1994 AND 1995 INDUSTRIAL ENERGY EFFICIENCY INCENTIVE PROGRAMS SIXTH-YEAR RETENTION STUDY

PG&E Study ID Numbers:
Process End Use: 311R2 (1994), 382R2 (1995)
Indoor Lighting End Use: 314R2 (1994), 325R2 (1995)

March 1, 2001

Measurement and Evaluation
Customer Energy Efficiency Policy & Evaluation Section
Pacific Gas and Electric Company
San Francisco, California

Disclaimer of Warranties and Limitation of Liabilities

As part of its Customer Energy Efficiency Programs, Pacific Gas and Electric Company (PG&E) has engaged consultants to conduct a series of studies designed to increase the certainty of and confidence in the energy savings delivered by the programs. This report describes one of those studies. It represents the findings and views of the consultant employed to conduct the study and not of PG&E itself.

Furthermore, the results of the study may be applicable only to the unique geographic, meteorological, cultural, and social circumstances existing within PG&E's service area during the time frame of the study. PG&E and its employees expressly disclaim any responsibility or liability for any use of the report or any information, method, process, results or similar item contained in the report for any circumstances other than the unique circumstances existing in PG&E's service area and any other circumstances described within the parameters of the study.

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1994 & 1995 Industrial Energy Efficiency Incentive Programs Sixth-Year Retention Study

PG&E Study ID Numbers:
Process End Use: 311R2 (1994), 382R2 (1995)
Indoor Lighting End Use: 314R2 (1994), 325R2 (1995)

Purpose of Study

This 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," 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.

This study measures the Effective Useful Life (EUL) of process and indoor lighting measures for which rebates were paid through Pacific Gas and Electric Company's 1994 & 1995 Industrial Energy Efficiency Incentive Programs. The EUL is the time at which half the units rebated and installed during the program year are no longer in place and operable.

Methodology

For each measure, this study assumes the time to non-retention follows some parametric distribution. Therefore, the general method of study is to collect retention data from participants and use those data to estimate the parameters of this distribution. The estimated parameters of the distribution for the time to non-retention are then used to estimate the median retention time or EUL.

The data necessary for this study were obtained from the Program tracking data and collected via on-site inspections. The on-site inspection data were collected at two points in time, three and six years after installation. A total of 59 projects (a project is a unique site and rebate application combination) provide the data for the retention analysis of process measures, and a total of 158 projects provide the data for the retention analysis of lighting measures.

The parameters of the distribution of the time to non-retention are estimated by fitting a general linear regression model to the logarithmic transformation of the time to non-retention reported in the data. To estimate the EUL, the estimated parameters are then employed in the survival function. This function is simply one minus the cumulative distribution function for the time to non-retention. The survival function gives the probability of retaining a unit of a measure until at least time t. Therefore, the estimate of the EUL is the time t^* such that the survival probability equals 50 percent.

Study Results

The results of this study are summarized in the table below. Results are presented separately for each unique measure and *ex ante* EUL combination. For simplicity, we refer to a unique measure and *ex ante* EUL combination as simply a "measure." For those measures for which all units were retained, the table only presents the *ex ante* EUL and the EUL realization rate, 1.0. For those measures for which some of the units were not retained, the table also presents the results of the retention analysis.

1994 & 1995 Industrial Energy Efficiency Incentive Programs
Summary of Effective Useful Life Estimates

Program Year	Measure	End Use	EUL (years) *ex ante*	*ex post* (estimated from study)	Adopted *ex post* (to be used in claim)	*ex post* Standard Error	80% Confidence Interval Lower Bound	80% Confidence Interval Upper Bound	p-value for *ex post* EUL	EUL Realization Rate (adopted *ex post* / *ex ante*)
1995	**550A**	Process	11.0	8.8	11.0	4.1	4.7	16.6	0.70	1.00
	550B		15.0	-	15.0	-	-	-	-	1.00
1995	**560A**	Process	10.0	-	10.0	-	-	-	-	1.00
	560B		14.5	-	14.5	-	-	-	-	1.00
	560C		20.0	-	20.0	-	-	-	-	1.00
1994-1995	**569A**	Process	5.0	-	6.8	-	-	-	-	1.36
	569B		14.5	3.0	3.0	1.6	1.3	6.8	0.06	0.21
	569C		19.5	49.0	19.5	51.6	11.6	207.5	0.43	1.00
	569D		25.0	-	6.0	-	-	-	-	0.24
1994	**590A**	Process	5.0	4.2	4.0	0.1	4.0	4.3	0.68	0.80
	590B		10.0	-	10.0	-	-	-	-	1.00
1994-1995	**599A**	Process	11.0	-	11.0	-	-	-	-	1.00
	599B		15.5	-	15.5	-	-	-	-	1.00
	599C		20.5	-	20.5	-	-	-	-	1.00
1994-1995	**L19**	Lighting	16.0	15.5	16.0	7.6	8.3	29.1	0.95	1.00
1994	**L23**	Lighting	16.0	12.4	16.0	3.7	8.5	18.2	0.45	1.00
1994	**L37**	Lighting	20.0	25.9	20.0	63.7	1.0	701.2	0.93	1.00
1994-1995	**L81**	Lighting	16.0	126.6	16.0	82.8	54.3	294.9	0.01	1.00

The *ex ante* EUL estimates are recommended for adoption in all cases except four. For process measure 569A, the *ex ante* measure life has been exceeded by all units in the study, and the *ex post* EUL reflects the current life of the studied measures. For process measure 569D, all units had failed by the end of the study period, and the *ex post* EUL is known with certainty. For process measures 569B and 590A, the *ex ante* EULs fell outside the 80 percent confidence interval developed in the *ex post* analysis, and thus the *ex post* EUL estimates are recommended for adoption.

Regulatory Waivers and Filing Variances

None.

1994 AND 1995 INDUSTRIAL ENERGY EFFICIENCY INCENTIVE PROGRAMS SIXTH-YEAR RETENTION STUDY

FINAL REPORT

PG&E Study ID Numbers:
Process End Use: 311R2 (1994), 382R2 (1995)
Indoor Lighting End Use: 314R2 (1994), 325R2 (1995)

Prepared for

Pacific Gas and Electric Company
San Francisco, California

Prepared by

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Oakland, California
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March 1, 2001

E EXECUTIVE SUMMARY

This report provides the results of the sixth-year retention study of Pacific Gas and Electric Company's (PG&E) 1994 & 1995 Industrial Energy Efficiency Incentive (IEEI) Programs (Programs), as required by the Measurement and Evaluation Protocols (M&E Protocols) of the California DSM Measurement Advisory Committee (CADMAC).[1]

As given in the M&E Protocols, the goal of a measure retention study is to determine "the length of time the measure(s) installed during the program year are maintained in operable condition." This issue is addressed by estimating each measure's Effective Useful Life (EUL). The EUL is defined as the time at which half the units installed during the program year are no longer in place and operable.

Each measure has an *ex ante* estimate of the EUL, which has been used in the earnings claims to date. A measure's *ex post* EUL is the EUL based on a retention study. If a measure's *ex ante* EUL is outside the 80 percent confidence interval for the measure's EUL determined by a retention study, the *ex post* EUL will be used for future earnings claims. Otherwise, the *ex post* EUL will not replace the *ex ante* EUL.

E.1 DATA

A total of nine measures qualified for inclusion in the study because they accounted for at least 50 percent of Program resource value in a given Program Year as required by the M&E Protocols, seven measures under the Programs in 1994 and six measures under the Programs in 1995. Four measures qualified for inclusion in the study under both Program years. In the case of the 1994 Programs, the seven measures selected for inclusion in the study accounted for 57 percent of the avoided energy costs that year. In the case of the 1995 Programs, the six measures selected for inclusion in the study accounted for 62 percent of the avoided energy costs that year. Table E-1 provides a list and description of measures included in the study, along with their contribution to Program resource value (as measured by energy avoided cost savings).

The projects (a project is a unique site and rebate application combination) identified to provide the retention data for these measures are among the projects included in the first-year impact evaluation of the PG&E Programs in either 1994 or 1995. The data necessary for this study were obtained from the Program tracking data and collected via on-site inspections. A total of 59 projects provide the data for the retention analysis of process measures, and a total of 158 projects provide the data for the retention analysis of lighting measures.

[1] California Public Utilities Commission, *Protocols and Procedures for the Verification of Costs, Benefits, and Shareholder Earnings from Demand-Side Management Programs*, 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.

Table E-1
Measures Included in the Study

Measure	Measure Description	Percent of Total Avoided Cost	Program Years
Processes			
550	Controls	28.5%	1995
560	Heat Recovery	3.3%	1995
569	Change/Add Equipment	16.5% (1994) 12.2% (1995)	1994-1995
590	Insulate	7.3%	1994
599	Other	5.3% (1994) 11.1% (1995)	1994-1995
Lighting			
L19	Reflectors With Delamping, 4 Ft Lamp Removed	8.2% (1994) 3.1% (1995)	1994-1995
L23	Fixture: T-8 Lamp & Electric Ballast, (Fem or New Fixture), 4 Ft Fixture	6.5%	1994
L37	HID Fixture: Interior, >= 176 Watts Lamp	3.6%	1994
L81	HID Fixture: Interior, Standard, 251-400 Watt Lamp	9.7% (1994) 4.2% (1995)	1994-1995

E.2 STUDY METHODS

E.2.1 Estimating the EUL

For each measure, this study assumes the time to non-retention follows some parametric distribution. Therefore, the general method of study is to collect retention data from participants and use those data to estimate the parameters of this distribution. The estimated parameters of the distribution for the time to non-retention are then used to estimate the median retention time or EUL.

The parameters of the distribution of the time to non-retention are estimated by fitting a general linear regression model to the logarithmic transformation of the time to non-retention reported in the data. To estimate the EUL, the estimated parameters are then employed in the survival function. This function is simply one minus the cumulative distribution function for the time to non-retention. The survival function gives the probability of retaining a unit of a measure until at least time t. Therefore, the estimate of the EUL is the time t^* such that the survival probability equals 50 percent.

E.2.2 Confidence Interval for the EUL

The lower and upper bounds of a confidence interval for the EUL are calculated as the exponential of the lower and upper bound values of the confidence interval for the log of the EUL, respectively. In general, the bounds of a confidence interval for a parameter are calculated as the parameter estimate ± the standard error of the parameter estimate times the critical value from the appropriate distribution for the desired level of confidence. The standard error of the log of the EUL estimate employed in the calculation of the confidence interval for the log of the EUL is provided by SAS®, the statistical analysis software used for the analysis. This standard error is a function of the standard errors of the parameter estimates of the general linear regression model. If necessary, the standard error of the log of the EUL estimate provided by SAS is adjusted by the square root of the design effect factor.

Adjustment to the Standard Error

When fitting a general linear regression model to the data for a given measure, an observation is the time to non-retention of a unit of the measure. The calculation of the standard errors of the parameter estimates assumes each observation is independent. This assumption, however, may be incorrect because an observation is a unit of the measure being analyzed and not the level at which sampling occurred. Sampling occurred at the project level. Therefore, the times to non-retention of units of a measure may be more similar within a project than between projects.

If the times to non-retention of units of a measure are more similar within a project than between projects and if the data analyzed for a measure are based on only a sample of projects that obtained a rebate for the measure, it is necessary to adjust the standard error of an estimate for the sample design by the square root of the design effect factor (Kish 1965). If the times to non-retention of units of a measure are no more similar within a project than between projects, then the square root of the design effect factor equals one and the unadjusted and adjusted standard error are equal. Usually, however, the design effect factor is greater than one.

Typically, the data analyzed for a measure are based on only a sample of projects that obtained a rebate for the measure, and it is necessary to adjust the standard error of the EUL estimate. If it is possible to obtain data from all the projects that obtained a rebate for a measure, it is not necessary to adjust the standard error of the EUL estimate. If all the units of a measure are included in the analysis, that the data collection occurred at the project level has no consequences and it is not necessary to adjust the standard error of the EUL estimate by the square root of the design effect factor.

E.3 SUMMARY OF RESULTS

The results of this study are summarized in Table E-2. Results are presented separately for each unique measure and *ex ante* EUL combination. For simplicity, we refer to a unique measure and *ex ante* EUL combination as simply a “measure.” For those measures for which all units were retained, Table E-1 only presents the *ex ante* EUL and the EUL realization rate, 1.0. For those measures for which some of the units were not retained, Table E-2 also presents the results of the retention analysis.

Table E-2
1994 & 1995 Industrial Energy Efficiency Incentive Programs
Summary of Effective Useful Life Estimates

Program Year	Measure	End Use	EUL (years) *ex ante*	EUL (years) *ex post* (estimated from study)	EUL (years) Adopted *ex post* (to be used in claim)	EUL (years) *ex post* Standard Error	80% Confidence Interval Lower Bound	80% Confidence Interval Upper Bound	p-value for *ex post* EUL	EUL Realization Rate (adopted *ex post* / *ex ante*)
1995	**550A**	Process	11.0	8.8	11.0	4.1	4.7	16.6	0.70	1.00
	550B		15.0	-	15.0	-	-	-	-	1.00
1995	**560A**	Process	10.0	-	10.0	-	-	-	-	1.00
	560B		14.5	-	14.5	-	-	-	-	1.00
	560C		20.0	-	20.0	-	-	-	-	1.00
1994-1995	**569A**	Process	5.0	-	6.8	-	-	-	-	1.36
	569B		14.5	3.0	3.0	1.6	1.3	6.8	0.06	0.21
	569C		19.5	49.0	19.5	51.6	11.6	207.5	0.43	1.00
	569D		25.0	-	6.0	-	-	-	-	0.24
1994	**590A**	Process	5.0	4.2	4.0	0.1	4.0	4.3	0.68	0.80
	590B		10.0	-	10.0	-	-	-	-	1.00
1994-1995	**599A**	Process	11.0	-	11.0	-	-	-	-	1.00
	599B		15.5	-	15.5	-	-	-	-	1.00
	599C		20.5	-	20.5	-	-	-	-	1.00
1994-1995	**L19**	Lighting	16.0	15.5	16.0	7.6	8.3	29.1	0.95	1.00
1994	**L23**	Lighting	16.0	12.4	16.0	3.7	8.5	18.2	0.45	1.00
1994	**L37**	Lighting	20.0	25.9	20.0	63.7	1.0	701.2	0.93	1.00
1994-1995	**L81**	Lighting	16.0	126.6	16.0	82.8	54.3	294.9	0.01	1.00

For lighting measures, the estimated or *ex post* EULs are obtained assuming a Weibull distribution for the time to non-retention for measures L19, L23, and L37. For measure L81, an Exponential distribution is assumed; models based on the other possible distributions did not converge. In all cases, the *ex ante* EUL estimate falls within the 80 percent confidence intervals that were constructed using the final lighting models. Thus, the recommended *ex post* EUL for each lighting measure are based on the *ex ante* EUL.

For process measures, only four survival models could be developed, for measures 550A, 569B, 569C, and 590A. For measure 569D, all units had failed by the end of the study period, and the measure life was known with certainty. For all other measures, there were no observed failures during the study period. In the case of measure 569A, the *ex ante* measure life has been exceeded by all units in the study, and the *ex post* EUL reflects the current life of the studied measures.

For process measures 550A, 569B, and 569C, an Exponential distribution was assumed for estimating the *ex post* EUL; models based on the other possible distributions did not converge. For measure 590A, a Weibull distribution is assumed, although all distributions returned similar results. For the analyzed measures, the *ex ante* EUL fell within the 80 percent confidence interval for measures 550A and 569C. Thus, the recommended *ex post* EULs for these measures are based on the *ex ante* EULs. For measures 569B and 590A, the *ex ante* EUL falls outside the 80 percent confidence interval, and therefore the *ex post* EUL estimates are recommended for adoption.

In general, and especially for lighting measures, the survival analysis process was problematic. Despite relatively low non-retention rates for lighting measures (15 percent or less at the end of the sixth year as shown in Table E-3), some of the initial survival models produced very short EULs – less than 11 years for three of the lighting measures. These modeling results imply that, while less that 15 percent of the units were removed in the first six years, 35 to 40 percent of the units will be removed in the next six years.

Table E-3
Non-Retention Rates To Date

End Use	Measure	ex ante EUL	% of Units Not Reatined to Date
Process	550A	11	33%
Process	550B	15	0%
Process	560A	10	0%
Process	560B	14.5	0%
Process	560C	20	0%
Process	569A	5	0%
Process	569B	14.5	67%
Process	569C	19.5	8%
Process	569D	25	100%
Process	590A	5	70%
Process	590B	10	0%
Process	599A	11	0%
Process	599B	15.5	0%
Process	599C	20.5	0%
Lighting	L19	16	14%
Lighting	L23	16	12%
Lighting	L37	20	15%
Lighting	L81	16	3%

In fitting the survival models to the current six years of survey data, we found that the models were very sensitive to removal patterns over time (although accurate equipment removal dates were not always easy to ascertain) and to the effects of a few projects where relatively large numbers of units were removed. In particular for lighting measures L19, L23, and L37, we identified one project for each measure that removed units (due to remodeling) near the end of the study period. The survival models interpreted these removals as the beginning of period where measure non-retention would begin to increase at an increasing rate. Statistical precision of the initial models also appeared to understate the true uncertainty of the measure life as one moved out beyond the model estimation period. While the models "fit" the current data well, they appear to be capturing a phenomenon (rapidly increasing rates of non-retention) that is not likely to continue into the future.

Final survival models for lighting measures were developed after excluding one influential project for each measure (L19, L23, and L37). These models provide somewhat higher EULs since a large amount of non-retention is eliminated from the analysis. More importantly, the final models produce estimates of statistical precision (wider confidence bands) that appear to be more in line with the true uncertainty of each measure's EUL.

1 INTRODUCTION

1.1 OVERVIEW

This report provides the results of the sixth-year retention study of Pacific Gas and Electric Company's (PG&E) 1994 & 1995 Industrial Energy Efficiency Incentive (IEEI) Programs (Programs), as required by the Measurement and Evaluation Protocols (M&E Protocols) of the California DSM Measurement Advisory Committee (CADMAC).[1] In this section, the protocol requirements are discussed, followed by a summary of the organization of the report.

1.2 PROTOCOL REQUIREMENTS

The M&E Protocols require retention studies be performed in the third and sixth years for rebates received under PG&E's Programs. The CADMAC Persistence Subcommittee directed the retention studies of PG&E's 1994 & 1995 Programs be combined into a single study.

As given in the M&E Protocols, the goal of a measure retention study is to determine "the length of time the measure(s) installed during the program year are maintained in operable condition." As agreed within the CADMAC Persistence Subcommittee, this issue is addressed by estimating each measure's Effective Useful Life (EUL). The EUL is defined as the median retention time, that is, the time at which half the units installed during the program year are no longer in place and operable. We refer to "no longer in place and operable" as "non-retention."

Each measure has an *ex ante* estimate of the EUL, which has been used in the earnings claims to date. A measure's *ex post* EUL is the EUL estimated by a retention study. If a measure's *ex ante* EUL is outside the 80 percent confidence interval for the measure's EUL determined by a retention study, the *ex post* EUL will be used for future earnings claims. Otherwise, the *ex post* EUL will not replace the *ex ante* EUL. Whether or not a measure's EUL is revised as a result of this study, the EUL may be revised in the future based on subsequent retention studies required by the M&E Protocols.

1.3 REPORT ORGANIZATION

The next section of this report, Section 2, describes the data employed in the study. Section 3 discusses the methods employed to estimate a measure's EUL and the standard error of the estimate. The calculation of both the confidence interval for the EUL and the p-value reported

[1] California Public Utilities Commission, *Protocols and Procedures for the Verification of Costs, Benefits, and Shareholder Earnings from Demand-Side Management Programs*, 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.

are also discussed in Section 3. Sections 4 and 5 present the results for process and lighting measures, respectively. Appendix A contains the on-site data collection instrument. Appendices B and C provide Tables 6B and 7B, respectively, required by the M&E Protocols.

2 DATA

This section of the report describes the data used in the retention analysis of PG&E's 1994 & 1995 IEEI Programs. A discussion of both the measures and projects (a project is a unique site and rebate application combination) included in this study is presented. These discussions are followed by a description of the sources of the data employed in the analysis. The section concludes with the details of preparing the data for analysis.

2.1 MEASURES INCLUDED IN THE STUDY

The M&E Protocols (Table 9A) indicate the measures to be studied in the retention analysis should be:

> "… 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."

Table 2-1 lists the measures included in this study and the Program year under which it qualified for inclusion. A total of nine measures qualified for inclusion in the study, seven measures under the Program in 1994 and six measures under the Program in 1995. Four measures, 569, 599, L19, and L81, qualified for inclusion in the study under both Program years. In the case of the 1994 Program, the seven measures selected for inclusion in the study accounted for 57 percent of the avoided energy costs that year. In the case of the 1995 Program, the six measures selected for inclusion in the study accounted for 62 percent of the avoided energy costs that Program year.

Table 2-1
Measures Included in the Study

Measure	Measure Description	Percent of Total Avoided Cost	Program Years
	Processes		
550	Controls	28.5%	1995
560	Heat Recovery	3.3%	1995
569	Change/Add Equipment	16.5% (1994) 12.2% (1995)	1994-1995
590	Insulate	7.3%	1994
599	Other	5.3% (1994) 11.1% (1995)	1994-1995
	Lighting		
L19	Reflectors With Delamping, 4 Ft Lamp Removed	8.2% (1994) 3.1% (1995)	1994-1995
L23	Fixture: T-8 Lamp & Electric Ballast, (Fem or New Fixture), 4 Ft Fixture	6.5%	1994
L37	HID Fixture: Interior, >= 176 Watts Lamp	3.6%	1994
L81	HID Fixture: Interior, Standard, 251-400 Watt Lamp	9.7% (1994) 4.2% (1995)	1994-1995

2.2 PROJECTS INCLUDED IN THE STUDY

A project is a unique site (identified by PG&E control number) and rebate application combination. A given rebate application may include a rebate request for more than one measure. Therefore, a project may be included in the analysis of the retention of more than one measure.

The projects included in this study are the same projects that were inspected for the third-year retention study of PG&E's 1994 & 1995 Programs. Table 2-2 gives the number of projects in the sample by Program year and measure.

Table 2-2
Projects Included in the Study

Program Years	Measure	End Use	Measure Description	Population	Sample
1994	550	Process	Controls	20	4
	560	Process	Heat Recovery	3	1
	569	Process	Change/Add Equipment	16	6
	590	Process	Insulate	3	1
	599	Process	Other	13	6
	L19	Lighting	Reflectors With Delamping, 4 Ft Lamp Removed	196	24
	L23	Lighting	Fixture: T-8 Lamp & Electric Ballast, (Fem or New Fixture), 4 Ft Fixture	283	29
	L37	Lighting	HID Fixture: Interior, >= 176 Watts Lamp	87	15
	L81	Lighting	HID Fixture: Interior, Standard, 251-400 Watt Lamp	194	12
Total 1994				815	98 (71 unique)
1995	550	Process	Controls	15	8
	560	Process	Heat Recovery	4	4
	569	Process	Change/Add Equipment	13	10
	590	Process	Insulate	2	2
	599	Process	Other	23	18
	L19	Lighting	Reflectors With Delamping, 4 Ft Lamp Removed	92	43
	L23	Lighting	Fixture: T-8 Lamp & Electric Ballast, (Fem or New Fixture), 4 Ft Fixture	164	58
	L81	Lighting	HID Fixture: Interior, Standard, 251-400 Watt Lamp	144	50
Total 1995				457	193 (146 unique)
Total 1994 and 1995				1272	291 (217 unique)

The projects included in the third-year retention study were among the projects included in the retention panels developed during the first-year impact evaluation of either the 1994 or 1995 Program. The projects included in the third-year retention study from the 1994 retention panel were selected as follows:

1. In the case of each end use, lighting and process, select the projects with the largest *ex ante* gross savings that together account for at least 70 percent of the *ex ante* gross savings of projects included in the first-year impact evaluation of the end use in 1994.
2. From this subset of projects included in the first-year impact evaluation of the 1994 Program, select any project that obtained a rebate for one of the measures included in this study.

The third-year retention study attempted a census of the projects in the 1995 retention panel that obtained a rebate for one of the measures included in this study.

2.2.1 Sample Disposition

Site inspections were conducted for 210 out of the 217 unique projects in the sample. Of the seven projects that weren't inspected, two were for projects at sites that are no longer PG&E customers, four projects involved customers who could not be contacted during the on-site inspection recruitment process, and one project involved a customer who refused an on-site inspection. Additionally, for three projects at sites that were visited, on-site inspections yielded incomplete data as the inspectors, in conjunction with customer staff, couldn't determine whether or not Program measures were still in place and operable.

2.3 DATA SOURCES

The data used in this study were obtained from three sources:

1. the PG&E Program tracking data for 1994 and 1995;
2. the first-year impact evaluation of the 1994 Program and of the 1995 Program; and
3. on-site inspections conducted for the third-year retention study and for this current retention study.

2.3.1 Program Tracking Data

For each project in the sample, the Program tracking data provides the following information:

- contact information; and

for each measure for which a rebate was obtained,

- the number of units of the measure for which a rebate was obtained,
- an initial installation date,
- the avoided energy costs, and
- the *ex ante* EUL.

There are two general types of measures (or end uses), lighting and process. In the cases of all lighting measures, a unit is a lamp; whereas a unit of a process measure is very specific to the process.

2.3.2 First-Year Impact Evaluations of the Program

For each project in the sample, the first-year impact evaluation of the 1994 or 1995 Program provides the following data:

- updated contact information; and

for each measure for which a rebate was obtained,

  - the number of units of the measure both rebated and installed (number of expected units when first inspected); and
  - the location of these units.

2.3.3 On-Site Inspections

In the cases of both the third-year and the current retention studies, for each project in the sample, an attempt was made to conduct an on-site inspection. For each project in the sample, the on-site inspection provides the following data:

- the date of the inspection; and

for each measure for which a rebate was obtained,

  - an updated installation date;
  - of the number of expected units of the measure, the number of units observed to be in place and the percentage of these units that are working; and
  - if known, in the case of each non-retained unit, the number of months prior to the date of the inspection the unit was not retained (these data were not collected when projects from the 1994 Program were inspected for the third-year retention study).

A unit not in place and/or not operable at the time of the inspection is classified as not retained for purposes of this analysis. Therefore, a unit is classified as not retained if it is removed and/or if it fails. When the inspector was able to determine the reason a unit was not retained, this information was recorded as well. A copy of the on-site data collection instrument is provided in Appendix A.

If a project was inspected for the third-year retention study, the number of units of a measure retained based on this inspection is the number of expected units of the measure for the on-site inspection attempted for the current retention study. The on-site inspections conducted for the third-year retention study also provide updated contact information.

For each project inspected for the current retention study, data were collected on the current occupant of the inspected space. These data are used to determine whether or not the occupant of the inspected space has changed since the measure(s) associated with the project was (were) installed.

2.4 Data Preparation

- In order to combine the Program tracking data with the on-site inspection data from the third-year retention study and with the on-site inspection data from the current retention study, if a project-measure combination is not already a unique observation in the Program tracking data, it is made a unique observation. To make such a combination a unique observation in the Program tracking data, the number of units for which a rebate was obtained is summed and the avoided energy costs are summed. In the case of the on-site inspection data, if the number of expected units of a measure is specified separately for various locations, the inspector may enter the data by location.

In order to combine the on-site inspection data from the third-year retention study with the on-site inspection data from the current retention study, if a project-measure-installation date-survey date combination is not a unique observation in each of the on-site inspection data sets, it is made a unique observation. To make such a combination a unique observation in an on-site inspection data set, the number of units rebated and installed is summed and the number of units retained is summed. No relevant data are lost when making a project-measure-installation date-survey date combination a unique combination in each of the on-site inspection data sets. Specifically, no data on the time to non-retention are lost.

- At a given site, more units of a measure may be observed to be in place than are expected. Furthermore, it may be difficult to determine which of the units of the measure observed to be in place correspond to the units of the measure associated with the sample project.

  Therefore, if the number of units of a measure observed to be in place exceeds the number of expected units, the number of observed units is reset to the number of expected units. The number of retained units is then calculated as the revised number of observed units times the original percentage of observed units that are working. And the number of non-retained units is the number of expected less the number of retained units.

- The methods employed in this study (discussed in the next section), namely, the fitting of the general linear regression model, allow inexact measures of the time to non-retention. This is done by specifying both a lower bound and an upper bound for the time to non-retention. The time to non-retention may be inexact for a unit of a measure not retained and it is clearly inexact for a unit of a measure still retained.

  For all units of a measure, the installation date and inspection dates are known. Ideally, in the case of a non-retained unit of a measure, the time to non-retention is calculated exactly using these data and the number of months prior to the relevant inspection the unit was not retained. If it is possible to calculate the exact time to non-retention, the lower and upper bounds for the time to non-retention both equal this exact time.

  Often, however, the number of months prior to an inspection a unit of a measure was not retained is unknown. If it is only known a unit was not retained some time before an inspection date, the lower bound of the time to non-retention is zero and the upper bound equals the number of years between the installation date and the relevant inspection date. Such observations are said to be left-censored. For SAS®, the statistical analysis software used for the analysis, to recognize an observation is left-censored, the lower bound is set equal to missing.

If it is also known a unit was retained after some date other than the installation date, the lower bound of the time to non-retention equals the number of years between the installation date and this date, and the upper bound equals the number of years between the installation date and the relevant inspection date. Such observations are said to be interval-censored. For example, a unit retained at the time of the third-year inspection but not retained some unknown time before the sixth-year inspection date is interval censored. Left-censoring is a special case of interval-censoring, where the lower bound of the time to non-retention equals zero.

The time to non-retention for a unit of a measure still retained at the time of the latest inspection is inexact. It is somewhere between the number of years between the installation date and the latest inspection date, and infinity. At some time, all units will not be retained. Therefore, in the case of a unit still retained, the lower bound of the time to non-retention equals the number of years between the installation date and the latest inspection date and the upper bound is infinity. Units still retained, then, are said to be right-censored. For SAS to recognize an observation is right-censored, the upper bound is set equal to missing.

3 STUDY METHODS

To analyze retention, this study employs a method commonly referred to as Survival Analysis. The method was first given this name because it was initially used to analyze death rates. The same set of techniques referred to as Survival Analysis is also referred to by several other names depending on the area of application. For example, in Engineering, "Survival Analysis" is Reliability Analysis and in Economics, it is Duration Analysis. In addition, the terminology employed in the analysis may vary depending on the area of application. In this report, we will use the Survival Analysis terminology, but will modify it when appropriate for the application of Survival Analysis to retention.

3.1 SURVIVAL ANALYSIS

3.1.1 The Basics

For each measure, this study assumes the time to non-retention follows some parametric distribution. Therefore, the general method of study is to collect retention data from participants and use those data to estimate the parameters of this distribution. The estimated parameters of the distribution for the time to non-retention are then used to estimate the median retention time or EUL.

The parameters of the distribution of the time to non-retention are estimated by fitting a general linear regression model to the logarithmic transformation of the time to non-retention reported in the data. This model can be written as

$$\ln(T_j) = \mu + \sigma\varepsilon_j,$$

where

T_j = measured time to non-retention;

μ = location parameter or intercept;

σ = scale parameter; and

ε_j = random error term.

The exponential of the error term of this model (e^{ε_j}) is assumed to follow the standardized form of the distribution of the time to non-retention. The general linear regression model is fitted by maximizing the log-likelihood function for the assumed distribution.

To estimate the EUL, the estimated parameters of the distribution of the time to non-retention are then employed in the survival function. This function is simply one minus the cumulative distribution function for the time to non-retention. The survival function $S(t;\theta)$ gives the probability of retaining a unit of a measure until at least time t, given the parameter vector θ.

Therefore, the estimate of the EUL is the time t^* such that the survival probability $S(t^*;\hat{\theta}) = 0.50$, where $\hat{\theta}$ is the vector of parameter estimates.

3.1.2 Distribution Options

This study considers the most common distributional assumptions made when conducting Survival Analysis:

- Gamma;
- Weibull;
- Exponential;
- Log-normal; and
- Log-logistic.

The Gamma distribution is the most general of the distributions listed above. It has three free parameters, location (μ), scale (σ), and shape; whereas the other distributions have only one or two free parameters. In fact, the Gamma distribution includes the Weibull, Exponential, and Log-normal distributions as special cases. The Weibull distribution also includes the Exponential distribution as a special case.

The Weibull, Log-normal, and Log-logistic distributions have two free parameters, location and scale; and the Exponential distribution has one free parameter, location. The Weibull and Log-normal distributions result as special cases of the Gamma distribution when the shape parameter equals one and zero, respectively. The Exponential distribution results as a special case of the Gamma distribution when both the shape and scale parameters equal one or as a special case of the Weibull distribution when the scale parameter equals one.

The Gamma distribution places fewer constraints on the parameters than the Weibull, Exponential, and Log-normal distributions. As a result, the parameter estimates obtained assuming the Gamma distribution will be most based on the data. If one of the other distributions is a good description of the data, its results will be similar to those of the less constrained Gamma distribution.

3.1.3 Distribution Adopted

The selection of the most appropriate distribution is based on several criteria:

- implications for the non-retention rate over time;
- likelihood ratio test;
- analysis of residuals; and
- maximum of the log-likelihood function.

Non-Retention Rate Over Time

The distributional assumption has implications for the non-retention rate over time. These implications are seen via the hazard function $h(t;\theta)$. Roughly, the hazard function can be thought of as the instantaneous probability of not retaining a unit at time *t*, given that the unit has been retained up to that time. Formally, it is the negative ratio of the survival probability density function *dS/dt* to the survival function,

$$h(t;\theta) = -\frac{dS/dt}{S(t;\theta)}.$$

An increasing hazard function means the non-retention rate increases as a unit of a measure ages, whereas a decreasing hazard function means the non-retention rate decreases as a unit of a measure ages. If the hazard function is constant, the non-retention rate remains constant as a unit of a measure ages.

The hazard function of the Gamma distribution may have a variety of shapes, including always increasing at an increasing rate. Unfortunately, however, it is often difficult to determine which possible shape the hazard function of the Gamma distribution actually takes on.

The Weibull distribution produces a hazard function that is either always decreasing or always increasing. If the scale parameter is greater than one then the hazard function is decreasing, whereas if the scale parameter is less than one then the hazard function is increasing. Recall, a Weibull distribution with scale parameter equal to one corresponds to the Exponential distribution. The Exponential distributional results in a constant hazard function.

If the hazard function of the Weibull distribution is increasing (the scale parameter is less than one), the rate of increase depends on the value of the scale parameter. If the scale parameter is between 0.5 and 1, the hazard function is increasing at a decreasing rate; if the scale parameter equals 0.5, the hazard function is increasing at a constant rate; and if the scale parameter is between 0 and 0.5, the hazard function is increasing at an increasing rate.

The Log-normal distribution produces a hazard function that increases to a peak then decreases. The larger the scale parameter, the sooner the hazard function reaches its peak and begins to decrease. A hazard function that is increasing then decreasing means that for some period of time after a unit of a measure is installed, the non-retention rate increases as the unit of the measure ages then, after some point, the non-retention rate decreases as the unit of the measure ages. This pattern may be reasonable up to a point if there is initially more non-retention because of immediate dissatisfaction and removal of units of a measure. The clear problem with assuming a Log-normal distribution is that once the non-retention rate decreases as a unit of a measure ages it does so thereafter.

The hazard function of the Log-logistic distribution may increase to a peak then decrease or it may be always decreasing. If the scale parameter is less than one then the hazard function is increasing then decreasing, whereas if the scale parameter is greater than or equal to one then the hazard function is always decreasing.

Likelihood Ratio Test

The likelihood ratio test provides a measure of how well the models fit the current study period data. If a distribution is a special case of another distribution, the appropriateness of the former versus the latter can be formally tested using the likelihood ratio test. Therefore, it is possible to compare the appropriateness of the Weibull, Exponential, and Log-normal distributions versus the Gamma distribution. It is also possible to compare the appropriateness of the Exponential distribution versus the Weibull distribution. Of course, the likelihood ratio test provides no insight into which distribution will provide the "best" EUL estimate, which requires, in most cases, a forecast outside of the current study period data.

Analysis of Residuals

According to Allison (1995), Cox-Snell residuals are commonly used in Survival Analysis and are defined as:

$$e_j = -\log(S(t_j;\hat{\theta})),$$

where

e_j = the residual at the observed time to non-retention t_j and

$S(t_j;\hat{\theta})$ = the estimated survival function at time t_j.

A residual will be right-censored, interval-censored, left-censored, or uncensored, if the observed time to non-retention it is associated with is right-censored, interval-censored, left-censored, or uncensored, respectively.

If the fitted general linear regression model is appropriate, the residuals have an approximate exponential distribution with scale parameter one. To determine whether or not this is the case, a general linear regression model is fitted to the logarithm of the residuals assuming the exponential of the error term follows the standardized form of the exponential distribution. An estimated scale parameter not statistically different from one at a 10 percent level of significance or better, suggests the general linear regression model fitted to the logarithmic transformation of the time to non-retention may be appropriate.

Maximum of the Log-Likelihood Function

Recall, under each assumed distribution, the general linear regression model is fitted by maximizing the log-likelihood function. A larger maximum value of the log-likelihood function suggests a better model fit.

3.2 STANDARD ERROR OF THE EUL ESTIMATE

3.2.1 Calculation of the Standard Error

Because the general linear regression model fitted is the log of the time to non-retention, the parameters thus estimated and employed in the survival function will directly produce the log of the EUL estimate such that the survival probability is 0.50. The estimate of the EUL is then obtained by calculating the exponential of this log value ($e^{ln(EUL\ estimate)}$). Calculating the standard error of the EUL estimate, however, is not as simple because the logarithmic transformation is non-linear.

If the distribution of the log of the EUL estimate is known, it may be possible to calculate the exact standard error of the EUL estimate. However, this distribution is unknown in this study, as it is in most studies. Therefore, the approximate standard error is calculated by SAS® using a first order Taylor expansion around the EUL estimate of the log of the time to non-retention. This approximation is a function of the log of the EUL estimate and the standard errors of the parameter estimates of the general linear regression model.

3.2.2 Adjustment to the Standard Error

When fitting a general linear regression model to the data for a given measure, an observation is the time to non-retention of a unit of the measure. This unit in the cases of all of the lighting measures is a lamp; whereas a unit of a process measure is very specific to the process. The calculation of the standard errors of the parameter estimates assumes each observation is independent. This assumption, however, may be incorrect because the level of an observation is a unit of the measure being analyzed and not the level at which sampling occurred. Sampling occurred at the project level. Recall, projects were selected for data collection. Therefore, the times to non-retention of units of a measure may be more similar within a project than between projects.

Several factors may cause the times to non-retention of units of a measure to be more similar within a project than between projects. Dissatisfaction or renovations may lead to the simultaneous removal of a large number of units, perhaps even all the units, of a measure within a project. Site-specific measure installation practices and the specific operating conditions may affect the time to non-retention. Units of a measure installed at the same time are likely to be of a similar quality and, therefore, have similar times to non-retention. In addition, the times to non-retention of units of a lighting measure may be more similar within a project than between projects because the unit is a lamp and one fixture may hold more than one lamp. Consequently, non-retention of one fixture may account for non-retention of more than one lamp.

While the times to non-retention of units of a measure may be more similar within a project than between projects, they are not expected to be identical within a project. Dissatisfaction or renovations do not necessarily lead to the simultaneous removal of all the units of a measure within a project. Similar measure installation practices, operating conditions, and measure quality may result in similar but not necessarily identical times to non-retention.

If the times to non-retention of units of a measure are more similar within a project than between projects and if the data analyzed for the measure are based on only a sample of projects that obtained a rebate for the measure, it is necessary to adjust the standard error of an estimate for the sample design by the square root of the design effect factor (Kish 1965). If the times to non-retention of units of a measure are no more similar within a project than between projects, then the square root of the design effect factor equals one and the unadjusted and adjusted standard error are equal. Usually, however, the design effect factor is greater than one.

If it is possible to obtain data from all the projects that obtained a rebate for a measure, it is not necessary to adjust the standard error of the EUL estimate. If all the units of a measure are included in the analysis, that the data collection occurred at the project level has no consequences and it is not necessary to adjust the standard error of the EUL estimate by the square root of the design effect factor.

The Design Effect Factor and Rho

In sampling terminology, a project is a cluster. In the case of a one-stage sample and assuming each cluster has the same number of units, the design effect factor can be expressed as

$$deff = 1 + rho(\bar{n} - 1)$$

where

rho = an estimate of the intra-cluster correlation *Rho* and

$\bar{n}$ = the average number of rebated and initially installed units of a measure per sample project (the total number of rebated and initially installed units of the measure across all sample projects included in the analysis of the measure divided by the total number of sample projects included in the analysis of the measure).

The equation for the population intra-cluster correlation (also known as the rate of homogeneity) *Rho* is

$$Rho = \frac{\sigma_b^2 - \dfrac{\sigma_w^2}{\bar{N} - 1}}{\sigma_o^2},$$

where

σ_b^2 = between-cluster population variance = $\dfrac{\sum_{i=1}^{C} N_i (\bar{T}_i - \bar{T})^2}{\sum_{i=1}^{C} N_i}$,

σ_w^2 = within-cluster population variance = $\dfrac{\sum_{i=1}^{C}\sum_{j=1}^{N_i}(T_{ij}-\overline{T}_i)^2}{\sum_{i=1}^{C}N_i}$;

σ_o^2 = overall population variance = $\dfrac{\sum_{i=1}^{C}\sum_{j=1}^{N_i}(T_{ij}-\overline{T})^2}{\sum_{i=1}^{C}N_i}$;

$\overline{N}$ = average number of units per cluster;

C = number of clusters;

N_i = number of units in cluster *i*;

$\overline{T}_i$ = average time to non-retention of a unit in cluster *i*;

$\overline{T}$ = average time to non-retention of a unit over all clusters; and

T_{ij} = time to non-retention of unit *j* in cluster *i*.

Noting that the overall population variance σ_o^2 equals the sum of the between- and within-cluster population variances σ_b^2 and σ_w^2, respectively, limit values of *Rho* can be determined and interpreted as follows:

- *Complete homogeneity within clusters* implies $\sigma_w^2 = 0$ and therefore $\sigma_b^2 = \sigma_o^2$ which leads to *Rho* = 1. *Rho* = 1 results in the largest design effect factor possible and, therefore, the largest adjustment to the standard error.
- *Extreme heterogeneity within clusters* implies σ_w^2 takes the largest possible value, σ_o^2, and, therefore, σ_b^2 = 0, which leads to *Rho* = $-1/(\overline{N}-1)$.
- *Units within a cluster no more closely related than units between clusters* implies $\sigma_b^2 = \sigma_w^2/(\overline{N}-1)$, which leads to *Rho* = 0. If this is the case, the design effect factor is one and the standard error obtained directly from the fit of the general linear regression model is correct.

In practice, *Rho* takes a value somewhere between zero and one. Negative values rarely happen. Thus, the design effect factor is usually larger than one.

Estimating Rho by Measure

In this study, *Rho* is estimated separately for each measure as

$$rho = \frac{\hat{\sigma}_b^2 - \dfrac{\hat{\sigma}_w^2}{\overline{n}-1}}{\hat{\sigma}_o^2},$$

where

$\bar{n}$ = as defined earlier (see equation for *deff*);

$\hat{\sigma}_b^2$ = estimate of the between-cluster population variance = $\dfrac{\sum_{i=1}^{c} n_i (p_i - p_o)^2}{\sum_{i=1}^{c} n_i}$;

$\hat{\sigma}_w^2$ = estimate of the within-cluster population variance = $\dfrac{\sum_{i=1}^{c} n_i p_i (1 - p_i)}{\sum_{i=1}^{c} n_i}$;

$\hat{\sigma}_o^2$ = estimate of the overall population variance = $\hat{\sigma}_b^2 + \hat{\sigma}_w^2 = p_o(1 - p_o)$;

c = number of projects included in the analysis of the measure;

n_i = number of rebated and initially installed units of the measure for project i;

p_i = proportion of rebated and initially installed units of the measure not retained as of the latest on-site inspection date for project i; and

p_o = proportion of rebated and initially installed units of the measure not retained as of the latest on-site inspection date over all projects $i = 1, 2, \ldots, c$.

Note, $\hat{\sigma}_b^2$ employs $\sum_{i=1}^{c} n_i$ as a divisor rather than the more typical $\sum_{i=1}^{c} n_i - 1$, because σ_b^2 employs $\sum_{i=1}^{C} N_i$ as a divisor.

Ideally $\hat{\sigma}_b^2$, $\hat{\sigma}_w^2$, and $\hat{\sigma}_o^2$ would be based on times to non-retention of units of the measure data. However, because the exact time to non-retention of a unit of a measure are difficult data to collect, typically, these data are the same for all non-retained units of a measure within a project. Therefore, $\hat{\sigma}_b^2$, $\hat{\sigma}_w^2$, and $\hat{\sigma}_o^2$ are instead based on the event of not retaining a unit of the measure data. That is, the proportion of rebated and initially installed units of the measure not retained. The design effect factor is expected to be similar for the event of non-retention as for the time to non-retention.

Value of rho Employed in the Analysis

The value of *rho* is calculated by measure, as just discussed, for all measures for which at least one unit of the measure was not retained. For each measure type, lighting and process, the average *rho* is then calculated, and this average is used in the calculation of the design effect factor. Therefore, the design effect factor and, hence, the adjustment to the standard error of the EUL estimate (square root of the design effect factor), is the same for all measures of the same type.

The design effect factor is calculated by measure type employing the average *rho* for a measure type because it is likely the *rho*s for measures of the same type contain information for each other. This is likely because data on all measures are limited by the difficulty of collecting data on the exact time to non-retention. Calculating the design effect by measure type minimizes this limitation by allowing all available data on the time to non-retention for a measure type to inform the value of the design effect factor. Also, the *rho*s for measures of the same type may contain information for each other because the same project may be included in the analysis of more than one measure. For example, 60 projects involved two lighting measures each, and five projects involved three lighting each.

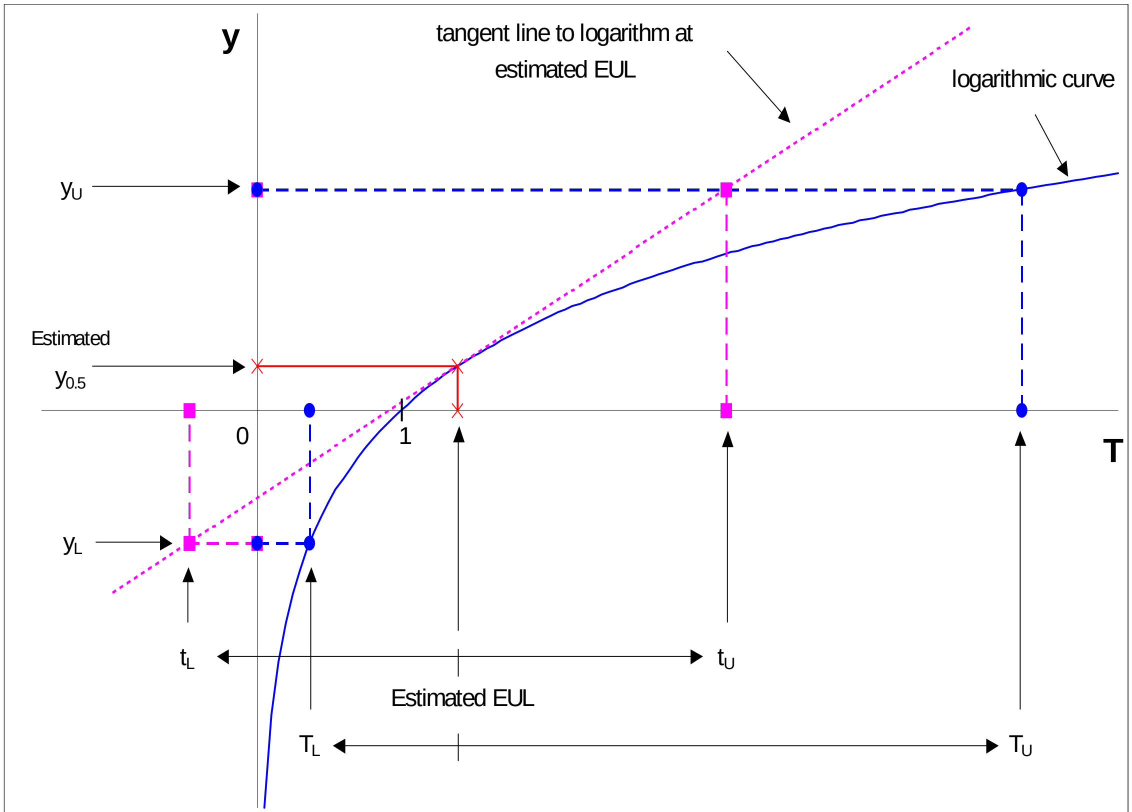
3.3 CONFIDENCE INTERVAL FOR THE EUL

Recall, it is only possible to calculate an approximate standard error of the EUL estimate. This is because it is the log of the EUL estimate that is directly obtained and the distribution of the log of the EUL estimate is unknown. A confidence interval for the EUL can be calculated using the adjusted, if necessary, approximate standard error of the EUL estimate. However, a more accurate confidence interval for the EUL can be obtained from the confidence interval for the log of the EUL. The lower and upper bounds of a confidence interval for the EUL equal the exponential of the lower and upper bound values of the confidence interval for the log of the EUL, respectively. This study calculates and reports this more accurate confidence interval for the EUL.

The lower and upper bounds of a confidence interval for the EUL based on the approximate standard error of the EUL estimate are the same distance from the EUL estimate. The confidence interval for the log of the EUL is similarly symmetric about the log of the EUL estimate. However, the confidence interval for the EUL based on the confidence interval for the log of the EUL is not symmetric about the EUL estimate. This result occurs because the logarithmic transformation is non-linear, explaining why the confidence interval for the EUL based on the approximate standard error of the EUL estimate is less accurate than the confidence interval for the EUL based on the confidence interval for the log of the EUL. The larger the approximate standard error of the EUL estimate, the greater the consequences of the non-linearity of the logarithmic transformation and the less accurate the confidence interval for the EUL based on the approximate standard error of the EUL estimate.

The non-linearity of the logarithmic transformation also explains why the confidence interval for the EUL based on the approximate standard error of the EUL estimate may contain negative values, which are clearly impossible. The confidence interval for the EUL based on the confidence interval for the log of the EUL will never contain negative values. The two methods of calculating a confidence interval of the EUL are illustrated in Figure 3-1.

Figure 3-1
Two Methods of Calculating a Confidence Interval for the EUL



(y_L, y_U) - Confidence Interval for the log of the EUL.

(T_L, T_U) - Confidence Interval for the EUL using the correct mapping.

(t_L, t_U) - Confidence Interval for the EUL using the approximate standard error.

3.3.1 Confidence Interval for the Log of the EUL

In general, the bounds of a confidence interval for a parameter are calculated as the parameter estimate ± the standard error of the parameter estimate times the critical value from the appropriate distribution for the desired level of confidence. The standard error of the log of the EUL estimate employed in the calculation of the confidence interval for the log of the EUL is provided by SAS. This standard error is a function of the standard errors of the parameter estimates of the general linear regression model. If necessary, the standard error of the log of the EUL estimate provided by SAS is adjusted by the square root of the design effect factor.

The log of an estimate of the EUL is assumed to be approximately normally distributed. Therefore, the critical value employed in the calculation of a confidence interval for the log of the EUL is approximated using the value from the Student distribution for the appropriate degrees of freedom and desired level of confidence. The degrees of freedom equals the effective sample size n_{eff} minus one, where n_{eff} is the number of units of the measure employed in the analysis divided by the design effect factor. The value of n_{eff} may be a non-integer.

3.4 THE P-VALUE

The p-value reported is for the null hypothesis: the *ex ante* and *ex post* EULs are equal, and the alternative hypothesis: the two EULs are not equal. In this study, a p-value of less than or equal to 0.20 would cause the null hypothesis to be rejected.

The p-value is calculated based on the value of the following test statistic:

$$\frac{\left|\ln(ex\ post\ EUL) - \ln(ex\ ante\ EUL)\right|}{adjusted, if\ necessary, standard\ error\ of\ the\ \ln(ex\ post\ EUL)}.$$

The log of the *ex post* EUL is assumed to have an approximate normal distribution with mean ln(EUL) and unknown variance. Therefore, this test statistic has an approximate Student distribution with degrees of freedom equal to the effective sample size n_{eff} minus one, per the earlier distributional assumption regarding the log of an estimate of the EUL.

3.5 WEIGHTS

The relative importance of a project in the retention analysis of a measure depends on the energy costs avoided by installing the measure. If the energy costs avoided per unit of a measure varies across projects, it is necessary to employ weights that reflect the different levels of energy costs avoided when estimating the general linear regression model.

In the retention analysis of a measure, the weight w_{ij} applied to each expected unit *j* of the measure in project *i* is calculated as

$$\frac{a_i}{\sum_{i=1}^{c} a_i n_i} \times \sum_{i=1}^{c} n_i \ ,$$

where

a_i = energy costs avoided per unit of the measure for project *i*,

n_i = as defined earlier (number of rebated and initially installed units of the measure for project *i*), and

c = as defined earlier (number of projects included in the analysis of the measure).

To obtain the correct unadjusted standard error of the EUL estimate, the sum of the weights must equal the number of observations included in the analysis. This is achieved by multiplying the component of the weight that reflects the different levels of energy costs avoided $\left(a_i \Big/ \sum_{i=1}^{c} a_i n_i \right)$ by the number of observations included in the analysis $\left(\sum_{i=1}^{c} n_i \right)$.

3.6 REFERENCES

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4 LIGHTING RETENTION RESULTS

This section of the report presents the retention analysis results for lighting measures installed under PG&E's 1994 & 1995 Programs. Recall, for each measure, the ultimate objective of this study is to estimate the median retention time or EUL. To begin, data descriptive of the lighting measure data employed in the analysis are provided. Next, the estimate of *rho* used in the adjustment of the standard error of an EUL estimate obtained from the survival analysis is reported. Lastly, the results of the survival analysis are discussed.

4.1 DESCRIPTIVE STATISTICS

Table 4-1 reports various statistics regarding retention in the analysis data by lighting measure. This table includes only those units of a lighting measure that were inspected in the sixth year. When third-year and sixth-year data are taken into account, the percentage of units of a lighting measure not retained since installation is: 14 percent for L19, 12 percent for L23, 15 percent for L37, and three percent for L81.

Table 4-1
Lighting Unit Retention During Selected Time Periods by Measure

Measure	Initially Installed Units	At 3rd-Year Study		At 6th-Year Study	
		Retained Units	% Installed Units Not Retained	Retained Units	% 3rd-Year Units Not Retained
L19	22,824	22,193	2.8%	19,558	11.9%
L23	70,848	68,726	3.0%	62,375	9.2%
L37	501	490	2.2%	428	12.7%
L81	2,267	2,217	2.2%	2,197	0.9%

Also interesting to note in Table 4-1, with the exception of lighting measure L81, non-retention increased from the period between installation and the third-year inspection to the period between the third and sixth-year inspections.

Table 4-2 presents a distribution of non-retention factors for lighting measures removed during the period between the third-year and sixth-year retention studies. As this table indicates, over eighty percent of all non-retention was due to facility remodels or changes of use. (Changes of use usually involve a complete facility overhaul – more extensive than a remodel – or removal of the entire facility.) Only four percent of the non-retention was due to equipment failure. While the third-year inspection data is not as conclusive, it appears that failures were also a small factor in non-retention for the earlier period. As discussed later, interpretation of survival models and recommended EULs are influenced by the fact that remodels and changes of facility use are the dominant factors contributing to non-retention, as compared to equipment failure.

Table 4-2
Lighting Measure Non-Retention Factors

Non-Retention Factor	Percent Lamps Affected
Equipment failed	4.3%
Remodel	32.4%
Unable to locate equipment	0.1%
Change of use	51.6%
Other	11.7%

Table 4-3 shows the number of projects in the analysis data set as compared with the number in the population and the sample by lighting measure (the numbers in this table are different from those in Table 4-1 because all data points from the third-year and sixth-year retention studies are included in this table and not in Table 4-1). This table also shows for the population, the number of lamps (units) for which a rebate was obtained and for the analysis data set, the number of lamps both rebated and installed (number of lamps expected). While the number of lamps rebated is known for the population of projects, the number of lamps installed is not known; it is only known for projects in the panel/sample and, therefore, in the analysis data set.

Table 4-3
Analysis Data by Lighting Measure

	Population		Sample / Analysis Data	
Measure	Projects	Rebated Units	Projects	Rebated and Installed Units
L19	288	108,695	67	26,604
L23	447	337,220	87	76,940
L37	87	1,884	15	501
L81	338	9,895	62	2,325
Total	1,160	457,694	231 (158 unique)	106,370

4.2 Adjustment to the Standard Error of the EUL Estimate

The standard error of the EUL estimate is a function of the log of the EUL estimate and the standard errors of the parameter estimates of the general linear regression model. The calculation of the standard errors of the parameter estimates assumes each observation is independent. This assumption, however, may be incorrect because when fitting a general linear regression model to the data for a given measure, the level of an observation is of a unit of the measure, whereas sampling occurred at the project level. Therefore, if the data analyzed for a measure are based on only a sample of projects that obtained a rebate for the measure, it is necessary to adjust the standard error of the EUL estimate. This is the case for all lighting measures.

It is necessary to correct the standard error of an EUL estimate to the extent the times to non-retention of units of a measure are more similar within a project than between projects. The extent to which the times to non-retention of units of a measure are more similar within a project than between projects and, therefore, the extent of the adjustment to the standard error, is reflected by the value of *rho*. Typically, *rho* ranges between zero and one. The closer *rho* is to one, the more similar the times to non-retention of units of a measure are within a project than between projects and the larger the adjustment to the standard error.

The value of *rho* is smallest for lighting measure L81, 0.70 and largest for lighting measure L37, 0.90. The average *rho* for lighting measures, which is used in the adjustment of the standard error of the EUL estimate for all lighting measures, is 0.80. These data are reported in Table 4-4 as well as data used in the calculation of *rho* by lighting measure. The parameter *rho* and its components are dimensionless. The components are dimensionless because they are estimated for the non-retention event, rather than for the time to non-retention.

Table 4-4
***rho* by Lighting Measure and Overall**

Measure		L19			L23			L37			L81		
Overall proportion of non retention (p_0)		14.21%			11.68%			14.57%			3.01%		
Variance Components	Within-project variance (σ_w^2)	0.0203	Min.	0.0000	0.0224	Min.	0.0000	0.0122	Min.	0.0000	0.0086	Min.	0.0000
			Max.	0.2500		Max.	0.2500		Max.	0.1875		Max.	0.2500
	Between-project variance (σ_b^2)	0.1016			0.0807			0.1122			0.0206		
	Overall variance (σ_o^2)	0.1219			0.1031			0.1245			0.0292		
rho		0.8330			0.7823			0.8987			0.6970		
Average rho (overall rho)		0.80											

4.3 SURVIVAL ANALYSIS RESULTS

4.3.1 Initial Results

The initial results of the survival analysis for each lighting measure are presented in Table 4-5. These results include all data points in the analysis dataset. Results are presented for each distribution for which it was possible to fit a general linear regression model. The standard errors reported in Table 4-5 are the corrected standard errors. For each lighting measure, if its *ex ante* EUL is outside the 80 percent confidence interval, it is smaller than the estimated or *ex post* EUL only when an Exponential distribution is assumed.

Table 4-5
Initial Survival Analysis Results by Lighting Measure – All Analysis Data

Measure	Distribution	Maximum of Log Likelihood	Selected Parameter Estimates Scale	*ex ante EUL* (years)	*ex post EUL* (years)	80% Confidence Interval (years)	Standard Error (years)
L19	*Exponential*	-11850.7	1.00 [a]	16.0	27.0	(18.6 , 39.4)	7.9
***rho =* 0.80**	*Log-logistic*	-10144.6	0.27		9.6	(7.7 , 11.9)	1.6
***neff =* 83**	*Log-normal*	-10208.5	0.56		10.6	(8.1 , 13.9)	2.2
	Weibull	-10145.3	0.29		9.1	(7.5 , 11.1)	1.4
L23	*Exponential*	-31518.7	1.00 [a]	16.0	32.5	(22.6 , 46.7)	9.1
***rho =* 0.80**	*Log-logistic*	-28463.5	0.32		11.1	(8.3 , 14.8)	2.5
***neff =* 108**	*Log-normal*	-29345.0	0.82		15.5	(10.4 , 23.2)	4.9
	Weibull	-28390.9	0.33		10.3	(8.0 , 13.2)	2.0
L37	*Exponential*	-265.6	1.00 [a]	20.0	30.8	(13.7 , 69.2)	18.7
***rho =* 0.80**	*Log-logistic*	-238.9	0.30		11.5	(6.4 , 20.8)	5.1
***neff =* 19**	*Log-normal*	-238.8	0.63		13.2	(6.6 , 26.6)	6.9
	Weibull	-238.9	0.31		10.7	(6.3 , 18.2)	4.3
L81 ***rho =* 0.80** ***neff =* 77**	*Exponential*	-356.5	1.00 [a]	16	126.6	(54.3 , 294.9)	82.8

[a]In the case of the Exponential distribution, the scale parameter is taken to equal one, it is not estimated.

4.3.2 Discussion of the Survival Analysis Distribution

The Distributions

As discussed in Section 3, the choice of the appropriate distributional assumption is dependent on several factors, including statistical fit and the implications for non-retention rates over time. It is also important to understand the basic phenomena being modeled to determine whether or not a distribution will provide a reasonable *forecast* of a non-retention pattern and the ensuing EUL.

When equipment failure is the major driver of non-retention, a Weibull distribution is often the strongest candidate for the survival analysis. This distribution allows for increasing non-retention rates as equipment ages. This pattern is particularly intuitive during the mid-to-later phases of a measure's life when failures dominate non-retention.

When business-related factors, such as remodels or changes of facility use, are the major factors driving non-retention, the Weibull distribution may not be as appropriate, unless one can accept that remodels/use-changes will increase at an increasing rate over the measure's life. For these types of factors, an Exponential distribution, which implies a constant non-retention rate over time, may be more reasonable. The problem with the Exponential distribution is that, at some point in the measure life, failures will increase, and the constant non-retention rate will not be appropriate.

The other distributions modeled, the Log-logistic and the Log-normal, provide for increasing then decreasing rates of non-retention. This pattern of non-retention may be reasonable for the early part of the measure life, but in the longer run, one does not generally expect non-retention rates to decrease as a measure ages. In addition, the point at which non-retention rates shift from increasing to decreasing is dependent on the shape of the distribution. This shape may not be fully understood if the data upon which the models are estimated does not capture the inflection point.

The Non-Retention Data

The current data (Table 4-1) show non-retention rates in the two percent to three percent range for the 0-to-3 year study period, increasing to between nine percent and 13 percent in the 3-to-6 year study period (with the exception of measure L81). In both periods, non-retention is dominated by building remodels and changes of use (see Table 4-2).

In the 0-to-3 year period, remodels and changes of use are low. Customers have just made an investment in a new lighting system (possibly as part of a remodel), and they are not likely to voluntarily remove the equipment for some foreseeable period. In fact, customers are unlikely to undertake an energy efficiency project unless they expect to remain in their facility long enough to see their investment pay off in lower energy bills. There is, of course, some level of unexpected facility/use turnover and ensuing removal of equipment.

At some point, voluntary non-retention is expected to increase as retrofitted facilities return to a more normal remodel/use-change pattern. Evidence of this increase is reflected in the 3-6 year non-retention data. It is not clear from the data whether or not the non-retention rates due to remodel/use-changes have reached a plateau.

Model Fitting and EUL Estimation

Because the data show an increasing rate of non-retention over time (except for measure L81) due to increased retention/use changes, the Log-logistic, Log-normal, and Weibull distributions tend to fit the data better (as can be seen in Table 4-4 in higher Log-Likelihood maxima and lower standard errors). All these distributions allow for an increasing non-retention rate during the initial portion of a measure's life (see Section 3). While these models provide a statistical "fit" to the current data during the first six years of the measure life, they appear to be capturing a phenomenon that is not likely continue into the future (a period of low remodels/changes-of-use followed by a period of higher remodels/changes-of-use).

The true uncertainty in the measure's EUL as we move out past the six-year study period is likely to be masked by the apparent statistical precision of the models. Using measure L19 for example, the model fit for a Weibull distribution shows an 80% confidence interval for the EUL to be between 7.5 and 11.1 years. This means that the model predicts that there is only a 20% chance that the true EUL will fall outside the 7.5-to-11.1 range, despite that fact than only 14% of the L19 measures have been removed after six years.

The Exponential distribution, which assumes a constant non-retention rate, is affected by low non-retention in the 0-to-3 year period, followed by higher non-retention in the 3-to-6 year period and does not fit the data as well as the other distributions.

For EUL estimation, the Weibull distribution projects non-retention rates that increase at an increasing rate and projects the shortest EULs. The Log-logistic and Log-normal distributions allow for increasing non-retention rates then force the non-retention to decrease after some point; they produce EULs that are somewhat higher than the EULs produced from the Weibull distribution. The Exponential distribution forces constant non-retention rates that are higher than the 0-to-3 year non-retention rates (except for measure L81) but are lower that the non-retention rates for the 3-to-6 year period. Because the data is strongly influenced by the low non-retention in the early period (with low remodel/use-change rates as discussed above), the Exponential distribution produces relatively high EUL estimates.

Based on the above discussion, it appears that the Weibull distribution produces EULs that are arguably too low for measures L19, L23, and L37, and the Exponential distribution produces EULs that are arguably too high. If 3-to-6 year retention rates in Table 4-1 (last column) are extended out into the future, they imply EUL estimates for measures L19, L23, and L37 that are between 15 and 18 years. These simple projections are generally consistent with the *ex ante* EULs.

4.3.3 Sensitivity to Influential Projects

In addition to concerns raised above about the effectiveness of the survival analysis in modeling the current removal patterns, it was determined that modeling results for measures L19, L23, and L37 were each being strongly influenced by single projects where a relatively large number of measures were removed towards the end of the six-year study period. For measures L19 and L23, the same site was going through a complete remodel and had removed 1,529 units of measure L19 and 1,552 units of measure L23. For measure L37 a different site removed 52 units.

In addition to the magnitude of these removals, it is important to note that the removals came near the end of the six-year study period (within the last year). This causes the Log-logistic, Log-normal, and Weibull models to forecast distributions with steeply increasing hazard rates as these models all expected the remainder of the units to begin failing. The forecasted EULs are therefore short.

To test the sensitivity of the analysis to these influential projects, models were rerun for measures L19, L23, and L37 without these observations. (This analysis was not carried out for measure L81 because the low amount of non-retention to date limits the usefulness of the survival models.) Table 4-6 presents the modified models. In comparing results from Table 4-6 to those from Table 4-5, one sees the EULs increase. This should be expected as sites with large amounts of non-retention are dropped. More interestingly, the bands of the 80% confidence intervals expand considerably, and the *ex ante* EUL estimates falls within each confidence band for all models where convergence was attained.

The sensitivity analysis shows that the current models are not very robust. Elimination of one project from that analysis set for each measure causes considerable changes in the estimated EULs and the associated confidence intervals. This is not entirely surprising, given the complexity of the process being modeled (with non-retention coming from a combination of failures, remodels, and changes of building use) and the length of time forecasts are required for. Models developed using six years of data are being asked to project out survival patterns over a ten to fifteen year period.

Table 4-6
Alternative Survival Analysis Results by Lighting Measure
Excludes One Influential Project for Each Measure

Measure	Distribution	Maximum of Log Likelihood	Selected Parameter Estimates Scale	*ex ante* EUL (years)	*ex post* EUL (years)	80% Confidence Interval (years)	Standard Error (years)
L19	*Exponential*	-8382.5	1.00 [a]	16.0	42.8	(26.3 , 69.6)	16.1
rho = 0.8	*Log-logistic*	-8090.1	0.48		17.4	(8.7 , 35.1)	9.4
n_{eff} = 79	*Log-normal*	-8083.6	1.00		22.0	(9.6 , 50.7)	14.2
	Weibull	-8091.2	0.49		15.5	(8.3 , 29.1)	7.6
L23	*Exponential*	-27946.1	1.00 [a]	16.0	38.4	(25.8 , 57.1)	11.8
rho = 0.8	*Log-logistic*	-26289.8	0.40		13.8	(9.0 , 21.2)	4.6
n_{eff} = 106	*Log-normal*	-26806.8	0.99		20.7	(11.5 , 37.2)	9.4
	Weibull	-26246.6	0.41		12.4	(8.5 , 18.2)	3.7
L37	*Exponential*	-68.3	1.00 [a]	20.0	157.5	(22.9 , 1085.8)	227.1
rho = 0.8	*Log-logistic*	-65.8	0.42		29.7	(0.8 , 1097.6)	80.0
n_{eff} = 16	*Weibull*	-65.8	0.43		25.9	(1.0 , 701.2)	63.7

[a]In the case of the Exponential distribution, the scale parameter is taken to equal one, it is not estimated.

4.3.4 Ex Post EUL Adopted

Combining information from the EUL modeling process along with simple trend line results, the following EULs are recommended.

Lighting Measure L19

Based on the initial models utilizing the full analysis dataset, the EUL produced by the Weibull distribution is *lower* than the *ex ante* EUL at the 80% confidence level, while the EUL produced by the exponential is *higher* than the *ex ante* EUL, also at the 80% confidence level. A simple trend analysis, using the 3-to-6 year non-retention rates (to eliminate the effects of very low non-retention rates during the first few years) implies an EUL of about 15 years, similar to the *ex ante* EUL. In addition, none of the alternative models developed by excluding one influential project cannot reject the *ex ante* EUL estimate at the 80% confidence interval.

At this time, we recommend adopting the *ex ante* EUL of 16 years. It falls between the initial EULs developed using the Weibull and Exponential distributions, is similar to a trend-line EUL, and cannot be rejected by the alternative survival models.

Lighting Measure L23

Similar to measure L19, the initial EUL produced by the Weibull distribution is lower than the *ex ante* EUL, and the EUL produced by the Exponential distribution is higher than the *ex ante* EUL. A trend-line EUL of about 18 years is similar to the *ex ante* EUL of 16 years. In addition, the *ex ante* EUL falls within the 80% confidence interval for all the adjusted EUL models. We recommend adopting the *ex ante* EUL at this time.

Lighting Measure L37

The initial EUL produced by the Weibull distribution is lower than the *ex ante* EUL at the 80% confidence level. The initial EUL produced by the Exponential distribution is higher than the *ex ante* EUL, but the difference is not statistically different at the 80% confidence level. A trend EUL estimate is in the 15-year range. Again, the *ex ante* EUL falls within the 80% confidence intervals for all adjusted models in Table 4-6. Thus for measure L37, we recommend adopting the *ex ante* EUL of 20 years.

Lighting Measure L81

Because of currently low non-retention rates, the only distribution that could be utilized in the modeling process for measure L81 was the Exponential distribution. The EUL produced by this distribution is 126.6 years. While this result is statistically different from the *ex ante* EUL estimate at the 80% confidence level, it does not appear to be reasonable. We recommend adopting the *ex ante* EUL of 16 years for this measure.

Presentation of Ex Post Analysis Results

In preparing M&E Protocols Table 6B, we have chosen to present the results of the adjusted survival analysis (Table 4-6) for measures L19, L23, and L37, and the results of the initial survival analysis (Table 4-5) for measure L81. In each case, we have taken the conservative approach in utilizing the distribution that produces the shortest EUL. This is the Weibull distribution for measures L19, L23, and L37, and the Exponential distribution of measure L81.

While the EULs from the adjusted survival analysis may not completely reflect the data collected for the project, we believe the actual level of uncertainty in the true EUL is better reflected in the adjusted confidence intervals. For measure L81, there is simply not enough non-retention to provide meaningful modeling results. This result is adequately reflected in the initial survival modeling results presented in Table 4-5.

4.4 ALTERNATIVE ADJUSTMENTS TO THE STANDARD ERROR OF THE EUL ESTIMATE

We tested the sensitivity of the survival analysis results to the value of *rho* employed in the adjustment of the standard error of the EUL estimate. In the cases of lighting measures L19, L23, and L37, the test employs the alternative survival analysis results obtained when a Weibull distribution is assumed. For lighting measure L81, the test employs the initial survival analysis results (with the Exponential distribution).

We consider the two extreme values of *rho*, zero and one, and a value in the middle, 0.5. The closer *rho* is to one the more similar the times to non-retention of units of a measure are within a project than between projects and the larger the adjustment to the standard error. The results of the sensitivity test are given in Table 4-7. For purposes of comparison, this table also includes the results for the value of *rho* estimated from the data and used in the analysis, 0.80. The results of the sensitivity test support our earlier conclusions for all lighting measures.

Table 4-7
Sensitivity Test Results by Lighting Measure

Measure	L19			L23			L37			L81		
ex ante EUL	16.0			16.0			20.0			16.0		
Dist.	Weibull			Weibull			Weibull			Exponential		
rho	*ex post EUL* (years)	80% Confidence Interval (years)	Standard Error (years)	*ex post EUL* (years)	80% Confidence Interval (years)	Standard Error (years)	*ex post EUL* (years)	80% Confidence Interval (years)	Standard Error (years)	*ex post EUL* (years)	80% Confidence Interval (years)	Standard Error (years)
0.00	15.5	(15.0 , 16.1)	0.4	12.4	(12.3 , 12.6)	0.1	25.9	(14.1 , 47.5)	12.3	126.6	(108.7 , 147.4)	15.1
0.50	15.5	(9.5 , 25.5)	6.0	12.4	(9.2 , 16.8)	2.9	25.9	(1.9 , 344.5)	50.8	126.6	(64.6 , 247.9)	66.0
0.80	**15.5**	**(8.3 , 29.1)**	**7.6**	**12.4**	**(8.5 , 18.2)**	**3.7**	**25.9**	**(1.0 , 701.2)**	**63.7**	**126.6**	**(54.3 , 294.9)**	**82.8**
1.00	15.5	(7.7 , 31.4)	8.4	12.4	(8.1 , 19.1)	4.1	25.9	(0.6 , 1059.3)	70.8	126.6	(49.3 , 325.0)	92.1

In the cases of lighting measures L19, L23, and L37, when the value of *rho* estimated from the data is employed in the adjustment of the standard error of the EUL estimate, 0.80, the *ex ante* EUL is inside the 80 percent confidence interval. For lighting measures L19 and L37, in the cases of all values of *rho* tested, the *ex ante* EUL remains inside the 80 percent confidence interval. For lighting measure L23, in the cases of all but one value of *rho* tested, the *ex ante* EUL remains inside the 80 percent confidence interval.

For lighting measure L23, the one exception is an extreme value of *rho*, zero. A value of *rho* = 0 means the times to non-retention of units of a measure are no more similar within a project than between projects, which is unlikely. It seems reasonable to expect the times to non-retention of units of a measure to be more similar within a project than between projects, and this expectation is supported by the value of *rho* estimated from the data, 0.80.

In the case of lighting measure L81, when the value of *rho* estimated from the data is employed in the adjustment of the standard error of the EUL estimate, the *ex ante* EUL is outside the 80 percent confidence interval. In the cases of all values of *rho* tested, the *ex ante* EUL remains outside the 80 percent confidence interval.

4.5 Summary of Lighting EUL Estimates

Table 4-8 summarizes the recommended lighting EUL estimates. The table first shows each measure and its contribution to 1994 and 1995 resource value. Next, *ex ante* EULs and recommended *ex post* EULs are shown, along with the reason for recommending each *ex post* EUL. As summarized above in the subsection discussing recommended EULs, the primary reason for retaining the *ex ante* EULs as the recommended *ex post* EULs are:

1. the *ex ante* EULs fall between *ex post* EUL estimates developed using various survival model distributions (most notably the Exponential and Weibull distributions);
2. the *ex ante* EULs are similar to EULs implied by trend lines (that exclude the first few years of low non-retention rates); and
3. the *ex ante* EULs are within the 80% confidence intervals developed using the preferred survival models (the adjusted models for measures L19, L23, and L37 and the initial model for measure L81).

Table 4-8
Summary of Lighting EULs

Measure	% of 1994 Program Resource Value	% of 1995 Program Resource Value	ex ante EUL	Recommended ex post EUL	Reason for Recommending ex post EUL
L19, delamping	8%	3%	16	16	Ex ante EUL not significantly different from ex post, with adjusted models - ex ante EUL similar to trend-line EUL
L23, T8s	7%		16	16	Ex ante EUL not significantly different from ex post, with adjusted models - ex ante EUL similar to trend-line EUL
L37, HIDs	4%		20	20	Ex ante EUL not significantly different from ex post, with adjusted models - ex ante EUL similar to trend-line EUL
L81, HIDs	10%	4%	16	16	Ex ante EUL significantly different from ex post but unreasonable high, with intial models - ex ante EUL similar to trend-line EUL

5 PROCESS RETENTION RESULTS

This section of the report presents the retention analysis results for process measures installed under PG&E's 1994 & 1995 Programs. Recall, for each measure, the ultimate objective of this study is to estimate the median retention time or EUL. To begin, data descriptive of the process measure data employed in the analysis are provided. Next, the estimate of *rho* used in the adjustment of the standard error of an EUL estimate obtained from the survival analysis is reported. Lastly, the results of the survival analysis are discussed.

5.1 DESCRIPTIVE STATISTICS

If a measure has two or more *ex ante* EULs, the data were separated into groups according to the *ex ante* EUL. Whereas all of the lighting measures have only one *ex ante* EUL, all of the process measures have at least two different *ex ante* EULs. For simplicity, we also refer to a unique measure and *ex ante* EUL combination as simply a "measure."

In the cases of nine process measures, all units of the measure continue to be retained. These process measures are listed in Table 5-1. On the other hand, there is one process measure, 569D, for which non-retention is 100 %. The population of process measure 569D consists of one unit.

Table 5-1
Process Measures with Zero Non-Retention

Measure
550B
560A
560B
560C
569A
590B
599A
599B
599C

Table 5-2 and Table 5-3 report various statistics regarding retention in the analysis data for the remaining process measures. These tables report the percentage of units not retained, both unweighted and weighted by energy costs avoided. Table 5-2 reports these data for the first three years and for the next three years (corresponding to the third-year and sixth-year retention studies). Table 5-3 reports these data for the entire six year time period.

Table 5-2
Process Unit Retention During Selected Time Periods by Measure

Measure	Initially Installed Units	At 3rd-Year Study			At 6th-Year Study		
		Retained Units	% Installed Units Not Retained	% Installed Units Weighted by Energy Costs Avoided, Not Retained	Retained Units	% 3rd-Year Units Not Retained	% 3rd-Year Units Weighted by Energy Costs Avoided, Not Retained
550A	522	363	30.5%	32.3%	341	6.1%	1.0%
569B	28	13	53.6%	65.3%	12	7.7%	1.0%
569C	16	14	12.5%	2.7%	10	28.6%	5.5%
590A	567	567	0.0%	0.0%	543	4.2%	70.1%

Table 5-3
Process Unit Retention Overall by Measure

Measure	Initially Installed Units	At 6th-Year Study		
		Retained Units	% Installed Units Not Retained	% Installed Units Weighted by Energy Costs Avoided, Not Retained
550A	522	341	34.7%	33.0%
569B	28	12	57.1%	65.7%
569C	16	10	37.5%	8.0%
590A	567	543	4.2%	70.1%

If the energy costs avoided per unit of a measure are similar across units of a measure (as is the case with the lighting measures), the percentage of units not retained and the percentage of units weighted by energy costs avoided not retained will be similar. However, if the energy costs avoided per unit of a measure vary substantially across units of a measure, the percentage of units not retained and the percentage of units not retained, weighted by energy costs avoided, may also be substantially different. The EUL is more specifically the time at which half the weighted units rebated and installed during the program year are no longer in place and operable.

Based on the percentage of units weighted by energy costs avoided not retained reported in Table 5-2 and Table 5-3, we know process measure 569B has an EUL of no more than approximately three years and process measure 590A has an EUL somewhere between approximately three and six years. Also, process measure 569C is likely to have a larger EUL than we would expect based on the percentage of units not retained since installation.

Table 5-4 shows the number of projects in the analysis data set as compared with the number in the population and the sample by process measure. This table also shows for the analysis data set, the number of units of a process both rebated and installed (number of units of a process expected during on-site inspections). The number of units of a process both rebated and installed is not known for the population of projects, it is only known for projects in the sample and, therefore, in the analysis data set.

Table 5-4
Analysis Data by Process Measure

Measure	Projects		Rebated and Installed Units in Sample / Analysis Data
	Population	Sample / Analysis Data	
550A	32	10	522
550B	3	2	239
560A	1	1	1
560B	4	3	3
560C	2	1	1
569A	2	1	196
569B	9	4	28
569C	17	10	16
569D	1	1	1
590A	2	2	567
590B	1	1	1
590C	2	0	0
599A	10	7	16
599B	4	4	21
599C	22	13	221
Total	112	60 (59 unique)	1,833

5.2 ADJUSTMENT TO THE STANDARD ERROR OF THE EUL ESTIMATE

The standard error of the EUL estimate is a function of the log of the EUL estimate and the standard errors of the parameter estimates of the general linear regression model. The calculation of the standard errors of the parameter estimates assumes each observation is independent. This assumption, however, may be incorrect because when fitting a general linear regression model to the data for a given measure, the level of an observation is of a unit of the measure, whereas sampling occurred at the project level. Therefore, if the data analyzed for a measure are based on only a sample of projects that obtained a rebate for the measure, it is necessary to adjust the standard error of the EUL estimate.

As indicated in Table 5-4, in the cases of all process measures under analysis except 590A (measures 550A, 569B, and 569C), only a sample of projects is included in the analysis. In the case of process measure 590A, the population of projects is in included in the analysis. Therefore, in the cases of process measures 550A, 569B, and 569C, it is necessary to adjust the standard error of the EUL estimate, but the standard error of the EUL estimate for process measure 590A is not adjusted.

It is necessary to correct the standard error of an EUL estimate to the extent the times to non-retention of units of a measure are more similar within a project than between projects. The extent to which the times to non-retention of units of a measure are more similar within a project than between projects and, therefore, the extent of the adjustment to the standard error, is reflected by the value of *rho*. Typically, *rho* ranges between zero and one. The closer *rho* is to one, the more similar the times to non-retention of units of a measure are within a project than between projects and the larger the adjustment to the standard error.

Data from all process measures for which some but not all units were not retained, 550A, 569B, 569C, and 590A, are included in the calculation of the adjustment to the standard error of a EUL estimate. The value of *rho* is smallest for process measure 569B, 0.30, and largest for process measures 569C and 590A, 1.0. The average *rho* for process measures, which is used in the adjustment of the standard error of the EUL estimate for all process measures, is 0.71. These data are reported in Table 5-5 as well as data used in the calculation of *rho* by process measure. The parameter *rho* and its components are dimensionless. The components are dimensionless because they are estimated for the non-retention event, rather than for the time to non-retention.

Table 5-5
***rho* by Process Measure and Overall**

Measure		550A	569B	569C	590A
Overall proportion of non retention (p_0)		34.67%	57.14%	37.50%	4.23%
Variance Components	Within-project variance (σ_w^2)	0.1002 (Min. 0.0000; Max. 0.2209)	0.1477 (Min. 0.0000; Max. 0.2500)	0.0000 (Min. 0.0000; Max. 0.0000)	0.0000 (Min. 0.0000; Max. 0.0000)
	Between-project variance (σ_b^2)	0.1263	0.0972	0.2344	0.0405
	Overall variance (σ_o^2)	0.2265	0.2449	0.2344	0.0405
rho		0.5491	0.2962	1.0000	1.0000
Average rho (overall rho)		0.71			

5.3 SURVIVAL ANALYSIS RESULTS

The results of the survival analysis for each process measure are presented in Table 5-6. Results are presented for each distribution for which it was possible to fit a general linear regression model. The standard errors reported in Table 5-6 are the corrected standard errors. In the cases of all process measures except 590A, it is possible to estimate the EUL only when an Exponential distribution is assumed; models using other distributions do not converge.

Table 5-6
Survival Analysis Results by Process Measure

Measure	Distribution	Maximum of Log Likelihood	Selected Parameter Estimates: Scale	*ex ante* EUL (years)	*ex post* EUL (years)	80% Confidence Interval (years)	Standard Error (years)
550A *rho* = 0.71 n_{eff} = 14	*Exponential*	-407.7	1.00 [a]	11.0	8.8	(4.7 , 16.6)	4.1
569B *rho* = 0.71 n_{eff} = 5	*Exponential*	-26.4	1.00 [a]	14.5	3.0	(1.3 , 6.8)	1.6
569C *rho* = 0.71 n_{eff} = 11	*Exponential*	-5.3	1.00 [a]	19.5	49.0	(11.6 , 207.5)	51.6
590A *rho* = 0.0 n_{eff} = 3	*Exponential*	-637.6	1.00 [a]	5.0	3.9	(3.6 , 4.1)	0.2
	Log-logistic	-401.7	0.25		3.7	(3.6 , 3.8)	0.1
	Log-normal	-399.5	0.42		4.0	(3.9 , 4.1)	0.1
	Weibull	-499.0	0.44		4.2	(4.0 , 4.3)	0.1

[a] In the case of the Exponential distribution, the scale parameter is taken to equal one, it is not estimated.

5.3.1 Ex Post EUL Adopted

For each process measure, this study must make a recommendation regarding the *ex post* EUL to be adopted.

Process Measure 550A

For process measure 550A, the *ex ante* EUL is inside the 80 percent confidence interval when an Exponential distribution is assumed (as this is the only distribution in which model convergence was attained). Therefore, at this time, we recommend adopting the *ex ante* EUL of 11 years as the *ex post* EUL for process measure 550A. Although 32.3 percent of units weighted by energy costs avoided were not retained during the first three years, only 1.0 percent of such units were not retained during the next three years.

Process Measure 569B

For process measure 569B, the *ex ante* EUL is outside the 80 percent confidence interval when an Exponential distribution (the only distribution with convergence) is assumed. The Exponential distribution produces an estimated or *ex post* EUL of 3.0 years, whereas the *ex ante* EUL is 14.5 years. Recall, at the time of the third-year inspection, 53.6 percent of units (unweighted) and 65.6 percent of units weighted by energy costs avoided were not retained. Therefore, we recommend adopting the *ex post* EUL of 3.0 years for process measure 569B.

Process Measure 569C

For process measure 569C, the *ex ante* EUL is inside the 80 percent confidence interval when an Exponential distribution is assumed. Again, the Exponential model was the only model that could be estimated as the models utilizing other distributions did not converge. Therefore, at this time, we recommend adopting the *ex ante* EUL of 19.5 years as the *ex post* EUL for process measure 569C. After six years, although 37.5 percent of units were not retained, only 8.0 percent of units weighted by energy costs avoided were not retained.

Process Measure 590A

For Process measure 590A, the *ex ante* EUL is always outside the 80 percent confidence interval and larger than the estimated or *ex post* EUL. Albeit, the *ex ante* EUL of 5.0 years is only slightly larger than any of the estimated EULs, which are all very similar and range between 3.7 and 4.2 years. The models reflect the fact that one project, with about 70% of the avoided-cost weighted measures removed all measures at about the fourth year of the measure's life. Since the population and the sample consisted of only two projects, the models are essentially interpolating to produce an EUL, given that over 50 percent of the units in the population have been removed. We recommend adopting an *ex post* EUL of four years, which is essentially consistent with all estimated EULs.

Process Measure 569D

The population of process measure 569D consists of one unit and the time to non-retention of this one unit was 5.6 years. Therefore, we recommend adopting an *ex post* EUL of 5.6 years for process measure 569D.

5.4 ALTERNATIVE ADJUSTMENTS TO THE STANDARD ERROR OF THE EUL ESTIMATE

We tested the sensitivity of the survival analysis results to the value of *rho* employed in the adjustment of the standard error of the EUL estimate. We consider the two extreme values of *rho,* zero and one, and a value in the middle, 0.5. The closer *rho* is to one the more similar the times to non-retention of units of a measure are within a project than between projects and the larger the adjustment to the standard error. The results of the sensitivity test are given in Table 5-7. For purposes of comparison, this table also includes the results for the value of *rho* estimated from the data and used in the analysis, 0.71. The results of the sensitivity test support our earlier conclusions for all process measures.

Table 5-7
Sensitivity Test Results by Process Measure

Meas.	550A			569B			569C		
ex ante EUL	11.0			14.5			19.5		
Dist.	Exponential			Exponential			Exponential		
rho	*ex post EUL* (years)	80% Confidence (years)	Standard Error (years)	*ex post EUL* (years)	80% Confidence (years)	Standard Error (years)	*ex post EUL* (years)	80% Confidence (years)	Standard Error (years)
0.00	8.8	(8.0 , 9.7)	0.7	3.0	(2.2 , 4.1)	0.7	49.0	(15.0 , 159.9)	43.2
0.50	8.8	(5.2 , 14.9)	3.5	3.0	(1.5 , 5.9)	1.4	49.0	(12.5 , 192.6)	49.3
0.71	**8.8**	**(4.7 , 16.6)**	**4.1**	**3.0**	**(1.3 , 6.8)**	**1.6**	**49.0**	**(11.6 , 207.5)**	**51.6**
1.00	8.8	(4.1 , 18.9)	4.9	3.0	(1.1 , 8.3)	1.9	49.0	(10.5 , 229.2)	54.7

For process measure 550A, we recommend adopting the *ex ante* EUL as the *ex post* EUL because the *ex ante* EUL is inside the only 80 percent confidence interval. In the cases of all but one value of *rho* tested, the *ex ante* EUL of 11 years remains inside the 80 percent confidence interval. The one value of *rho* that produces a result different from the value of *rho* used in the analysis is an extreme value of *rho*, zero. A value of *rho*=0 means the times to non-retention of units of a measure are no more similar within a project than between projects, which is unlikely. It seems reasonable to expect the times to non-retention of units of a measure to be more similar within a project than between projects, and this expectation is supported by the value of *rho* estimated from the data, 0.71.

For process measure 569B, we recommend adopting an *ex post* EUL smaller than the *ex ante* EUL because the *ex ante* EUL is outside the only 80 percent confidence interval and larger than the *ex post* EUL. In the cases of all values of *rho* tested, the *ex ante* EUL of 14.5 years remains outside the 80 percent confidence interval.

For process measure 550A, we recommend adopting the *ex ante* EUL as the *ex post* EUL because the *ex ante* EUL is inside the only 80 percent confidence interval. In the cases of all values of *rho* tested, the *ex ante* EUL of 19.5 years remains inside the 80 percent confidence interval.

5.5 SUMMARY OF PROCESS EUL ESTIMATES

Because there are so many combinations of process measures and *ex ante* EULs within each primary Process measure, Table 5-8 was constructed to summarize the recommended process EUL estimates. The table first shows each primary process measure and its contribution to 1994 and 1995 resource value. Next, the various sub-measures based on *ex ante* EUL are shown along with the percent of primary measure resource value they account for. Finally *ex ante* EULs, and recommended *ex post* EULs are shown, along with the reason for recommending each *ex post* EUL. Overall, there are four reasons for recommending an *ex post* EUL:

1. survival models produce EULs that are significantly different from *ex ante* EULs at the 80 percent confidence level;
2. survival models produce EULs that are not significantly different;

3. there was no observed non-retention; and
4. all units of a measure had not been retained and the measure life was known with certainty.

In cases where survival models produce significantly different results or where the measure life is known with certainty (cases one and four above), the calculated *ex post* EUL is recommended. In cases where the survival models produce results that are not significantly different or where there was no observed non-retention (cases two and three above), the *ex ante* EUL is retained; except for measure 569A where there was not non-retention and the *ex ante* measure life had been exceeded. In this case we recommend an *ex post* EUL of seven years, reflecting the current life of the units under study.

Table 5-8
Summary of Process EULs

Primary Measure	% of 1994 Program Resource Value	% of 1995 Program Resource Value	Measure	% of Primary Measure	ex ante EUL	Recommended ex post EUL	Reason for Recommending ex post EUL
550		29%	550A	92.3%	11	11	Not significantly different
			550B	7.7%	15	15	No non-retention
560		3%	560A	6.8%	10	10	No non-retention
			560B	74.7%	14.5	14.5	No non-retention
			560C	18.6%	20	20	No non-retention
569	17%	12%	569A	0.3%	5	7	No non-retention
			569B	24.2%	14.5	3	Significantly different
			569C	72.8%	19.5	19.5	Not significantly different
			569D	2.7%	25	6	Known life
590	10%		590A	2.5%	5	4	Significantly different
			590B	97.5%	10	10	No non-retention
599	5%	11%	599A	14.5%	11	11	No non-retention
			599B	6.1%	15.5	15.5	No non-retention
			599C	79.4%	20.5	20.5	No non-retention

A

ON-SITE DATA COLLECTION INSTRUMENT

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Control Num	Application Num	Check Num	Check Date	Check paid to
«CNTL»	«CODE»	«CHECKNO»	«CHKIS_DT»	«Payable»
Complex				
«Custname», «Seradd», «Sercity», CA «SERZIP»				

Project Description: «Prjdesc» «Prjdesc2»

Measure Description: «Measdesc»

Item Description: «ITEMDSC»

Location: «LOCATION»

Other notes: «PRJNOTES»

Measure Level Data: Number of units originally purchased: **«P_NUMPUR»**
Paid Savings: **«P_KWH»** kWh **«P_KW»** kW **«P_THM»** therms
Rebate: «P_REBATE»

Measure Attribute Measure Number →		
Measure Code	*«P_MEASUR»*	**Corrections (If Any)**
Install Date	«INSTDATE»	
Customer Equipment Name	«CUSTEQP»	
Manufacturer	«EQPMFR»	
Model Number	«MODELNUM»	
Serial Number	*SERIALNM*	
Rated Output Capacity / Size	«EQPSIZE»	
Rated Input Volts / RL Amps / therms	«EQPPOWER»	
Lamps per fixture	«LAMPFIXT»	
Number Expected	«OBSERV»	
Number Observed	«OBSERV»	
Percent in Working Condition	WORKING	
Discrepancy Code ***see table below***	DISCREP	
Removal Code ***see table below***	REMOVE	
Months Since Removal	REMOVEALD	

Table 1-Observed/Expected Discrepancy Codes

Code		Description
D	1	Removed, not replaced
	2	Removed, replaced with different (describe)
	4	Never installed
	5	Temporarily taken out of operation
	6	Could not locate
	7	Other (describe)

Table 2-Removal Codes

Code		Description
R	1	Equip failed, not replaced
	2	Remodeled/Equipment replaced
	3	Unable to locate equivalent replacement
	4	Change of use
	5	Other (describe)

B

TABLE 6B

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Protocol Table 6B
Results of Sixth-Year Retention Study
Pacific Gas and Electric Company's 1994 & 1995 Industrial Energy Efficiency Incentive Programs

PG&E Study ID Numbers:
Process End Use: 311R2 (1994), 382R2 (1995)
Indoor Lighting End Use: 314R2 (1994), 325R2 (1995)

Item 1			Item 2		Item 3	Item 4	Item 5	Item 6		Item 7	Item 8	Item 9
			EUL (years)									
								80% Confidence Interval				
Measure	End Use	Measure Description	*ex ante*	Source of *ex ante*	*ex post* (estimated from study)	Adopted *ex post* (to be used in claim)	*ex post* Standard Error	Lower Bound	Upper Bound	p-value for *ex post* EUL	EUL Realization Rate (adopted *ex post* / *ex ante*)	"Like" Measures Associated with Studied Measures
550A	Process	Controls	11.0	a	8.8	11.0	4.1	4.7	16.6	0.70	1.00	None
550B			15.0	a	-	15.0	-	-	-	-	1.00	
560A	Process	Heat Recovery	10.0	a	-	10.0	-	-	-	-	1.00	None
560B			14.5	a	-	14.5	-	-	-	-	1.00	
560C			20.0	a	-	20.0	-	-	-	-	1.00	
569A	Process	Change/Add Equipment	5.0	a	-	6.8	-	-	-	-	1.36	None
569B			14.5	a	3.0	3.0	1.6	1.3	6.8	0.06	0.21	
569C			19.5	a	49.0	19.5	51.6	11.6	207.5	0.43	1.00	
569D			25.0	a	-	6.0	-	-	-	-	0.24	
590A	Process	Insulate	5.0	a	4.2	4.0	0.1	4.0	4.3	0.68	0.80	None
590B			10.0	a	-	10.0	-	-	-	-	1.00	
599A	Process	Other	11.0	a	-	11.0	-	-	-	-	1.00	None
599B			15.5	a	-	15.5	-	-	-	-	1.00	
599C			20.5	a	-	20.5	-	-	-	-	1.00	
L19	Lighting	Reflectors With Delamping, 4 Ft Lamp Removed	16.0	a	15.5	16.0	7.6	8.3	29.1	0.95	1.00	None
L23	Lighting	Fixture: T-8 Lamp & Electric Ballast, (Fem or New Fixture), 4 Ft Fixture	16.0	a	12.4	16.0	3.7	8.5	18.2	0.45	1.00	None
L37	Lighting	HID Fixture: Interior, >= 176 Watts Lamp	20.0	a	25.9	20.0	63.7	1.0	701.2	0.93	1.00	None
L81	Lighting	HID Fixture: Interior, Standard, 251-400 Watt Lamp	16.0	a	126.6	16.0	82.8	54.3	294.9	0.01	1.00	None

[a] PG&E Advice Letter 1800-G/1446-E. 1994 DSM Program Activity and Expected Earnings. As approved by the California Public Utilities Commission April 19, 1994. PG&E Advice Letter 1867-G/1481-E. 1995 DSM Program Activity and Expected Earnings. As approved by the California Public Utilities Commission May 8, 1995.

C TABLE 7B

C.1 OVERVIEW INFORMATION

a. Study Title and Study ID Number

Study Title: 1994 and 1995 Industrial Energy Efficiency Incentive Programs Sixth-Year Retention Study.

Study ID Number: Process end use, 311R2 (1994) and 382R2 (1995). Indoor lighting end use, 314R2 (1994) and 325R2 (1995).

b. Program, Program Years, and Program Description

Program: Industrial Energy Efficiency Incentive (IEEI).

Program years: 1994 and 1995.

Program description: The Programs provided incentives to industrial customers to install energy-efficiency measures. The Programs included the Retrofit Express Program (RE), the Retrofit Efficiency Options Program (REO), the Advanced Performance Options Program (APO), and the Customer Efficiency Options Program (CEO).

c. End Uses and Measures Covered

This study covers process and lighting end uses. Table C-1 lists the measures covered by end use.

Table C-1
Measures Included in the Study

Measure	Measure Description
Processes	
550	Controls
560	Heat Recovery
569	Change/Add Equipment
590	Insulate
599	Other
Lighting	
L19	Reflectors With Delamping, 4 Ft Lamp Removed
L23	Fixture: T-8 Lamp & Electric Ballast, (Fem or New Fixture), 4 Ft Fixture
L37	HID Fixture: Interior, >= 176 Watts Lamp
L81	HID Fixture: Interior, Standard, 251-400 Watt Lamp

d. Method and Models Used

In the cases of lighting measure L81 and process measures 550A, 569B, and 569C, the final model specification used for the study assumes an Exponential distribution. For these measures, it is possible to estimate the EUL only when an Exponential distribution is assumed. Models using other distributions do not converge. In the cases of all other measures, the final model specification used for the study assumes a Weibull distribution.

See the Study Methods (Section 3) for a complete discussion of the methods employed in this study. Also see the Lighting and Process Retention Results sections (4 and 5, respectively) for the results of the final model specification as well as the other model specifications considered.

e. Analysis Sample Size

Table C-2 and Table C-3 show the analysis sample sizes by measure for lighting and process end uses, respectively. These tables show both the number of projects and the number of units of a measure included in a measure's analysis data set. Projects were selected for data collection and a unit of a measure is the level at which the data are analyzed. Third-year on-site inspections were conducted September 1997 through November 1998, and sixth-year on-site inspections were conducted October through December 2000. In the cases of all lighting measures, a unit is a lamp; whereas a unit of a process measure is very specific to the process.

Table C-2
Analysis Sample Sizes by Lighting Measure

Measure	Projects	Rebated and Installed Units
L19	67	26,604
L23	87	76,940
L37	15	501
L81	62	2,325
Total	231 (158 unique)	106,370

Table C-3
Analysis Sample Sizes by Process Measure

Measure	Projects	Rebated and Installed Units
550A	10	522
550B	2	239
560A	1	1
560B	3	3
560C	1	1
560D	0	0
569A	1	196
569B	4	28
569C	10	16
569D	1	1
590A	2	567
590B	1	1
590C	0	0
599A	7	16
599B	4	21
599C	13	221
Total	60 (59 unique)	1,833

C.2 DATABASE MANAGEMENT

a. Data Sources and Elements

Program tracking data and third-year on-site inspection data for 1994:
SV1TK_94.SD2 SAS dataset.

Program tracking data for 1995:
TRACK_95.SD2 SAS dataset.

Third-year on-site inspection data for 1995:
SURV1_95.SD2 SAS dataset.

Sixth-year on-site inspection data and first-year impact evaluation data:
SURV2.SD2 SAS dataset.

See section 2.3 for a list of the data elements obtained from each of these sources.

b. Data Attrition

In the cases of five process measures, 560A, 569D, 590A, 590B, and 599B, an attempt was made to conduct an on-site inspection of all projects that obtained a rebate for the measure. In the cases of the remaining process measures and all lighting measures, an attempt was made to conduct an on-site inspection of only a sample of projects that obtained a rebate for the measure.

Site inspections were conducted for 210 out of the 217 unique projects in the sample. Of the seven projects that weren't inspected, two were for projects at sites that are no longer PG&E customers, four projects involved customers who could not be contacted during the on-site inspection recruitment process, and one project involved a customer who refused an on-site inspection. Additionally, for three projects at sites that were visited, on-site inspections yielded incomplete data as the inspectors, in conjunction with customer staff, couldn't determine whether or not Program measures were still in place and operable.

For each lighting measure, Table C-4 shows the number of projects in the population and analysis data set. Table C-5 shows these same data for each process measure. These tables also report the number of units of each measure rebated and installed in the analysis data set. In addition, Table C-4 reports the number of units of each lighting measure rebated in the population (these data are unavailable in the cases of process measures). All sample projects and rebated and installed units are included in the analysis data set because between the on-site inspection conducted for current retention study and the on-site inspection conducted for the third-year retention study, all necessary data were collected for each sample project at least one time. Therefore, if a sample project obtained a rebate for a given measure, all of its rebated and installed units of the measure are included in the measure's analysis data set.

Table C-4
Analysis Data by Lighting Measure

Measure	Population		Sample / Analysis Data	
	Projects	Rebated Units	Projects	Rebated and Installed Units
L19	288	108,695	67	26,604
L23	447	337,220	87	76,940
L37	87	1,884	15	501
L81	338	9,895	62	2,325
Total	1,160	457,694	231 (158 unique)	106,370

Table C-5
Analysis Data by Process Measure

Measure	Projects		Rebated and Installed Units in Sample / Analysis Data
	Population	Sample / Analysis Data	
550A	32	10	522
550B	3	2	239
560A	1	1	1
560B	4	3	3
560C	2	1	1
560D	1	0	0
569A	2	1	196
569B	9	4	28
569C	17	10	16
569D	1	1	1
590A	2	2	567
590B	1	1	1
590C	2	0	0
599A	10	7	16
599B	4	4	21
599C	22	13	221
Total	113	60 (59 unique)	1,833

c. Data Used to Merge Data Sets

In order to combine the Program tracking data with the on-site inspection data from the third-year retention study and with the on-site inspection data from the current retention study, if a project-measure combination is not already a unique observation the Program tracking data, it is made a unique observation. A project is a unique site—identified by PG&E control number--and rebate application combination. Both the Program tracking data and on-site inspection data employ common codes for the measures. To make a project-measure combination a unique observation in the Program tracking data, the number of units for which a rebate was obtained is summed and the avoided energy costs are summed.

In order to combine the on-site inspection data from the third-year retention study with the on-site inspection data from the current retention study, if a project-measure-installation date-survey date combination is not a unique observation in each of the on-site inspection data sets, it is made a unique observation. To make such a combination a unique observation in an on-site inspection data set, the number of units rebated and installed is summed and the number of units retained is summed. No relevant data are lost when making a project-measure-installation date-survey date combination a unique combination in the each of the on-site inspection data sets. Specifically, no data on the time to non-retention are lost.

d. Data Collected Specifically for the analysis but not Used

All data collected specifically for the analysis were used.

C.3 SAMPLING

a. Sampling Procedures and Protocols

The sample projects included in this study are the same sample projects that were inspected for the third-year retention study of PG&E's 1994 & 1995 IEEI Programs. See section 2.2 for a discussion of the projects included in the third-year retention study.

b. Survey Information

The on-site data collection instrument is provided in Appendix A. The sample disposition is discussed earlier in section C.2.b. An on-site inspection was at least partially completed for all but seven the 217 unique sample projects. Therefore, no effort was made to test or correct for non-response bias.

c. Statistical Descriptions

Table C-6
Lighting Unit Retention During Selected Time Periods by Measure

Measure	Initially Installed Units	At 3rd-Year Study		At 6th-Year Study	
		Retained Units	% Installed Units Not Retained	Retained Units	% 3rd-Year Units Not Retained
L19	22,824	22,193	2.8%	19,558	11.9%
L23	70,848	68,726	3.0%	62,375	9.2%
L37	501	490	2.2%	428	12.7%
L81	2,267	2,217	2.2%	2,197	0.9%

Table C-7
Process Measures with Zero Non-Retention

Measure
550B
560A
560B
560C
569A
590B
599A
599B
599C

Table C-8
Process Unit Retention During Selected Time Periods by Measure

Measure	Initially Installed Units	At 3rd-Year Study			At 6th-Year Study		
		Retained Units	% Installed Units Not Retained	% Installed Units Weighted by Energy Costs Avoided, Not Retained	Retained Units	% 3rd-Year Units Not Retained	% 3rd-Year Units Weighted by Energy Costs Avoided, Not Retained
550A	522	363	30.5%	32.3%	341	6.1%	1.0%
569B	28	13	53.6%	65.3%	12	7.7%	1.0%
569C	16	14	12.5%	2.7%	10	28.6%	5.5%
590A	567	567	0.0%	0.0%	543	4.2%	70.1%

Table C-9
Process Unit Retention Overall by Measure

Measure	Initially Installed Units	At 6th-Year Study		
		Retained Units	% Installed Units Not Retained	% Installed Units Weighted by Energy Costs Avoided, Not Retained
550A	522	341	34.7%	33.0%
569B	28	12	57.1%	65.7%
569C	16	10	37.5%	8.0%
590A	567	543	4.2%	70.1%

C.4 DATA SCREENING AND ANALYSIS

a. Treatment of Outliers and Missing Data Points

Typically, the residuals of a fitted model are examined for the presence of any outliers. However, in Survival Analysis, residuals do not have the typical definition. The discussion of the analysis of residuals in section 3.1.3 provides a definition of residuals commonly used in Survival Analysis. We do not attempt to use the residuals so defined to determine outliers. However, we do attempt to determine influential data points (see section C.4.g below).

b. Background Variables

See the discussion of Omitted Factors below (C.4.e.2).

c. Data Screens

If a sample project obtained a rebate for a given measure and either the third or sixth-year on-site inspection was at least partially completed for the measure, the project is included in the measure's analysis data set.

d. Model Statistics

Each general linear regression model was fitted using the SAS LIFEREG procedure. The standard model statistics for all final general linear regression models are provided in Table C-10. The table provides the corrected standard errors and the approximate p-value associated with the corrected standard errors. The p-value for the intercept corresponds to a test of the hypothesis that the intercept equals 0. A p-value is not provided for the scale parameter because the distribution of the scale parameter is presumably unknown.

Table C-10
Final General Linear Regression Model Statistics

Measure	Distribution	Intercept(μ)			Scale(σ)[a]	
		Estimate (ln (years))	Standard Error (ln (years))	p-value	Estimate (dimensionless)	Standard Error (dimensionless)
Processes						
550A	Exponential	2.54	0.47	<0.01	1.00	-
569B	Exponential	1.46	0.54	<0.01	1.00	-
569C	Exponential	4.26	1.05	<0.01	1.00	-
590A	Weibull	1.58	0.31	<0.01	0.44	0.25
Lighting						
L19	Weibull	2.92	0.55	<0.01	0.49	0.22
L23	Weibull	2.67	0.34	<0.01	0.41	0.14
L37	Weibull	3.41	2.73	0.21	0.43	0.76
L81	Exponential	5.21	0.65	<0.01	1.00	-

[a]In the case of the Exponential distribution, the scale parameter is taken to equal one, it is not estimated.

The parameter estimates in Table C-10 produce the EUL estimates in Table C-11.

Table C-11
Summary of EUL Estimates

Measure	EUL (years)					p-value for *ex post* EUL
	ex ante	*ex post* (estimated from study)	*ex post* Standard Error	80% Confidence Interval: Lower Bound	80% Confidence Interval: Upper Bound	
Processes						
550A	11.0	8.8	4.1	4.7	16.6	0.70
569B	14.5	3.0	1.6	1.3	6.8	0.06
569C	19.5	49.0	51.6	11.6	207.5	0.43
590A	5.0	4.2	0.1	4.0	4.3	0.68
Lighting						
L19	16.0	15.5	7.6	8.3	29.1	0.95
L23	16.0	12.4	3.7	8.5	18.2	0.45
L37	20.0	25.9	63.7	1.0	701.2	0.93
L81	16.0	126.6	82.8	54.3	294.9	0.01

e. Specification

See the Study Methods section (3) for a complete discussion of the methods employed in this study. Also see the Lighting and Process Retention Results sections (4 and 5, respectively) for the results of the final model specification as well as the other model specifications considered.

1. Heterogeneity

The heterogeneity of projects is recognized and addressed in the model specification and estimation procedures in at least two ways.

i. The number of units rebated and installed of a measure may vary across projects. In this analysis, an observation is a unit of a measure. Therefore, the number of observations on a project included in the analysis is equal to the number of units rebated and installed under the project.

ii. If the energy costs avoided per unit of a measure varies across projects, when estimating the general linear regression model, weights that reflect the different levels of energy costs avoided are employed.

2. Omitted Factors

For each measure, this study assumes the time to non-retention follows some parametric distribution. The time to non-retention is then modeled as function of only the parameters of this distribution. The result is a single estimate of the EUL.

It is possible to include in the model of the time to non-retention the parameters of the assumed distribution as well as other independent variables. The additional independent variables may be background variables such as economic and political activity and/or variables that vary by project or even by unit of a measure within a project. Two categorical variables that are likely to vary by project and may affect the time to non-retention are

- whether or not the same firm occupies the space and
- whether the space is being used for the same or a different purpose.

Modeling the time to non-retention as a function of the parameters of the assumed distribution as well as other independent variables will provide insight into the effect of these other independent variables on the time to non-retention. However, it is unclear whether additional independent variables will result in a better estimate of the EUL.

The value of modeling the time to non-retention as a function of background variables and/or variables that vary by project depends on at least three factors:

1. the magnitude of their effect on the time to non-retention;
2. how accurately their future values can be estimated; and
3. if the result is more than one estimate of the EUL (e.g., if a variable is categorical), whether or not the various EUL estimates and their standard errors can be meaningful combined.

The future values of background variables and/or variables that vary by project may not be able to be accurately estimated. In addition, the ultimate objective of this study is to estimate a single EUL for the population of a measure, not to estimate different EULs for different subpopulations of a measure. Therefore, we model the time to non-retention as a function of only the parameters of the assumed distribution.

f. Error in Measuring Variables

There are no particular concerns regarding error in measuring variables. An on-site inspection was at least partially completed for all but seven the 217 unique sample projects. Therefore, no effort was made to test or correct for non-response bias. In addition, the methods employed are well suited to handle imprecise measures of the time to non-retention.

g. Influential Data Points

In the cases of lighting measures L19, L23, and L37, the survival analysis results based on all the data often result in an EUL estimate that appears to be inconsistent with the percentage of units of the measure still retained after six years. Consequently, for each of these measures, we attempt to determine if a single project is primarily responsible for the EUL estimate obtained. For each of the lighting measures considered (L19, L23, and L37), this appears to be the case.

For each of the lighting measures L19, L23, and L37, we excluded from the analysis the five projects with the largest number of units of the measure not retained, one project at a time. We focused on the results when a Weibull distribution is assumed and these are the results discussed here. In the cases of lighting measures L19 and L37, excluding the largest project results in a substantially higher EUL estimate. Excluding any of the next four largest projects increases or decreases the EUL estimate only slightly.

For lighting measure L23, excluding either the largest or second largest project increases the EUL estimate only slightly; however, the confidence interval for the estimate expands considerably. Excluding any of the next three largest projects increases or decreases the EUL estimate only slightly and the confidence intervals for don't vary substantially.

h. Missing Data

There are effectively no missing data. All sample projects and rebated and installed units are included in the analysis data set because between the on-site inspection conducted for current retention study and the on-site inspection conducted for the third-year retention study, all necessary data were collected for each sample project at least one time. Therefore, if a sample project obtained a rebate for a given measure, all of its rebated and installed units of the measure are included in the measure's analysis data set. Also, as stated earlier in C.4.f, the methods employed are well suited to handle imprecise measures of the time to non-retention.

i. Precision

See sections 3.2 and 3.3.