied by the measure level ex post EUL and TDF values to calculate the Resource Benefit, Net for the third and fourth earnings claims.	The AEAP results in end use level AEAP values. The proposed method makes maximum use of evaluation findings to allocate the end use level AEAP values to the measure level. Allocation to the measure level allows both third and fourth earnings claims to be calculated as specified in the Protocols.

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Appendix C: On-Site Survey Instrument

PY1996 Agricultural Program Retention Questionnaire

Customer Name		Audit Num:
Business Name		Orig CAC Surveyor
Customers Address		Division
City		Assigned To:
Phone		Old Audit ID:
New Contact Name		Date Customer Talked To:
New Phone Number	Area Code	Is a Site Visit Necessary?
PG&E Audit Acct.		Date Site Visited
New PGE Acct.		
<u>1996 Measure:</u>	<u>Measure Code</u>	<u>Measure Description</u>

Pump Repair
Micro Irrigation
HID Lighting

<u>Location Description - Pump Repair, Micro Conversion, HID Lighting</u>

Pump Repair Audits

Is the 1996 measure still in place and operable (yes/no) ____________________

If no, approximate date removed from service ______________________________

If not in place and operable, explain why not

____

Has this pump been repaired since participating in the PG&E program? (yes/no) If so, when? _______

Micro Conversion Audits ONLY

There were ____ original acreage converted to micro irrigation. How many acres still have it? ______________________________

If not 100% still there, when was it removed from service? (approx.) _________________

If not 100% still there, why was the micro irrigation removed from service?

____

____

Did the grower change from micro-jets to drippers or vice versa? If so, why and when?

____

____

Lighting Audits ONLY

Num Fixtures	**Group Descriptions**	**Lamp Fixture**	**Watt**

What % of the equipment from this measure is still in place and operable? ________________

If not 100% still in place and operable, when was it removed from service? (approx.)______________

If not 100% still in place and operable, why was it removed from service?

Auditors Comments:

IF POSSIBLE, FILL IN ACTUAL NUMBER OF FIXTURES INSTEAD OF PERCENT.

There were ____ original fixtures installed. How many fixtures are still in place and operable? ______________________

If not 100% still in place and operable, when were they removed from service? (approx.)___________

If not 100% still in place and operable, why were they removed from service?

Auditors Comments:

PY1997 Agricultural Program Retention Questionnaire

Customer Name		Audit Num:
Business Name		Orig CAS Surveyor
Customers Address		Division
City		Assigned To:
Phone		Old Audit ID:
New Contact Name		Date Customer Talked To:
New Phone Number	Area Code	Is a Site Visit Necessary?
PG&E Audit Acct.		Date Site Visited
New PGE Acct.		
1997 Measure:	Measure Code	Measure Description

Pump Audit
Micro Conversion Audit

Location Description – Pump Repair, Micro Conversion

Pump Repair Audits ONLY

Is the 1997 measure still in place and operable? (yes/no) ____________________

If no, approximate date removed from service: ____________________________

If not in place and operable, explain why not.

____

Has this pump been repaired since participating in the PG&E program? (yes/no) If so, when? ____

Micro Conversion Audits ONLY

There were ____ original acreage converted to micro irrigation. How many acres still have it? _____________________________

If not 100% still there, when was it removed from service? (approx.) _________________

If not 100% still there, why was the micro irrigation removed from service?

____

____

Did the grower change from micro-jets to drippers or vice versa? If so, why and when?

____

____

Auditors Comments:

____