Retention Study of Pacific Gas & Electric Company's 1996 and 1997 Commercial Energy Efficiency Programs

1996-1997 Commercial Lighting & HVAC Ninth Year Retention

PG&E Study ID number: 333aR2 & 333bR2
CALMAC Study ID number: PGE0237.01 and PGE2038.01

January 25, 2006

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

All inquiries should be directed to:

James Turnure
Revenue Requirements
Pacific Gas and Electric Company
P. O. Box 770000, Mail Code B9A
San Francisco, CA 94177

Ninth Year Retention Study for PG&E's 1996 & 1997 Commercial EEI Program Lighting and HVAC Technologies PG&E Study ID #s: 333aR2 & 333bR2 CALMAC Study ID #s: PGE0237.01 and PGE2038.01

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 March 1998, Pursuant to Decisions 94-05-063, 94-10-059, 94-12-021, 95-12-054, 96-12-079, 98-03-063, and 99-06-052.

This study measures the effective useful life (EUL) for all HVAC and lighting energy efficiency technologies for which rebates were paid in 1996 and 1997 by Pacific Gas & Electric Company's (PG&E's) Commercial Energy Efficiency Incentive (CEEI) Programs. Retrofits were performed under three different PG&E programs, the Retrofit Express (RE), Retrofit Efficiency Options (REO), and Customize Incentives (CI) Programs.

Methodology

The Protocols assert the purpose of a retention study is to collect data on the fraction of installed measures in place and operable in order to produce a revised estimate of its EUL. The ultimate goal is to estimate the EUL (or the median number of years that the measure is still in place and operable), which can be realized by identifying the measure's survival function. For this study, the survival function describes the percentage of measures installed that are still operable and in place at a given time. Survival analysis is the process of analyzing empirical failure/removal data in order to model a measure's survival function. As much as possible, we have attempted to employ classical survival analysis techniques to our study approach.

Our overall approach consists of five analysis steps that were used to estimate each of the studied measures' EULs:

1. ***Compile summary statistics*** on the raw retention data.
2. ***Visually inspect*** the retention data, by simply calculating the cumulative percentage of equipment that had failed in a given month, and plotting the percentage over time.
3. ***Develop a trend line*** from the survival plots. Using the plots developed in (2) above, a trend line was estimated using standard linear regression techniques. We modeled the trend as a linear and an exponential function.
4. ***Develop a survival function*** using classical survival techniques. We modeled the survival function assuming five of the most common survival distributions: exponential, logistic, lognormal, Weibull and gamma. In each case, we used the resulting survival function to estimate the EUL.

5. ***Develop competing risks models*** for measures in which the distribution of the failures and removals was different. Using the LIFEREG procedure in SAS from step 4 above, separate output was generated for failures and removals for these measures. Then, the best fitting distributions for each event were combined to form one survival function. This fifth step was not used for the L19 delamping measure since this measure observed only one failure type.

Study Results

The exhibit below presents the final EULs for the studied and like measures. Provided are the ex ante and ex post EULs, the 80 percent confidence intervals for the ex post results, the final EUL used for the filing claim, and the realization rate.

PG&E's 1996 & 1997 Commercial Energy Efficiency Incentives Program
Summary of Ex Post Effective Useful Life Estimates
Lighting and HVAC End Uses

	Measure	EUL		Upper 80% CL	Lower 80% CL	EUL for Claim	Realization Rate
Measure Description	Code	Ex Ante	Ex Post	Ex Post	Ex Post	-	-
LIGHTING							
Optical Reflectors w/ Fluorescent Delamp							
REFLECTORS WITH DELAMPING, 4 FT LAMP REMOVED	**L19**	**16**	**205**	**471**	**-61**	**16**	**1.0**
REFLECTORS WITH DELAMPING, 2 FT LAMP REMOVED	L17	16	-	-	-	16	1.0
REFLECTORS WITH DELAMPING, 3 FT LAMP REMOVED	L18	16	-	-	-	16	1.0
REFLECTORS WITH DELAMPING, 8 FT LAMP REMOVED	L20	16	-	-	-	16	1.0
T8 Lamps and Electronic Ballasts							
FIXTURE: T-8 LAMP & ELEC BLST, (FEM or NEW FIXTURE), 4 FT FIXT	**L23**	**16**	**17**	**22**	**11**	**16**	**1.0**
FIXTURE: T-8, 4-LAMP, 8 FT FIXTURE	L12	16	-	-	-	16	1.0
FIXTURE: T-8 LAMP & ELEC BLST, (FEM or NEW FIXTURE), 2 FT FIXT	L21	16	-	-	-	16	1.0
FIXTURE: T-8 LAMP & ELEC BLST, (FEM or NEW FIXTURE), 3 FT FIXT	L22	16	-	-	-	16	1.0
FIXTURE: T-8 LAMP & ELEC BLST, (FEM or NEW FIXTURE), 8 FT FIXT	L24	16	-	-	-	16	1.0
FIXTURE: 2 FT T-8 W/EL BLST, 1 31-W T-8 U OR 2 17-W T-8	L69	16	-	-	-	16	1.0
FIXTURE: 2 FT T-8 W/EL BLST, 2 31-W T-8 U OR 4 17-W T-8	L70	16	-	-	-	16	1.0
FIXTURE: 2 FT T-8 W/EL BLST, 3 31-W T-8 U OR 6 17-W T-8	L71	16	-	-	-	16	1.0
FIXTURE: 4 FT T-8 W/ELEC BLST, 1 32-WATT T-8 LAMP	L72	16	-	-	-	16	1.0
FIXTURE: 4 FT T-8 W/ELEC BLST, 2 32-WATT T-8 LAMPS	L73	16	-	-	-	16	1.0
FIXTURE: 4 FT T-8 W/ELEC BLST, 3 32-WATT T-8 LAMPS	L74	16	-	-	-	16	1.0
FIXTURE: 8-FT T-8 W/EL BLST, 2 8-FT T-8 OR 4 32-W, 4-FT T-8	L75	16	-	-	-	16	1.0
FIXTURE: 8-FT T-8 W/EL BLST, 1 8-FT T-8 OR 2 32-W, 4-FT T-8	L160	16	-	-	-	16	1.0
FIXTURE: T-8 HIGH-OUTPUT LAMP & ELEC BLST, (FEM or NEW FIXTURE), 8 FT	L184	16	-	-	-	16	1.0
High Intensity Discharge							
HID FIXTURE: INTERIOR, STANDARD, 251-400 WATT LAMP	**L81**	**16**	**14**	**23**	**4**	**16**	**1.0**
HID FIXTURE: INTERIOR, STANDARD, 101-175 WATT LAMP	L26	16	-	-	-	16	1.0
HID FIXTURE: INTERIOR, STANDARD, 176-250 WATT LAMP	L27	16	-	-	-	16	1.0
HID FIXTURE: EXTERIOR, 0-100 WATT LAMP	L28	16	-	-	-	16	1.0
HID FIXTURE: EXTERIOR, 101-175 WATT LAMP	L29	16	-	-	-	16	1.0
HID FIXTURE: EXTERIOR, >= 176 WATT LAMP	L30	16	-	-	-	16	1.0
HID FIXTURE: INTERIOR, COMPACT, 36-70 WATT LAMP	L79	16	-	-	-	16	1.0
HID FIXTURE: INTERIOR, COMPACT, 71-100 WATT LAMP	L80	16	-	-	-	16	1.0
HID FIXTURE: INTERIOR, COMPACT, 36-70 WATTS LAMP, INCANDESCENT	L187	16	-	-	-	16	1.0
HID FIXTURE: INTERIOR, COMPACT, 36-70 WATTS LAMP, MERCURY VAPOR	L188	16	-	-	-	16	1.0
HID FIXTURE: INTERIOR, COMPACT, 71-100 WATTS LAMP, INCANDESCENT	L189	16	-	-	-	16	1.0
HID FIXTURE: INTERIOR, COMPACT, 71-100 WATTS LAMP, MERCURY VAPOR	L190	16	-	-	-	16	1.0
HID FIXTURE: INTERIOR, STANDARD, 101-175 WATTS LAMP, INCANDESCENT	L191	16	-	-	-	16	1.0
HID FIXTURE: INTERIOR, STANDARD, 101-175 WATTS LAMP, MERCURY VAPOR	L192	16	-	-	-	16	1.0
HID FIXTURE: INTERIOR, STANDARD, 176-250 WATTS LAMP, INCANDESCENT	L193	16	-	-	-	16	1.0
HID FIXTURE: INTERIOR, STANDARD, 176-250 WATTS LAMP, MERCURY VAPOR	L194	16	-	-	-	16	1.0
HID FIXTURE: INTERIOR, STANDARD, 251-400 WATTS LAMP, INCANDESCENT	L195	16	-	-	-	16	1.0
HID FIXTURE: INTERIOR, STANDARD, 251-400 WATTS LAMP, MERCURY VAPOR	L196	16	-	-	-	16	1.0
HID FIXTURE: EXTERIOR, 0-100 WATTS LAMP, INCANDESCENT	L197	16	-	-	-	16	1.0
HID FIXTURE: EXTERIOR, 0-100 WATTS LAMP, MERCURY VAPOR	L198	16	-	-	-	16	1.0
HID FIXTURE: EXTERIOR, 101-175 WATTS LAMP, INCANDESCENT	L199	16	-	-	-	16	1.0
HID FIXTURE: EXTERIOR, 101-175 WATTS LAMP, MERCURY VAPOR	L200	16	-	-	-	16	1.0
HID FIXTURE: EXTERIOR, >= 176 WATTS LAMP, INCANDESCENT	L201	16	-	-	-	16	1.0
HID FIXTURE: EXTERIOR, >= 176 WATTS LAMP, MERCURY VAPOR	L202	16	-	-	-	16	1.0
HVAC							
A/C: CENTRAL, < 65 KBTU/HR, AIR-COOLED, SPLIT-SYS/SNGL PKG	**S160**	**15**	**21**	**28**	**15**	**15**	**1.0**
A/C: CENTRAL, < 65 KBTU/HR, AIR-COOLED, SPLIT-SYSTEM (yr<96)	S1	15	-	-	-	15	1.0
A/C: CENTRAL, < 65 KBTU/HR, AIR-COOLED, SINGLE PACKAGE (yr<96)	S2	15	-	-	-	15	1.0
A/C: CENTRAL, >= 135 & < 760 KBTU/HR, AIR-COOLED, SINGLE PKG (yr<96)	S4	15	-	-	-	15	1.0
A/C: CENTRAL, >= 65 & < 135 KBTU/HR, AIR-COOLED, SPLIT-SYS/SNGL PKG	S161	15	-	-	-	15	1.0
A/C: CENTRAL, >= 135 & < 240 KBTU/HR, AIR-COOLED, SPLIT-SYS/SNGL PKG	S162	15	-	-	-	15	1.0
A/C: CENTRAL, >= 240 & < 760 KBTU/HR, AIR-COOLED, SPLIT-SYS/SNGL PKG	S163	15	-	-	-	15	1.0

* Studied Measures are in Bold.

Regulatory Waivers

There were no regulatory waivers filed for this study.

NINTH YEAR RETENTION STUDY FOR PG&E'S 1996 & 1997 COMMERCIAL EEI PROGRAM LIGHTING AND HVAC TECHNOLOGIES

PG&E STUDY ID#S: ***333AR2 & 333BR2***
CALMAC STUDY ID #S: ***PGE0237.01 AND PGE2038.01***

FINAL REPORT

Prepared for

Rafael Friedmann
Pacific Gas & Electric Co.
245 Market Street
San Francisco, CA 94105

Prepared by

QUANTUM CONSULTING INC.
2001 Addison Street, Suite 300
Berkeley, CA 94704

January 25, 2006

TABLE OF CONTENTS

TABLE OF CONTENTS
(continued)

LIST OF EXHIBITS

LIST OF EXHIBITS
(continued)

ATTACHMENTS

1. EXECUTIVE SUMMARY

This section presents a summary of the ninth year retention study results of Pacific Gas & Electric Company's (PG&E's) Commercial Energy Efficiency Incentive (CEEI) Program for lighting and HVAC technologies. The retention study described in this report covers all HVAC and lighting technologies installed at commercial accounts, as determined by the Marketing Decision Support System (MDSS) sector code, that were included under the RE, REO, and CI programs and for which rebates were *paid* during calendar years 1996 and 1997.

1.1 PROTOCOL REQUIREMENTS

This study was conducted under the rules specified in the "Protocols and Procedures for the Verification of Cost, Benefits, and Shareholder Earnings from Demand Side Management Programs" (the Protocols).[1] This evaluation has endeavored to meet all Protocol requirements.

The retention study results in ex post effective useful lives for each lighting and HVAC measure, and a comparison of realization rates from the ex ante to ex post estimates. The definition of the effective useful life, provided in Appendix A, Measurement Terms and Definitions, of the Protocols is: "an estimate of the median number of years that the measures installed under the program are still in place and operable".

Although there are dozens of measures installed under the Lighting and HVAC programs, the Protocols only require a subset of the measures be studied. The Protocols require the utilities to study either "the top ten measures, excluding measures that have been identified as miscellaneous (per Table C-9), ranked by the net resource value or the number of measures that constitutes the first 50% of the estimated resource value, whichever number of measures is less". For consistency, we will refer to the studied measures as the "Top 50% Measures" throughout this report.

The Protocols state that "measures not included in the … retention studies will be divided into two groups: 'like measures' and 'other measures.' Like measures are defined by the Protocols as measures that are believed to be similar to measures included in the retention studies. We have classified all groups of like measures with similar applications, operating conditions, and operating loads.

Exhibit 1-1 presents the list of studied measures and associated like measures covered under this retention study. In addition, Exhibit 1-1 provides the percent of net resource benefit attributable to each studied measure.

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[1] California Public Utilities Commission Decision 93-05-063, Revised March 1998, Pursuant to Decisions 94-05-063, 94-10-059, 94-12-021, 95-12-054, 96-12-079, 98-03-063, and 99-06-052.

Exhibit 1-1
Mapping of Like Measures

Program and Technology Group	Studied Measures	Percent of Total Net Resource Benefit		Measure Grouping
		1996	1997	Like Measures
LIGHTING END USE				
Retrofit Express Program				
Optical Reflectors w/ Fluor. Delamp	L19	16%	18%	L17, L18, L20, L76 - L77
T8 Lamps and Electronic Ballasts	L23	31%	34%	L9 - L12, L21, L22, L24, L69 - L75, L117 - L124, L160, L13, L112
High Intensity Discharge (251-400)	L81	7%	3%	L25, L78 - L80, L26, L27
HVAC END USE				
Retrofit Express Program				
Central Air Conditioning	S160	1%	5%	S1, S2, S4, S160 - S163

1.2 STUDY APPROACH OVERVIEW

As stated above, the Protocols assert the purpose of a retention study is to collect data on the fraction of installed measures in place and operable in order to produce a revised estimate of its EUL. The ultimate goal is to estimate the EUL (or the median number of years that the measure is still in place and operable), which can be realized by identifying the measure's survival function. For this study, the survival function describes the percentage of measures installed that are still operable and in place at a given time. Survival analysis is the process of analyzing empirical failure/removal data in order to model a measure's survival function. As much as possible, we have attempted to employ classical survival analysis techniques to our study approach.

Our overall approach consists of five analysis steps that were used to estimate each of the studied measures' EULs:

1. ***Compile summary statistics*** on the raw retention data.

2. ***Visually inspect*** the retention data, by simply calculating the cumulative percentage of equipment that had failed in a given month, and plotting the percentage over time.

3. ***Develop a trend line*** from the survival plots. Using the plots developed in (2) above, a trend line was estimated using standard linear regression techniques. We modeled the trend as a linear and an exponential function.

4. ***Develop a survival function*** using classical survival techniques. We modeled the survival function assuming five of the most common survival distributions: exponential, logistic, lognormal, Weibull and gamma. In each case, we used the resulting survival function to estimate the EUL.

5. ***Develop competing risks models*** for measures in which the distribution of the failures and removals was different. Using the LIFEREG procedure in SAS from step 4 above, separate output was generated for failures and removals for these measures. Then, the best fitting distributions for each event were combined to form one survival function.

This fifth step was not used for the L19 delamping measures since the measures observed only one failure type.

1.3 STUDY RESULTS

The recommended results for the L23 T-8 measure (T-8 lamps and electronic ballasts), the L81 HID measures (high intensity discharge fixtures 251-400), and the S160 measures (Central A/C) are based on the competing risks models. Of the three models created, the best-fit model is the model of choice. This model is based upon the combination of unique distributions for each event type chosen based upon the maximum of the Log-likelihood estimate generated during the LIFEREG procedure in SAS. For the L19 measure (delamping), the recommended results are based on the best fitting LIFEREG procedure results since there were no competing failure types for this measure. It is important to note that the study results for the L19 measure were very large and not statistically significant. This is due to a very small number of failures having occurred during the study period.

Exhibit 1-2 presents the recommended ex post estimates of the EUL. Because each of the analysis techniques did not provide results that were statistically significantly different from the ex ante results, measured at the 80 percent confidence interval, all of the ex post EULs are based on the ex ante estimates. Also presented are the final study results, and the corresponding upper and lower 80 percent confidence interval. Finally, the program realization rates are provided, which are the ratios of the ex ante and ex post estimates. For all measures, the realization rate is one; i.e., the ex post EULs fully corroborates using the ex ante EUL values.

Exhibit 1-2
Final Ex Post EUL Estimates

				Study Results				Realization
End Use	**Technology**	**Measure**	**Ex Ante**	**Upper**	**Median**	**Lower**	**Ex Post**	**Rate**
Lighting	Optical Reflectors w/ Fluor. Delamp	L19	16	471	205	-61	16	100%
	T8 Lamps and Electronic Ballasts	L23	16	22	17	11	16	100%
	High Intensity Discharge (251-400)	L81	16	23	14	4	16	100%
HVAC	Central Air Conditioning	S160	15	28	21	15	15	100%

Exhibit 1-3 presents the final EULs for the studied and like measures. Provided are the ex ante and ex post EULs, the 80 percent confidence intervals for the ex post results, the final EUL used for the filing claim, and the realization rate.

Exhibit 1-3
Final EUL Estimates
For Studied and Like Measures

Measure Description	Measure Code	EUL Ex Ante	EUL Ex Post	Upper 80% CL Ex Post	Lower 80% CL Ex Post	EUL for Claim -	Realization Rate -
LIGHTING							
Optical Reflectors w/ Fluorescent Delamp							
REFLECTORS WITH DELAMPING, 4 FT LAMP REMOVED	**L19**	**16**	**205**	**471**	**-61**	**16**	**1.0**
REFLECTORS WITH DELAMPING, 2 FT LAMP REMOVED	L17	16	-	-	-	16	1.0
REFLECTORS WITH DELAMPING, 3 FT LAMP REMOVED	L18	16	-	-	-	16	1.0
REFLECTORS WITH DELAMPING, 8 FT LAMP REMOVED	L20	16	-	-	-	16	1.0
T8 Lamps and Electronic Ballasts							
FIXTURE: T-8 LAMP & ELEC BLST, (FEM or NEW FIXTURE), 4 FT FIXT	**L23**	**16**	**17**	**22**	**11**	**16**	**1.0**
FIXTURE: T-8, 4-LAMP, 8 FT FIXTURE	L12	16	-	-	-	16	1.0
FIXTURE: T-8 LAMP & ELEC BLST, (FEM or NEW FIXTURE), 2 FT FIXT	L21	16	-	-	-	16	1.0
FIXTURE: T-8 LAMP & ELEC BLST, (FEM or NEW FIXTURE), 3 FT FIXT	L22	16	-	-	-	16	1.0
FIXTURE: T-8 LAMP & ELEC BLST, (FEM or NEW FIXTURE), 8 FT FIXT	L24	16	-	-	-	16	1.0
FIXTURE: 2 FT T-8 W/EL BLST, 1 31-W T-8 U OR 2 17-W T-8	L69	16	-	-	-	16	1.0
FIXTURE: 2 FT T-8 W/EL BLST, 2 31-W T-8 U OR 4 17-W T-8	L70	16	-	-	-	16	1.0
FIXTURE: 2 FT T-8 W/EL BLST, 3 31-W T-8 U OR 6 17-W T-8	L71	16	-	-	-	16	1.0
FIXTURE: 4 FT T-8 W/ELEC BLST, 1 32-WATT T-8 LAMP	L72	16	-	-	-	16	1.0
FIXTURE: 4 FT T-8 W/ELEC BLST, 2 32-WATT T-8 LAMPS	L73	16	-	-	-	16	1.0
FIXTURE: 4 FT T-8 W/ELEC BLST, 3 32-WATT T-8 LAMPS	L74	16	-	-	-	16	1.0
FIXTURE: 8-FT T-8 W/EL BLST, 2 8-FT T-8 OR 4 32-W, 4-FT T-8	L75	16	-	-	-	16	1.0
FIXTURE: 8-FT T-8 W/EL BLST, 1 8-FT T-8 OR 2 32-W, 4-FT T-8	L160	16	-	-	-	16	1.0
FIXTURE: T-8 HIGH-OUTPUT LAMP & ELEC BLST, (FEM or NEW FIXTURE), 8 FT	L184	16	-	-	-	16	1.0
High Intensity Discharge							
HID FIXTURE: INTERIOR, STANDARD, 251-400 WATT LAMP	**L81**	**16**	**14**	**23**	**4**	**16**	**1.0**
HID FIXTURE: INTERIOR, STANDARD, 101-175 WATT LAMP	L26	16	-	-	-	16	1.0
HID FIXTURE: INTERIOR, STANDARD, 176-250 WATT LAMP	L27	16	-	-	-	16	1.0
HID FIXTURE: EXTERIOR, 0-100 WATT LAMP	L28	16	-	-	-	16	1.0
HID FIXTURE: EXTERIOR, 101-175 WATT LAMP	L29	16	-	-	-	16	1.0
HID FIXTURE: EXTERIOR, >= 176 WATT LAMP	L30	16	-	-	-	16	1.0
HID FIXTURE: INTERIOR, COMPACT, 36-70 WATT LAMP	L79	16	-	-	-	16	1.0
HID FIXTURE: INTERIOR, COMPACT, 71-100 WATT LAMP	L80	16	-	-	-	16	1.0
HID FIXTURE: INTERIOR, COMPACT, 36-70 WATTS LAMP, INCANDESCENT	L187	16	-	-	-	16	1.0
HID FIXTURE: INTERIOR, COMPACT, 36-70 WATTS LAMP, MERCURY VAPOR	L188	16	-	-	-	16	1.0
HID FIXTURE: INTERIOR, COMPACT, 71-100 WATTS LAMP, INCANDESCENT	L189	16	-	-	-	16	1.0
HID FIXTURE: INTERIOR, COMPACT, 71-100 WATTS LAMP, MERCURY VAPOR	L190	16	-	-	-	16	1.0
HID FIXTURE: INTERIOR, STANDARD, 101-175 WATTS LAMP, INCANDESCENT	L191	16	-	-	-	16	1.0
HID FIXTURE: INTERIOR, STANDARD, 101-175 WATTS LAMP, MERCURY VAPOR	L192	16	-	-	-	16	1.0
HID FIXTURE: INTERIOR, STANDARD, 176-250 WATTS LAMP, INCANDESCENT	L193	16	-	-	-	16	1.0
HID FIXTURE: INTERIOR, STANDARD, 176-250 WATTS LAMP, MERCURY VAPOR	L194	16	-	-	-	16	1.0
HID FIXTURE: INTERIOR, STANDARD, 251-400 WATTS LAMP, INCANDESCENT	L195	16	-	-	-	16	1.0
HID FIXTURE: INTERIOR, STANDARD, 251-400 WATTS LAMP, MERCURY VAPOR	L196	16	-	-	-	16	1.0
HID FIXTURE: EXTERIOR, 0-100 WATTS LAMP, INCANDESCENT	L197	16	-	-	-	16	1.0
HID FIXTURE: EXTERIOR, 0-100 WATTS LAMP, MERCURY VAPOR	L198	16	-	-	-	16	1.0
HID FIXTURE: EXTERIOR, 101-175 WATTS LAMP, INCANDESCENT	L199	16	-	-	-	16	1.0
HID FIXTURE: EXTERIOR, 101-175 WATTS LAMP, MERCURY VAPOR	L200	16	-	-	-	16	1.0
HID FIXTURE: EXTERIOR, >= 176 WATTS LAMP, INCANDESCENT	L201	16	-	-	-	16	1.0
HID FIXTURE: EXTERIOR, >= 176 WATTS LAMP, MERCURY VAPOR	L202	16	-	-	-	16	1.0
HVAC							
A/C: CENTRAL, < 65 KBTU/HR, AIR-COOLED, SPLIT-SYS/SNGL PKG	**S160**	**15**	**21**	**28**	**15**	**15**	**1.0**
A/C: CENTRAL, < 65 KBTU/HR, AIR-COOLED, SPLIT-SYSTEM (yr<96)	S1	15	-	-	-	15	1.0
A/C: CENTRAL, < 65 KBTU/HR, AIR-COOLED, SINGLE PACKAGE (yr<96)	S2	15	-	-	-	15	1.0
A/C: CENTRAL, >= 135 & < 760 KBTU/HR, AIR-COOLED, SINGLE PKG (yr<96)	S4	15	-	-	-	15	1.0
A/C: CENTRAL, >= 65 & < 135 KBTU/HR, AIR-COOLED, SPLIT-SYS/SNGL PKG	S161	15	-	-	-	15	1.0
A/C: CENTRAL, >= 135 & < 240 KBTU/HR, AIR-COOLED, SPLIT-SYS/SNGL PKG	S162	15	-	-	-	15	1.0
A/C: CENTRAL, >= 240 & < 760 KBTU/HR, AIR-COOLED, SPLIT-SYS/SNGL PKG	S163	15	-	-	-	15	1.0

* Studied Measures are in Bold.

The remainder of this report will present our analysis methodology and the results from each of the five analysis steps.

2. INTRODUCTION

This report summarizes the retention study of Pacific Gas & Electric Company's (PG&E's) Commercial Energy Efficiency Incentive (CEEI) Program for lighting and HVAC technologies. The evaluation effort includes customers who were paid rebates in 1996 and 1997. Technologies installed under the paid year 1996 and 1997 CEEI Program were covered by three separate program options: the Retrofit Express (RE) Program, the Retrofit Efficiency Options (REO) Program and the Customized Incentives (CI) Program.

2.1 THE RETROFIT EXPRESS PROGRAM

The RE program offered fixed rebates to customers who installed specific electric energy-efficient equipment. The program covered the most common energy saving measures and spans lighting, air conditioning, refrigeration, motors, and food service. Customers were required to submit proof of purchase with these applications in order to receive rebates. The program was marketed to small- and medium-sized commercial, industrial, and agricultural customers. The maximum rebate amount, including all measure types, was $300,000 per account. No minimum amount was required to qualify for a rebate.

Lighting and HVAC end-use rebates were offered in the program for the following technologies:

Lighting Technologies

- Halogen lamps
- Compact fluorescent lamps
- T-12 and T-8 fluorescent lamps
- Compact fluorescent lamps and LED's
- Electronic ballasts
- T-8 and T-10 lamps and electronic ballasts
- High-intensity discharge (HID) fixtures
- Occupancy sensors, bypass or delay timers, photocells, and time clock controls
- Removal of lamps and ballasts

HVAC Technologies

- High-efficiency central air-conditioning units in various capacity ranges
- Variable speed drive HVAC fans
- High-efficiency package terminal air-conditioning units
- Programmable thermostats, bypass timers, and electronic timeclocks
- Reflective window film
- Water chillers of various capacity ranges
- Direct evaporative cooler units, evaporative condensers, and evaporative cooler towers

2.2 THE RETROFIT EFFICIENCY OPTIONS PROGRAM

The REO program targeted commercial, industrial, agricultural, and multi-family market segments most likely to benefit from these selected measures. Customers were required to submit calculations for the projected first-year energy savings along with their application prior to installation of the high efficiency equipment. PG&E representatives worked with customers to identify cost-effective improvements, with special emphasis on operational and maintenance measures at the customers' facilities. Marketing efforts were coordinated amongst PG&E's divisions, emphasizing local planning areas with high marginal electric costs to maximize the program's benefits.

The REO program did not include any lighting measures. Nine HVAC technologies, however, were included, which can be summarized into four general technology groups, described below:

Technology
• Variable frequency drive supply fans
• Installation of high efficiency water chillers
• Variable air volume supply systems, which replace constant air volume supply systems
• Evaporative cooling towers

2.3 THE CUSTOMIZED INCENTIVES PROGRAM

The Customized Incentives program offered financial incentives to commercial, industrial and agricultural (CIA) customers who undertook large or complex projects that save gas or electricity. These customers were required to submit calculations for projected first-year energy impacts with their applications prior to installation of the project. The maximum incentive amount for the Customized Incentives program was $500,000 per account, and the minimum qualifying incentive was $2,500 per project. The total incentive payment for kW, kWh, and therm savings was limited to 50 percent of direct project cost for retrofit of existing systems. Since the program also applied to expansion projects, the new systems incentive was limited to 100 percent of the incremental cost to make new processes or added systems energy efficient. Customers were paid 4¢ per kWh and 20¢ per therm for first-year annual energy impacts. A $200 per peak kW incentive for peak demand impacts required that savings be achieved during the hours PG&E experiences high power demand.

As a result of program design, the measures installed were similar to or the same as those for the RE program, but were installed in larger and more complex projects. The Lighting measures are the same as those described above for the RE program. For HVAC, the following technologies were rebated in 1996 and 1997:

Technology

- HVAC variable speed drive
- High efficiency chiller
- Energy Management Systems (EMS)
- Other miscellaneous Customized Incentives HVAC measures, which included:
  - Installation of various energy efficient motors
  - Installation of various HVAC controls
  - Various technologies (i.e., precoolers and economizers) added to increase overall system efficiency

2.4 STUDY REQUIREMENTS

The retention study described in this report covers all HVAC and lighting technologies installed at commercial accounts, as determined by the Marketing Decision Support System (MDSS) sector code, that were included under the RE, REO, and CI programs and for which rebates were *paid* during calendar year 1996 and 1997.

This study was conducted under the rules specified in the "Protocols and Procedures for the Verification of Cost, Benefits, and Shareholder Earnings from Demand Side Management Programs" (the Protocols).[2] This evaluation has endeavored to meet all Protocol requirements.

The retention study results in ex post effective useful lives for each lighting and HVAC measure, and a comparison of realization rates from the ex ante to ex post estimates. The definition of the effective useful life, provided in Appendix A, Measurement Terms and Definitions, of the Protocols is:

Effective Useful Life (EUL) – An estimate of the median number of years that the measures installed under the program are still in place and operable.

2.4.1 Studied Measures

Although there are dozens of measures installed under the Lighting and HVAC programs, the Protocols only require a subset of the measures be studied. The Protocols refer to the studied measures as the "Top 10 or Top 50% Measures", which is defined as:

Top 10 or Top 50% Measures – The utility should select the top ten measures, excluding measures that have been identified as miscellaneous (per Table C-9), ranked by the net resource value or the number of measures that constitutes the first 50% of the estimated resource value, whichever number of measures is less.

[2] California Public Utilities Commission Decision 93-05-063, Revised March 1998, Pursuant to Decisions 94-05-063, 94-10-059, 94-12-021, 95-12-054, 96-12-079, 98-03-063, and 99-06-052.

For the 1996 and 1997 CEEI Program, the number of measures that constitutes the first 50% of the estimated resource value is only three. For consistency, we will refer to these measures throughout the report as the "Top 50% Measures."

For the 1996 and 1997 CEEI Program, HVAC and Lighting comprise the studied end-uses. Among these end-uses, the following measures shown in Exhibit 2-1 are identified as the "Top 50% Measures", as defined above.

Exhibit 2-1
Top 50% Measures for Paid Year 1996 and 1997

Paid Year	MDSS Measure Codes	Measure Description	% of Net Resource Benefit	Cumulative % of Net Resource Benefit
1996	L19	Optical Reflectors w/ Fluor. Delamp	16%	16%
	L23	T8 Lamps and Electronic Ballasts	31%	47%
	L81	High Intensity Discharge (251-400)	7%	54%
1997	L19	Optical Reflectors w/ Fluor. Delamp	18%	18%
	L23	T8 Lamps and Electronic Ballasts	34%	52%
	L81	High Intensity Discharge (251-400)	3%	55%

In addition to studying the measures identified in Exhibit 2-1, PG&E decided to study one additional HVAC measures for program years 1996 and 1997, shown in Exhibit 2-2. Adding this measure brings the cumulative net resource benefit up to 55% in 1996 and 60% in 1997.

Exhibit 2-2
Other Studied Measures for Paid Year 1996 and 1997

Paid Year	MDSS Measure Codes	Measure Description	% of Net Resource Benefit	Cumulative % of Net Resource Benefit
1996	S160	Central Air Conditioning	1%	55%
1997	S160	Central Air Conditioning	5%	60%

2.4.2 Like Measures

The Protocols state that "measures not included in the … retention studies will be divided into two groups: 'like measures' and 'other measures.' Like measures are defined by the Protocols as:

> **Like Measures** – measures that are believed to be similar to measures included in the retention studies.

We have classified all groups of like measures with similar applications, operating conditions, and operating loads. Exhibit 2-3 presents the mapping of studied measures to like measures.

Exhibit 2-3
Mapping of Like Measures

Program and Technology Group	Studied Measures	Percent of Total Net Resource Benefit 1996	Percent of Total Net Resource Benefit 1997	Measure Grouping: Like Measures
LIGHTING END USE				
Retrofit Express Program				
Optical Reflectors w/ Fluor. Delamp	L19	16%	18%	L17, L18, L20, L76 - L77
T8 Lamps and Electronic Ballasts	L23	31%	34%	L9 - L12, L21, L22, L24, L69 - L75, L117 - L124, L160, L13, L112
High Intensity Discharge (251-400)	L81	7%	3%	L25, L78 - L80, L26, L27
HVAC END USE				
Retrofit Express Program				
Central Air Conditioning	S160	1%	5%	S1, S2, S4, S160 - S163

The Protocols require that "like measures adopt the same percent adjustment [or realization rate] for the measure effective useful lives of the similar studied measures . . . to adjust their ex ante measure effective useful lives."

Other measures are defined as:

> **Other Measures** – measures that are different from the measures included in the retention study.

Therefore, other measures consist of all HVAC and Lighting measures that are not classified as either studied or like measures. The Protocols require that, for other measures, the ex ante estimate of the effective useful life will be adjusted by the average percentage adjustment [or realization rate] of all the studied measures within that end use."

2.4.3 Combining Program Years

The Protocols also require that two Program Years, 1996 and 1997, be combined and that the studies be conducted on the schedule for Program Year 1996. The Protocols state that combining the two studies "should increase the accuracy of the survival function and decrease the cost of completing the retention studies." Furthermore, "the retention studies shall include data from participant groups from two or more sequential years to increase the robustness of the sample and to allow for the estimation of a survival function for a number of different measures."

Because the Top 50% Measures for the 1997 Program Year are a subset of the 1996 Top 50% Measures, the Protocol's suggestion to combine the two studies will greatly enhance the accuracy of the retention study, without incurring additional cost.

2.4.4 Accepting Ex Post EULs

The Protocols state that "the estimated ex post measure EULs that result from the retention study will be compared to the ex ante EUL estimates. Hypothesis testing procedures will be used to determine if the estimated ex post measure EUL is statistically significantly different from the ex ante measure EUL. If the estimated ex post measure EUL is significantly different than the ex ante measure EUL, the estimated ex post measure EUL will be used. Otherwise, the ex ante estimate will continue to be used. Hypothesis testing will be conducted at the 20% significance level."

2.4.5 Objectives

The research objectives are therefore as follows:

- Collect data on the fraction of the measures that are in place and operable, for all studied measures.
- For each studied measure, calculate the ex post EUL, and the realization rates from ex ante to ex post.
- For each like measure, calculate the ex post EUL, based on a transferred realization rate from the studied measures.
- For each remaining HVAC and lighting measure, calculate the ex post EUL, based on the average realization rate from all studied and like measures.
- Complete tables 6 and 7 of the Protocols.

2.5 STUDY APPROACH OVERVIEW

As stated above, the Protocols assert the purpose of a retention study is to collect data on the fraction of installed measures in place and operable in order to produce a revised estimate of its EUL. The ultimate goal is to estimate the EUL (or the median number of years that the measure is still in place and operable), which can be realized by identifying the measure's survival function. For this study, the survival function describes the percentage of measures installed that are still operable and in place at a given time. At any given time, the hazard rate is the rate at which measures fail or are removed. Survival analysis is the process of analyzing empirical failure/removal data in order to model a measure's survival function. As much as possible, we have attempted to employ classical survival analysis techniques to our study approach.

Our overall approach was to apply survival analysis to our collected retention data in order to develop a survival function for each of the studied measures. Some of the common survival functions take on the logistic cumulative distribution function. Although there is no documentation to support the ex ante survival function assumptions, discussions with the authors of the Protocols indicated that the ex ante EULs are based on a logistic survival function.

However, the form of the logistic survival function assumed by the Protocol authors is *not* the commonly used form of the logistic model. Generally, in survival analysis, the log-logistic model is used, which is a special form of the logistic distribution. It is this distribution that we used in our analysis. Other commonly used survival functions are based on the exponential, Weibull, lognormal, and gamma distributions. For this retention study, we have examined each of these distributions. We have used the SAS System and the SAS companion guide, "Survival Analysis Using the SAS System[3]," in order to estimate the survival functions based on the retention data for each of our studied measures.

An important issue to keep in mind for this analysis is the definition of survival. Recall that the EUL is defined as the median number of years that the measures installed under the program are still in place and operable. Therefore, to "survive", a measure must not have been removed or have failed. Unfortunately, it is likely that the underlying distribution of measures having failed is very different than the distribution of removals.

There is much literature to suggest, for example, that electronic ballast failures follow an exponential distribution. The exponential survival function has a constant hazard rate. In other words, the rate at which electronic ballasts fail is constant over time. This belief is founded on the fact that electronic devices are likely to fail at any point in time with equal probability. Because electronic ballasts may have anywhere from 30 to 120 parts, plus more than twice as many solder joints as there are parts, it is likely that the ballast may also fail at any point in time, with equal probability.[4]

However, the removal of an electronic ballast is more dependent on human interaction. For example, consider the act of remodeling, or upgrading the system as new technologies emerge. Both of these actions are likely to occur in the latter stage of the equipment's life. However, if the customer is not satisfied with the technology, the removal may occur early on in the equipment's life. Whatever the case may be, it is likely that the survival function of equipment removal differs from the survival function of the equipment failure.

These reasons have led us to develop a competing risks model that accounts for varying distributions for each event type. The LIFEREG procedure in SAS is used to generate output for each unique event type (failures and removals). This output is then used to generate a competing risks model that produces a survival function that is comprised of the best fitting distribution for each event type.

Our overall approach consists of five analysis steps that were used to estimate each of the studied measures' EULs:

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[3] Allison, Paul D., "Survival Analysis Using the SAS System, A Practical Guide", SAS Institute, NC, 1995.

[4] Energy User News, Vol. 23 No. 10, October 1998. Electronics, Energy Products and Life-Cycle Costing, pp. 28.

1. ***Compile summary statistics*** on the raw retention data.

2. ***Visually inspect*** the retention data. By calculating the cumulative percentage of equipment that had failed in a given month, and plotting this percentage over time, an empirical survival function emerges.

3. ***Develop a trend line*** from the survival plots. Using the plots developed in (2) above, we estimated a trend line using standard linear regression techniques. We modeled the trend as a linear and an exponential function. In each case, we plotted the resulting trend line and visually compared it to the survival plot developed in (2). Furthermore, we used the resulting trend line to estimate the EUL.

4. ***Develop a survival function*** using classical survival techniques. Using the SAS System and the SAS companion guide, "Survival Analysis Using the SAS System," we modeled the survival function assuming five of the most common survival distributions: exponential, logistic, lognormal, Weibull and gamma. In each case, we plotted the resulting distribution and visually compared it to the survival plot developed in (2). Furthermore, we used the resulting survival function to estimate the EUL.

5. **Develop competing risks models** *for measures in which the distribution of the failures and removals was different. Using the LIFEREG procedure in SAS from step 4 above, separate output was generated for failures and removals for these measures. Then, the best fitting distributions for each event were combined to form one survival function. This fifth step was not used for the L19 delamping measure since the measure observed only one failure type.*

The details surrounding each of these steps are provided in Section 3.

2.6 REPORT LAYOUT

This report is divided into four sections, plus attachments. *Sections 1 and 2* are the *Executive Summary* and the *Introduction*. *Section 3* presents the *Methodology* of the evaluation. *Section 4* presents the detailed results and a discussion of important findings. *Attachment 1* provides copies of the Lighting and HVAC retention audit instruments and finally *Attachment 2* provides the Protocol Tables 6B and 7B.

3. METHODOLOGY

This section provides the specifics surrounding the methods used to conduct the Retention Study for the 1996 and 1997 Pacific Gas & Electric Company (PG&E) Commercial Energy Efficiency Incentive (CEEI) Programs. It begins with a detailed discussion on the sampling plan for the Retention Study. From there, details regarding the study methodology are presented, along with intermediate results from each of the five approaches implemented.

3.1 SAMPLE DESIGN

3.1.1 Existing Data Sources

PG&E's 1996 and 1997 first year CEEI program impact evaluations established "retention panels" of approximately 350 sites in 1996 and 250 sites in 1997 for the Lighting and HVAC end uses. At each of these sites the rebated equipment was documented by make, model, and location. As part of the fourth year retention study and other data collection efforts, retention data had been collected on a total of 433 1996 and 1997 sites that had installed at least one of the studied measures. Because many of the customers in the original retention panels did not install studied measures, the sample frame of customers being studied was opened to all 1996 and 1997 participants to increase the robustness of the analysis.

Exhibit 3-1 provides the available sample frame for each studied measure, along with the number of sites that have existing retention data.

Exhibit 3-1
Available Sample Frame and Sites with Existing Retention Data by Studied Measure

Measure Code	Measure Description	Participant Population (1996/97 MDSS)	Total Sites Previously Contacted
L19	Optical Reflectors w/ Fluor. Delamp	1,076	91
L23	T8 Lamps and Electronic Ballasts	4,097	143
L81	High Intensity Discharge (251-400)	163	54
S160	Central Air Conditioning	1,199	145
TOTAL		6,535	433

3.1.2 Sample Design Overview

For this retention study, an attempt was made to re-contact all 433 sites previously contacted. Furthermore, this sample frame was supplemented with the entire lighting and HVAC population of sites with studied measures. The objective of the sample design to collect retention data on 325 HVAC sites and 375 lighting sites. The distribution of measures within the lighting end use was for 75 L81 measures (which has a limited sample frame as shown above), 150 L19 measures and 150 L23 measures.

3.1.3 Final Distribution

The sampling goals discussed above were achieved. Because there is some overlap in measures being installed at the same site, particularly with the L23 and L19, some measures exceeded their sample goal. Exhibit 3-2 below provides the final sample disposition, which includes the number of sites with available retention data used for this study. For sites that had existing retention data that we were unable to contact, we used the existing retention data from the fourth year study.

Exhibit 3-2
Final Sample Disposition

Measure Code	Measure Description	Participant Population (1996/97 MDSS)	Total Sites Previously Contacted	Total Sites Contacted with Retention Data
L19	Optical Reflectors w/ Fluor. Delamp	1,076	91	214
L23	T8 Lamps and Electronic Ballasts	4,097	143	270
L81	High Intensity Discharge (251-400)	163	54	99
S160	Central Air Conditioning	1,199	145	401
TOTAL		6,535	433	984

3.1.4 Data Collection Strategy

The data collection effort surrounding the survival analysis included a combination of telephone and on-site surveys. When possible, these data were gathered using telephone surveys, with alternate data collection using on-site audits where installations were too complex to be supported by self-reported data. In general, on-sites were required for many of the lighting end use installations, while HVAC equipment survival was more readily verified using the telephone interview only. The following outlines the data collection procedures.

An auditor contacted each site by telephone to assess whether an on-site audit was necessary, or if a telephone survey would suffice. If the auditor determined that the information could be obtained over the telephone, the auditor conducted the telephone survey immediately, or at the customer's earliest convenience. If an on-site audit was deemed necessary, and the participant was willing, an appointment was scheduled and an auditor visited the site.

Equipment survival data were collected by the auditor, who prompted each site contact to locate the retention technologies using information available from the retention panels (when available). At that time, information was recorded regarding the success or failure in locating the panel-specified equipment.

For each unit of equipment in the retention panel, it was determined whether (1) the equipment was still installed, and (2) if it was operable. If the equipment was not in place or was not operable, it was determined when it was removed or stopped operating according to the owner or operators best recollection. Reasons for removal or failure to operate were also collected. If equipment was replaced, it was determined if the equipment was replaced with a standard, equivalent or higher efficiency technology. Finally, it was determined if replaced equipment was done so under warranty.

3.2 ANALYSIS OVERVIEW

As discussed in Section 2.4, the purpose of a retention study is to collect data on the fraction of measures in place and operable in order to produce a revised estimate of its EUL. The desired result of our approach was to apply survival analysis to our collected retention data in order to develop a survival function for each of the studied measures.

Before attempting to estimate a survival function for a given measure, we first evaluated the data collected to see if there was enough data to support an estimate. For this step, for each studied measure, we compiled summary statistics on the raw retention data, and visually inspected the empirical survival function that we observed over the first eight to nine years.

Next we used the empirical survival function to forecast the survival function using basic linear regression techniques. We analyzed both a linear trend, as well as an exponential trend (which is one of the most common forms of a survival function).

Next, we used classical survival analysis techniques to develop a survival function. This analysis was performed using the SAS System and the SAS companion guide, "Survival Analysis Using the SAS System." As part of this step, we attempted to model the survival function using five of the most commonly used survival distributions: exponential, logistic, lognormal, Weibull and gamma.

Finally, we constructed Competing Risks models for measures in which the distribution of the failures and removals was different. This technique allows us to create a single optimal model in situations where failures are most appropriately modeled using one distribution, while removals are better represented by another distribution. Three different competing risks scenarios were developed for each measure: a best-fit model that matched the best fitting distributions (based on the Log-likelihood estimator in SAS), a minimum EUL model, and a maximum EUL model. Statistical methods are employed to determine which distribution best fits the data.

Our overall approach consists of five analysis steps that were used to estimate each of the studied measures' EULs:

1. ***Compile summary statistics*** on the raw retention data.

2. ***Visually inspect*** the retention data.

3. ***Develop a trend line*** from the survival plots.

4. ***Develop a survival function*** using classical survival techniques.

5. ***Develop competing risks models*** that model each event with a different distribution.

The details surrounding each of these methods are provided below.

3.3 SUMMARY STATISTICS

As discussed above, the first step of our analysis was to compile summary statistics on the sample retention data. For each measure in our sample, these statistics include:

- the number of units installed at the site;
- the number of units still operable and in place;
- the number of units that had failed or been removed;
- the number of failed units that had been replaced under warranty;
- the percentage of units that had failed or been removed; and
- the ex ante EUL.

The CADMAC has agreed that failed equipment that is replaced under warranty should be counted as if it is still operable and in place, although in this study no units were replaced under warrantee. Exhibit 3-3 summarizes this data at the measure level.

Exhibit 3-3
Summary Statistics on Retention Sample Data

End Use	Technology	Measure	# Records in dataset	# of Sites Contacted	Units	Total Number of Units	Number of Units that Failed or were Removed	Number of Units in Place and Operable	Percent Failed or Removed
Lighting	Optical Reflectors w/ Fluor. Delamp	L19	1076	214	Fixtures	28,250	654	27,596	2.3%
	T8 Lamps and Electronic Ballasts	L23	4097	270	Ballasts	62,490	7,370	55,120	11.8%
	High Intensity Discharge (251-400)	L81	163	99	Lamps	2,574	267	2,307	10.4%
HVAC	Central Air Conditioning	S160	1199	401	Tons	5,843	192	5,651	3.3%

If we make the assumption that the failure/removal rates provided in Exhibit 3-3 are constant over time, then our survival function would take on the exponential distribution, which is one of the most commonly used distributions in survival analysis. Assuming the failures/removals occurred over a nine-year period, we can estimate the median EUL. Exhibit 3-4 provides the estimated EULs based on these assumptions for the data collected in the 2005 survey (limiting our data to the 2005 survey data allows us to meet the assumption that all failures/removals are equally distributed over a nine year period).

Exhibit 3-4
Illustrative Ex Post EUL Estimates
Based on Exponential Distribution and Conservative Assumptions

End Use	Technology	Measure	Percent Failed, Removed, Replaced	Annualized Failure, Removal, Replacement Rate^	Mean Life*	Median Life*	Ex Ante EUL
Lighting	Optical Reflectors w/ Fluor. Delamp	L19	2.6%	0.3%	340	236	16
	T8 Lamps and Electronic Ballasts	L23	14.6%	1.6%	62	43	16
	High Intensity Discharge (251-400)	L81	16.4%	1.8%	55	38	16
HVAC	Central Air Conditioning	S160	4.0%	0.4%	226	157	15

^ Includes only 9th year survey data and assumes failures and removals occur over a nine year period.
* Assuming a constant failure rate over time.

Even based on these conservative assumptions, the estimates of median lives greatly exceed the ex ante estimates of EUL.

It is important to note that during some of the follow-up surveys (which were done either on-site or over the phone by an experienced auditor), it was not always possible to identify the exact equipment that was included in the retention panel. In some cases we were unable to identify the exact amount of equipment at the facility, which sometimes lead to larger or smaller estimates of equipment in place and in operation.

Because we obtained counts of the number of units that had failed or been removed, we could verify the unit counts in the retention panel. This was done by adding the number of units found to be in place and operable, to the number of units that had failed or been removed. In the cases where the number of verified units was smaller than the number of units in the retention panel, we conducted our analysis on only the number that we verified during the survey.

3.4 VISUAL INSPECTION

For this step, we developed an empirical survival function that was observed from the raw retention data over the first nine years of the measures' lives. As discussed above, this task was conducted for all measures, regardless of the amount of failures or removals in the sample data.

To develop the empirical function, we calculated for each month the percentage of equipment that was in place and operable. Although this appears to be a straightforward calculation, there were two issues that arose:

- The dates associated with failures and removals were not always well populated.
- Not all customers were surveyed over the same length of time.

Missing Failure Dates

Three common terms used in classical survival analysis are "left-hand censoring", "right-hand censoring", and "interval censoring". Left-hand censoring means that it is known that a failure/removal has occurred, but it is unknown when the failure/removal occurred. It is only known that the failure/removal occurred before a certain date.

Right-hand censoring is more common in our data. Right-hand censoring means that at the last time the customer was surveyed, a failure/removal had not occurred, so the time when the equipment will fail or be removed is unknown.

Interval censoring, as the name implies, means that it is known that a failure has occurred during a known interval. If no event has occurred, the interval is assumed to be right-hand censored.

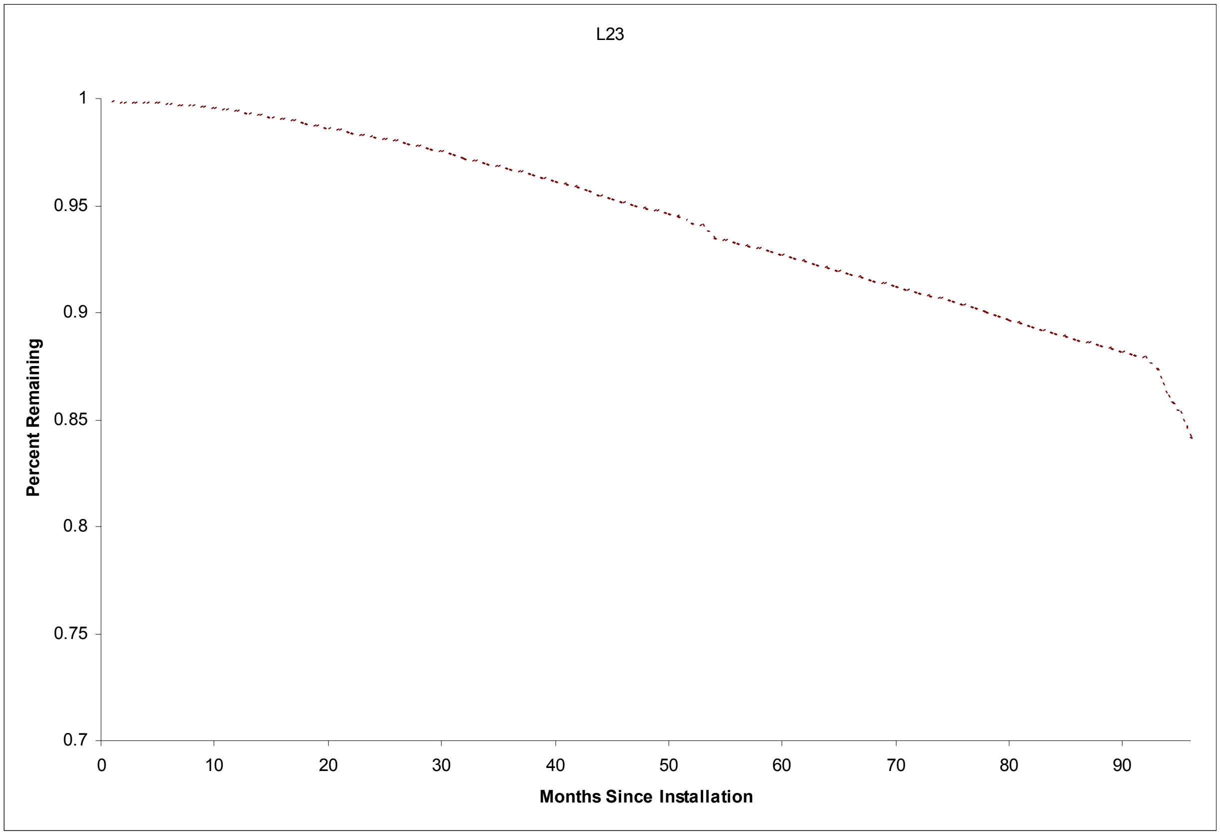
The SAS procedures that are discussed below in Section 3.6 are capable of handling right-hand censored data and in some cases left-hand and interval censored data. But for this more simplistic task, some assumptions were required.

1. For missing failure dates, generate a random date (based on a uniform distribution) between the date the measure was installed and the date the follow-up survey was conducted.

2. To estimate the percentage of equipment operable and in place in month M, do not include the equipment if the survey length is less than month M, regardless if a failure/removal occurred prior to month M.

Exhibit 3-5 provides an example of a derived empirical survival function the L23 T8 measure, over the first eight years of the measure's life:

Exhibit 3-5
Final Empirical Survival Function
for all Studied Lighting Measures



3.5 TREND LINES

Based on the empirical survival functions presented above, a trend line was developed to estimate the survival function over the life of the measure, and estimate the measure's EUL. Only the first 100 months of the empirical survival functions were used, as retention data were only gathered over the first eight to nine years of the measures' life. This was done for all of the Lighting and HVAC measures.

Two trend lines and corresponding EULs were estimated using linear regression as follows:

- The first trend line was assumed to have a linear relationship over time. Therefore, the trend line was developed using a linear regression with the percentage of equipment operable and in place as the dependent variable, and the month as the independent variable. For a linear survival function, the EUL (median life) is calculated as:

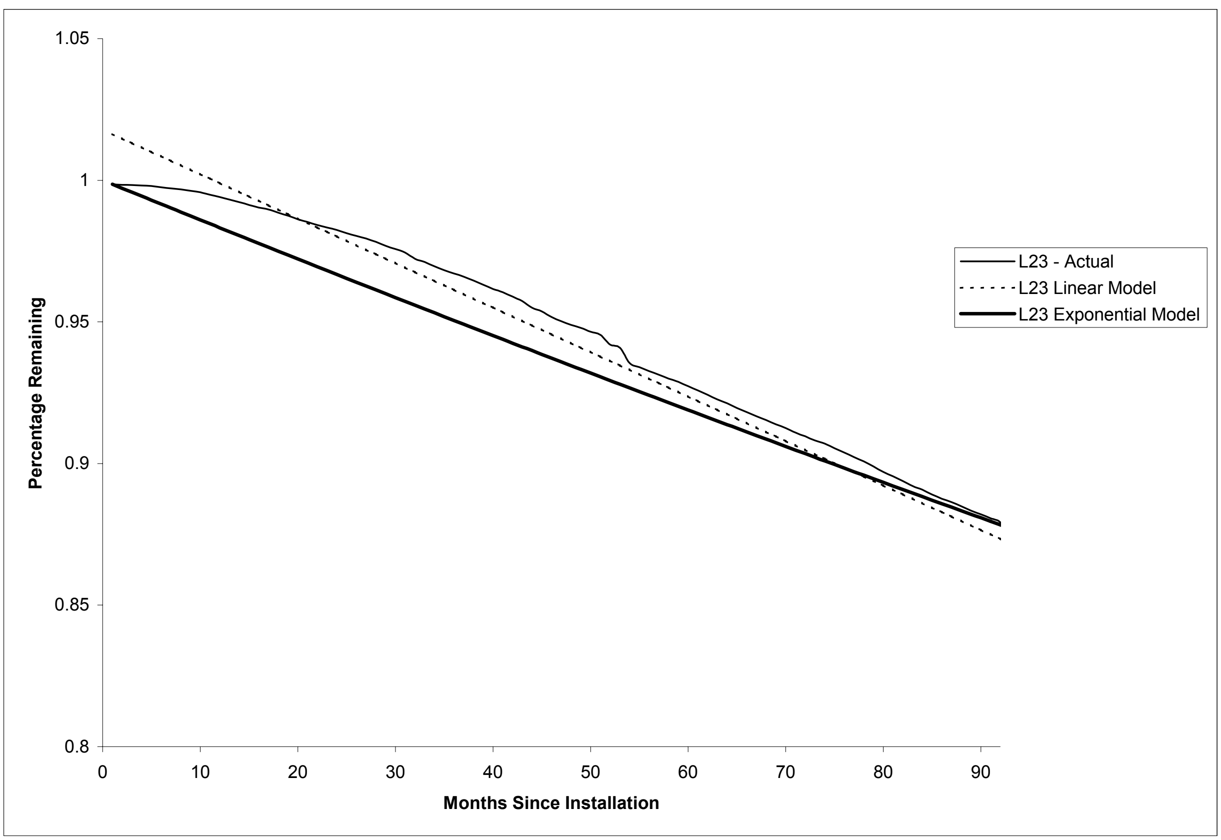
  EUL = (0.5 – intercept)/slope

- The second trend line was assumed to follow the exponential distribution, which is one of the most common distributions used in survival analysis. The trend line was also used with linear regression by making a transformation on the percentage of equipment operable and in place. The natural log of the percentage of equipment operable and in place was used as the dependent variable, and the month as the independent variable. Although the exponential distribution is appropriate for many survival functions, we have doubts about the applicability of the exponential distribution to this data due to the very small hazard rate. Because the exponential distribution asymptotically approaches zero, and the fact that the initially low hazard rates will remain constant, this distribution produces some very large EUL estimates. For an exponential survival function, the EUL (median life) is calculated as:

EUL = ln(2)/slope

Exhibit 3-6 provides an example for the L23 (T8 lamp replacing T12) measure, comparing the linear and exponential survival functions with the empirical function developed above, for the first eight years of the measure's life. This exhibit illustrates how the two trend lines compare to the empirical function during the earlier parts of the measure's life.

Exhibit 3-6
Comparison of Empirical Survival Function and Linear Trendline
L23 T8 Measure



The resulting EULs based on the linear and exponential survival function developed are presented in Section 4.

It is important to note that the exponential distribution has some important assumptions that should be addressed. Most importantly, the exponential distribution assumes a constant hazard rate. Although this distribution works well to explain certain data, this assumption is not believed to be valid for many technologies. As we will discuss in more detail in Section 4, this approach is not recommended for the final study results. In addition to the concern of the exponential distribution having properties that are not in line with our expectations, developing a trend line on empirical data in this manner is not optimal. The empirical data is interval and right hand censored, meaning that for some failures/removals, the time of the event is unknown; and it is also unknown when currently operating equipment may fail. This trendline approach does not statistically correct for censored data in the way that classical survival analysis approaches do, as discussed in the following section.

3.6 CLASSICAL SURVIVAL ANALYSIS

This step in our approach is founded on applying classical survival analysis techniques to the retention data in order to develop a survival function. Using the SAS System and the SAS companion guide, "Survival Analysis Using the SAS System," we have modeled the survival function assuming five of the most common survival distributions: exponential, logistic, lognormal, Weibull and gamma. In each case, we have plotted the resulting distribution and visually compared it to the empirical functions developed above. Furthermore, we have used the resulting survival function to estimate the EUL.

Some of the same issues we faced when developing the empirical survival function need to be addressed here as well. The problem of right-hand censoring is not an issue for SAS. The LIFEREG procedure, which we used for all of our modeling in this step, is capable of handling right-hand censored data.

SAS is also capable of handling left-hand censored data. In fact, our retention data is actually not left-hand censored, but interval censored. The true definition of left-hand censoring is that we know that an event occurred earlier than some time t, but we don't know exactly when. Interval censoring occurs when the time of failure occurrence is known to be somewhere between two times, but we don't know exactly when. Left censoring can be seen as a special case of interval censoring.

Although the LIFEREG procedure is capable of handling both left and interval censoring, interval censored data is more predictive than left hand censoring. Another commonly used survival analysis procedure in SAS in PHREG. Unfortunately, this procedure cannot handle either left or interval censored data. Therefore, we only conducted our analysis using the LIFEREG procedure.

Exhibit 3-7 provides an example for the L23 T8 measure, comparing the empirical survival function over the first 8 years of the measure's life, to the estimated survival functions based on the exponential, logistic, lognormal and Weibull distributions, using the LIFEREG procedure.

Exhibit 3-7
Comparison of Survival Functions
Exponential, Logistic, Lognormal, and Weibull versus Empirical Function
L23 T8 Measure

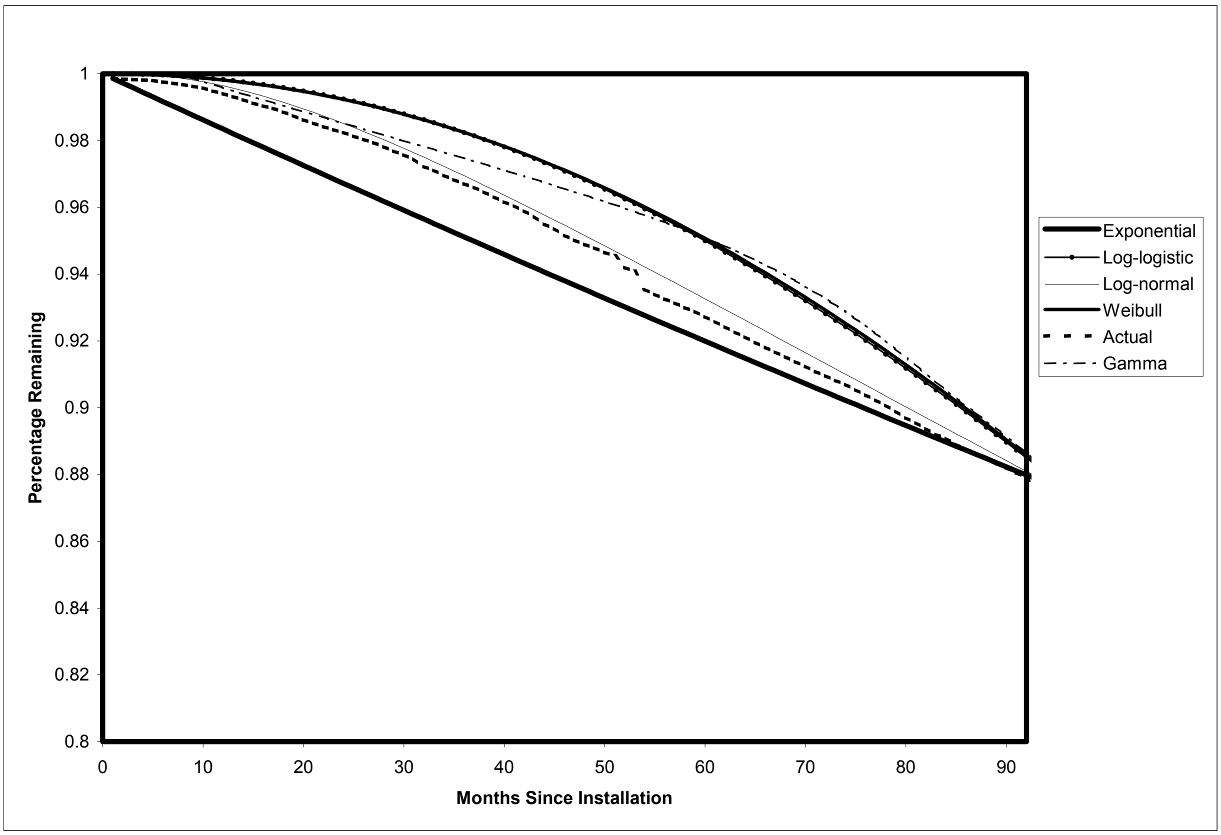
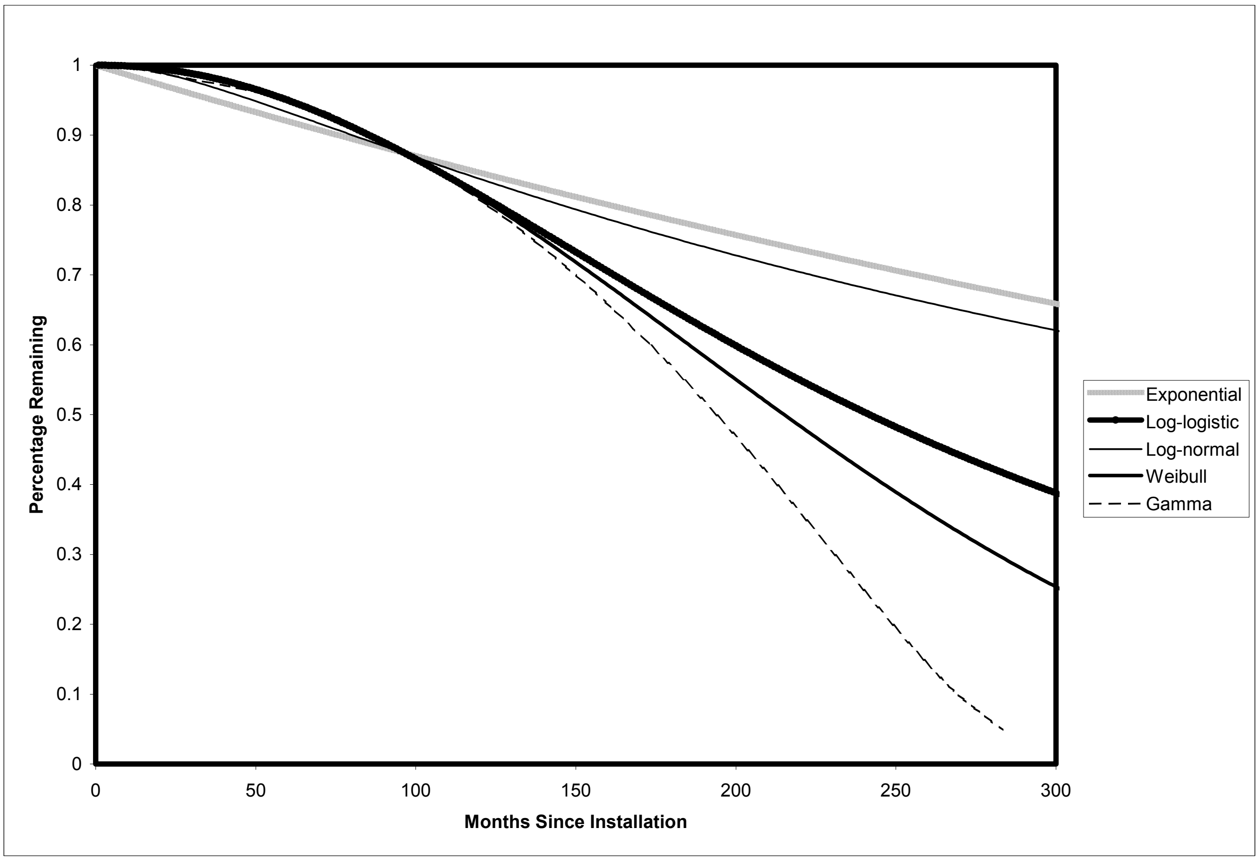


Exhibit 3-8 provides forecasts generated by these four survival functions over the first 300 months of the measures life for the L23 T8 measure.

Exhibit 3-8
Exponential, Logistic, Lognormal, and Weibull Survival Functions
Based on LIFEREG Procedure
L23 T8 Measure



Section 4 summarizes all of the results of the LIFEREG models.

It should be noted that the standard errors developed by the LIFEREG model, that were directly output by SAS were adjusted to account for intra-site correlation issues, because the failure and removal rates associated with measures installed at the same site are correlated. For example, when a removal occurs, it is likely that many measures are removed at once. To a lesser extent, failures are correlated since they may all come from the same manufacturing lot, they are all likely to be installed under the same circumstances, and they are also used in a similar manner. Attachment 1, Protocol Table 7B, discusses the development of standard errors in more detail.

3.7 COMPETING RISKS MODELS

The final analysis step, as described in Section 3.2 above, was to develop competing risks models to account for multiple events influencing the survival distribution. The first task in developing competing risks models was to calculate hazard functions for all events individually. The hazard rate at each time step is simply the derivative of the survival function, or the number of events occurring over that time step divided by the remaining population at that time.

The next task is to create the competing risks model. This is accomplished by combining hazard rates from both failures and removals into one joint probability function.

Three different sets of output were generated from this model. The first output contains the best-fitting distribution for each event based on the log-likelihood estimate, which is a parameter output by SAS used to judge how well the model fits the actual data. The second output provides the minimum EUL estimate, and the third output provides the maximum EUL estimate. A summary of the different distributions that were chosen for each of the models is presented in Exhibit 3-9. The L19 delamping measure only experienced one event type during this study (removals), excluding it from the competing risks models. As a result the competing risks analysis was performed only on the L23 T8, L81 HID, and S160 CAC measures.

Exhibit 3-9
Comparison of Distributions used in the Competing Risks Model

		Distribution	
Measure	**Method**	**Failures**	**Removals**
L23	Best Fit	Weibull	Log-Normal
	Min EUL	Gamma	Exponential
	Max EUL	Exponential	Log-Normal
L81	Best Fit	Log Normal	Weibull
	Min EUL	Gamma	Weibull
	Max EUL	Exponential	Exponential
S160	Best Fit	Weibull	Log-normal
	Min EUL	Gamma	Gamma
	Max EUL	Exponential	Exponential

The resulting survival functions for the L23 T8 measure are provided in Exhibit 3-10. For the best-fitting model, the Weibull distribution was selected for failures and the Log-Normal distribution was selected for removals.

Exhibit 3-10
Resulting Survival Functions from the Competing Risks Model
L23 T8 Measure

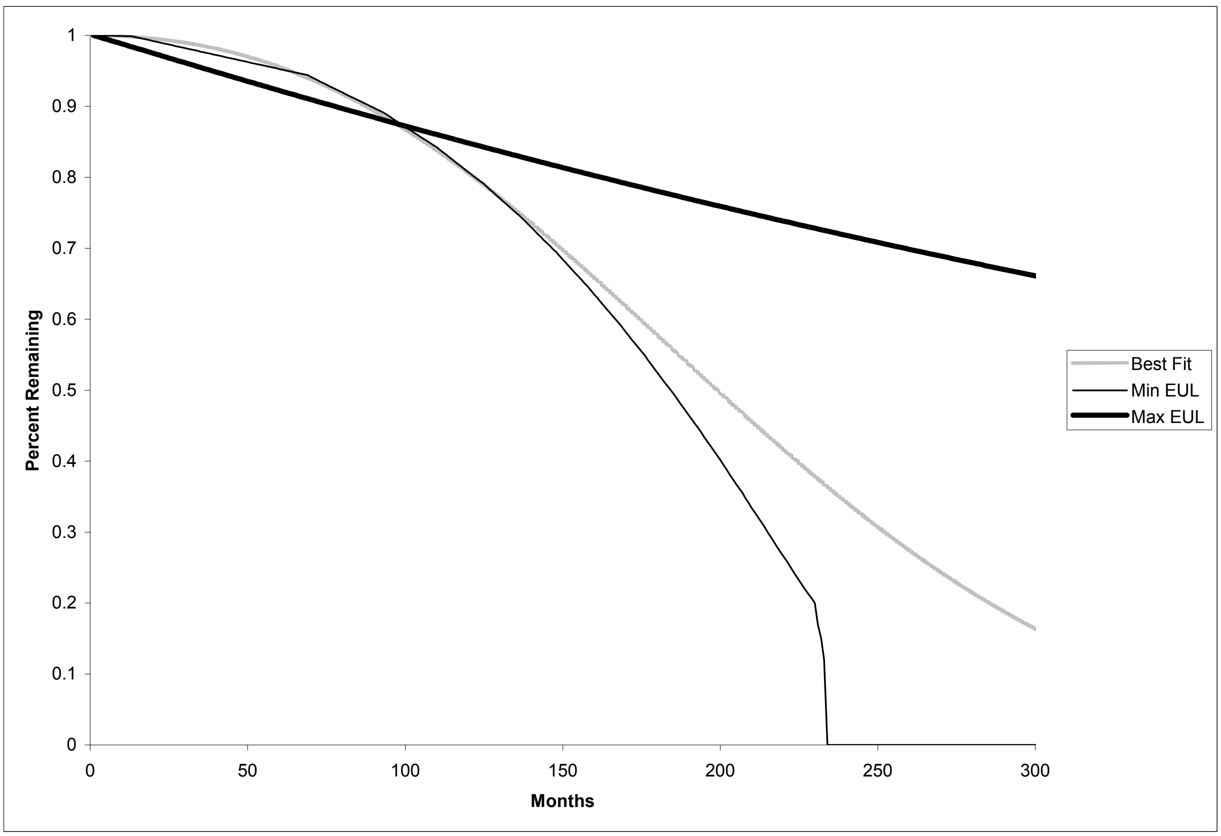


Exhibit 3-11 presents the results from the competing risks models in tabular format for the L23 T8 measure. For each case, the competing risks model EUL prediction is given along with its associated standard error. The properties for the event distributions (from the LIFEREG procedure in SAS) used to construct each competing risks model are also provided.

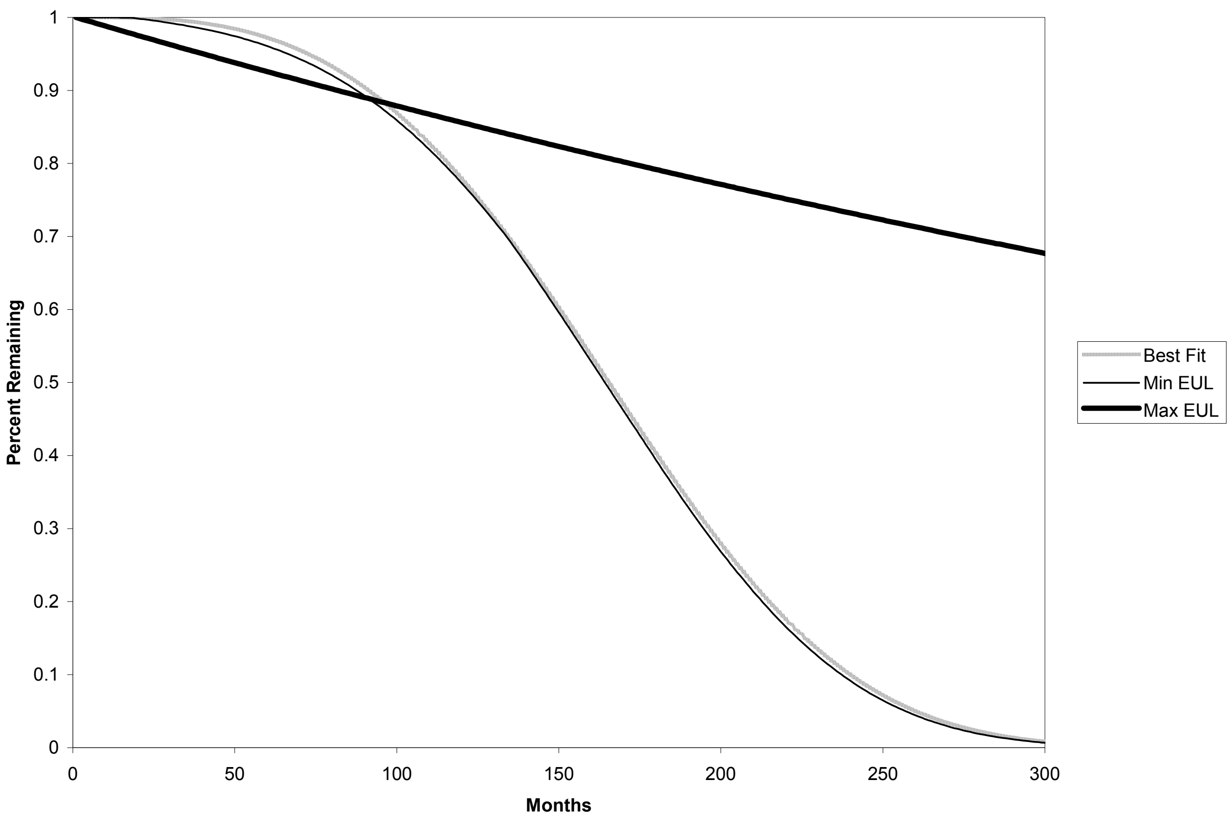
Exhibit 3-11
Results from Competing Risks Models
L23 T8 Measure

					Variable		Resulting
Measure	**Method**		**Model**		**Intercept**	**Scale**	**EUL**
L23	Best Fit	Combined		Parameter Estimate	-	-	**16.6**
				Standard Error	-	-	4.1
		Failures	Weibull	Parameter Estimate	5.46	0.42	**16.8**
				Standard Error	0.02	0.01	3.2
		Removals	Log-Normal	Parameter Estimate	9.82	2.31	**1538.3**
				Standard Error	0.26	0.11	4316.9
L23	Min EUL	Combined		Parameter Estimate	-	-	**15.3**
				Standard Error	-	-	1.5
		Failures	Gamma	Parameter Estimate	5.42	0.18	**15.3**
				Standard Error	0.00	0.00	0.8
		Removals	Exponential	Parameter Estimate	9.04	1.00	**485.0**
				Standard Error	0.04	0.00	202.0
L23	Max EUL	Combined		Parameter Estimate	-	-	**41.9**
				Standard Error	-	-	11.6
		Failures	Exponential	Parameter Estimate	6.68	1.00	**46.0**
				Standard Error	0.01	0.00	6.1
		Removals	Log-Normal	Parameter Estimate	9.82	2.31	**1538.3**
				Standard Error	0.26	0.11	4316.9

As the exhibit shows, there is a wide variation in the EUL from the minimum to the maximum. The actual range is 15.3 years for the minimum EUL and 41.9 years for the maximum EUL, with the best fit being very close to the minimum EUL with an EUL of 16.6 years.

Exhibit 3-12 provides the competing risks results for the L81 HID measures. For the best-fitting model, the Log-Normal distribution was selected for failures and the Weibull distribution was selected for removals.

Exhibit 3-12
Resulting Survival Functions from the Competing Risks Model L81 HID Measure



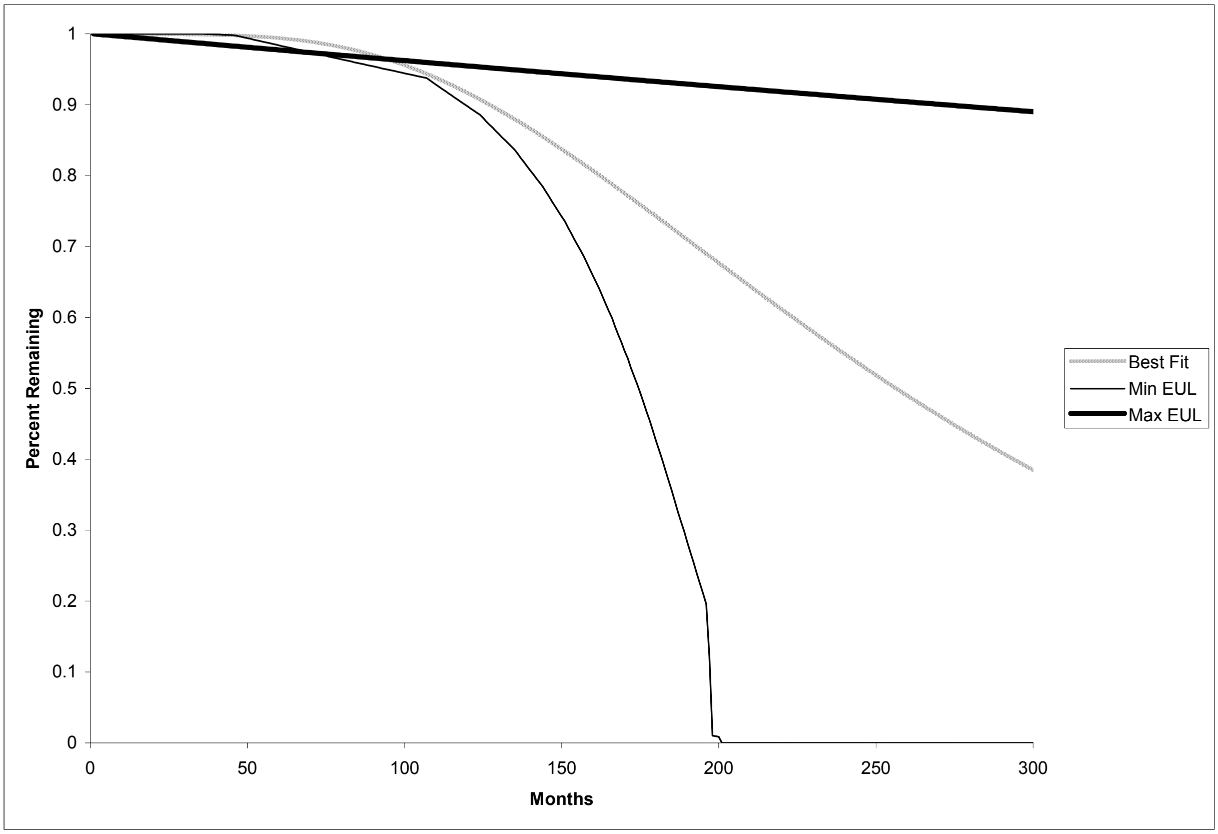
The detailed results from the competing risks models for the L81 HID measure are presented in Exhibit 3-13. Again, the competing risks model EUL prediction is provided along with the underlying assumptions.

Exhibit 3-13
Results from Competing Risks Models
L81 HID Measure

					Variable		Resulting
Measure	**Method**	**Model**			**Intercept**	**Scale**	**EUL**
L81	Best Fit	Combined		Parameter Estimate	-	-	**13.8**
				Standard Error	-	-	7.4
		Failures	Log Normal	Parameter Estimate	6.63	1.05	**63.4**
				Standard Error	0.27	0.13	61.9
		Removals	Weibull	Parameter Estimate	5.25	0.30	**14.3**
				Standard Error	0.04	0.02	2.0
L81	Min EUL	Combined		Parameter Estimate	-	-	**13.7**
				Standard Error	-	-	5.7
		Failures	Gamma	Parameter Estimate	6.02	0.28	**29.1**
				Standard Error	0.06	0.00	6.1
		Removals	Weibull	Parameter Estimate	5.25	0.30	**14.3**
				Standard Error	0.04	0.02	2.0
L81	Max EUL	Combined		Parameter Estimate	-	-	**44.3**
				Standard Error	-	-	29.2
		Failures	Exponential	Parameter Estimate	8.33	1.00	**240.0**
				Standard Error	0.14	0.00	124.7
		Removals	Exponential	Parameter Estimate	6.85	1.00	**54.3**
				Standard Error	0.06	0.00	13.5

Exhibit 3-14 provides the competing risks results for the S160 CAC measures. For the best-fitting model, the Weibull distribution was selected for failures and the Log-Normal distribution was selected for removals.

Exhibit 3-14
Resulting Survival Functions from the Competing Risks Model S160 CAC Measure



The detailed results from the competing risks models for the S160 CAC measure are presented in Exhibit 3-15. Again, the competing risks model EUL prediction is provided along with the underlying assumptions.

Exhibit 3-15
Results from Competing Risks Models
S160 CAC Measure

Measure	Method	Model			Variable Intercept	Variable Scale	Resulting EUL
S160	Best Fit	Combined		Parameter Estimate	-	-	**21.3**
				Standard Error	-	-	4.9
		Failures	Weibull	Parameter Estimate	7.24	0.53	**95.5**
				Standard Error	0.53	0.10	142.9
		Removals	Log-normal	Parameter Estimate	5.58	0.55	**22.0**
				Standard Error	0.07	0.04	4.8
S160	Min EUL	Combined		Parameter Estimate	-	-	**14.5**
				Standard Error	-	-	3.0
		Failures	Gamma	Parameter Estimate	7.11	0.28	**81.2**
				Standard Error	0.09	0.00	22.9
		Removals	Gamma	Parameter Estimate	5.25	0.10	**14.5**
				Standard Error	0.07	0.23	113.6
S160	Max EUL	Combined		Parameter Estimate	-	-	**148.6**
				Standard Error	-	-	32.4
		Failures	Exponential	Parameter Estimate	9.65	1.00	**893.7**
				Standard Error	0.18	0.00	477.2
		Removals	Exponential	Parameter Estimate	8.03	1.00	**178.2**
				Standard Error	0.08	0.00	42.5

Section 4 provides the recommended results by studied measure, and presents all of the results developed from the analysis steps discussed in this section.

4. RESULTS

This section presents the final results of the 1996 and 1997 CEEI Retention Study. As discussed in detail in Section 3, the overall approach consists of five analysis steps that were used to estimate each of the studied measures' EULs:

1. ***Compile summary statistics*** on the raw retention data.
2. ***Visually inspect*** the retention data.
3. ***Develop a trend line*** from the survival plots.
4. ***Develop a survival function*** using classical survival techniques.
5. ***Develop competing risks models*** that incorporate different distributions for failures and removals.

4.1 COMPILE SUMMARY STATISTICS

Exhibit 4-1 presents the percentage of measures that were found to have failed or been removed over the study period. As discussed in Section 3 an EUL was estimated was based on this percentage, assuming a constant failure rate over the life of the measure.

Exhibit 4-1
Summary Statistics on Raw Retention Data

End Use	Technology	Measure	Percent Failed, Removed, Replaced	Annualized Failure, Removal, Replacement Rate^	Mean Life*	Median Life*	Ex Ante EUL
Lighting	Optical Reflectors w/ Fluor. Delamp	L19	2.6%	0.3%	340	236	16
	T8 Lamps and Electronic Ballasts	L23	14.6%	1.6%	62	43	16
	High Intensity Discharge (251-400)	L81	16.4%	1.8%	55	38	16
HVAC	Central Air Conditioning	S160	4.0%	0.4%	226	157	15

^ Includes only 9th year survey data and assumes failures and removals occur over a nine year period.
* Assuming a constant failure rate over time.

4.2 VISUAL INSPECTION

Using the raw retention data, we developed empirical distributions of the survival function for each of the studied measures. As discussed in Section 3, these empirical functions were used primarily as the basis for developing EULs based on linear regression. These EULs are presented in Section 4.3 below.

4.3 DEVELOP A TREND LINE

Using the empirical functions developed above, a trend line was estimated using standard linear regression techniques. We modeled the trend as a linear and an exponential function (by taking the log of the percentage operable). In each case, we plotted the resulting trend line and visually compared it to the empirical survival function developed above.

The results of the trendline regressions are provided in Exhibit 4-2 for the three Lighting measures and HVAC measure. Also provided in Exhibit 4-2 is the estimated EUL for each measure. Clearly, the results of the linear and exponential trendline estimate indicate that the ex post EUL estimates are significantly larger than the ex ante estimates (which are 16 years for all lighting measure and 15 years for the HVAC measure). The results for the measures would all easily reject the ex ante estimate at the 80 percent confidence level.

It is important to note that the exponential distribution has some important assumptions that should be addressed. Most importantly, the exponential distribution assumes a constant hazard rate. Although this distribution works well to explain certain data, this assumption is not believed to be valid for many technologies. In addition, developing a trend line on empirical data in this manner is not optimal. The empirical data is interval and right hand censored, meaning that for some failures/removals, the time of the event is unknown; and it is also unknown when currently operating equipment may fail. This trendline approach does not statistically correct for censored data in the way that classical survival analysis approaches do, as discussed in the following section.

Exhibit 4-2
Regression Results of Linear and Exponential Trendlines
and Resulting Ex Post EUL Estimates

Measure	Measure Description	Intercept	t-Statistic	Slope	t-Statistic	EUL
	Linear Distribution					
L19	Optical Reflectors w/ Fluor. Delamp	1.01	1326	-0.0004	-30	120
L23	T8 Lamps and Electronic Ballasts	1.02	445	-0.0016	-44	27
L81	High Intensity Discharge (251-400)	1.02	383	-0.0012	-28	37
S160	HID Combined	1.01	538	-0.0003	-12	123
	Exponential Distribution					
L19	Optical Reflectors w/ Fluor. Delamp	-	-	0.0003	34	216
L23	T8 Lamps and Electronic Ballasts	-	-	0.0014	54	41
L81	High Intensity Discharge (251-400)	-	-	0.0010	34	60
S160	HID Combined	-	-	0.0002	14	252

4.4 DEVELOP A SURVIVAL FUNCTION

Using classical survival techniques, we modeled the survival function assuming five of the most common survival distributions: exponential, logistic, lognormal, Weibull and gamma. In each case, we plotted the resulting distribution and visually compared it to the survival plot developed above. Furthermore, we used the resulting survival function to estimate the EUL.

Exhibit 4-3 provides the results of the classical survival analysis. Shown are the model results for each measure, and for each type of distribution modeled. Furthermore, the resulting EUL estimates are provided. The gamma distribution for the L81 measure did not converge and thus was excluded from the analysis.

Exhibit 4-3
Comparison of Survival Model Results
Exponential, Logistic, Lognormal, Weibull and Gamma Models
L23 T8, L19 Delamping, L81 HID, S160 CAC Measures

Measure	Model		Variable			Resulting
			Intercept	Scale	Shape	EUL
L19	Exponential	Parameter Estimate	8.31	1.00	-	**234.6**
		Standard Error	0.04	0.00	-	74.8
	Logistic	Parameter Estimate	6.90	0.62	-	**82.9**
		Standard Error	0.09	0.02	-	63.4
	Log-Normal	Parameter Estimate	7.81	1.63	-	**205.2**
		Standard Error	0.12	0.06	-	207.3
	Weibull	Parameter Estimate	6.93	0.63	-	**67.6**
		Standard Error	0.09	0.02	-	47.4
	Gamma	Estimate	6.80	0.32	2.00	**56.6**
		Standard Error	0.02	0.00	0.00	11.3
L23	Exponential	Parameter Estimate	6.58	1.00	-	**41.5**
		Standard Error	0.01	0.00	-	5.2
	Logistic	Parameter Estimate	5.49	0.47	-	**20.1**
		Standard Error	0.02	0.01	-	4.3
	Log-Normal	Parameter Estimate	6.12	1.35	-	**37.9**
		Standard Error	0.03	0.02	-	12.0
	Weibull	Parameter Estimate	5.55	0.49	-	**17.9**
		Standard Error	0.02	0.01	-	3.3
	Gamma	Estimate	0.49	0.00	2.43	16.2
		Standard Error	0.01	0.00	0.00	0.9
L81	Exponential	Parameter Estimate	6.63	1.00	-	**43.7**
		Standard Error	0.06	0.00	-	9.8
	Logistic	Parameter Estimate	5.17	0.30	-	**14.7**
		Standard Error	0.04	0.02	-	2.0
	Log-Normal	Parameter Estimate	5.32	0.66	-	**17.0**
		Standard Error	0.05	0.03	-	2.9
	Weibull	Parameter Estimate	5.21	0.31	-	**13.7**
		Standard Error	0.04	0.02	-	1.7
	Gamma	Estimate	-	-	-	**-**
		Standard Error	-	-	-	-
S160	Exponential	Parameter Estimate	7.85	1.00	-	**148.1**
		Standard Error	0.07	0.00	-	29.8
	Logistic	Parameter Estimate	5.37	0.25	-	**18.0**
		Standard Error	0.06	0.02	-	2.9
	Log-Normal	Parameter Estimate	5.78	0.69	-	**27.1**
		Standard Error	0.08	0.04	-	6.1
	Weibull	Parameter Estimate	5.39	0.25	-	**16.6**
		Standard Error	0.06	0.02	-	2.4
	Gamma	Estimate	5.34	0.12	2.22	**15.5**
		Standard Error	0.02	0.00	0.00	0.8

4.5 DEVELOP COMPETING RISKS MODELS

Competing risks models were developed to account for different events having different underlying distributions. Models were only developed for the L23 T8 measure, the L81 HID measures, and the S160 CAC measures since the L19 delamping measure observed only one failure type. Results from the best-fitting, minimum EUL and maximum EUL competing risks models are provided in Exhibit 4-4.

Exhibit 4-4
Competing Risks Model Results
L23 T8, L81 HID and S160 CAC Measures

Measure	Method	EUL	Standard Error
L23	Best Fit	**16.6**	4.1
	Min EUL	**15.3**	1.5
	Max EUL	**41.9**	11.6
L81	Best Fit	**13.8**	7.4
	Min EUL	**13.7**	5.7
	Max EUL	**44.3**	29.2
S160	Best Fit	**21.3**	4.9
	Min EUL	**14.5**	3.0
	Max EUL	**148.6**	32.4

Both the L23 and L81 measures have ex ante EULs of 16 years, while the S160 measures have an ex ante EUL of 15 years. The results presented in Exhibit 4-4 illustrate that the EULs resulting from the best fit competing risks scenario for all three measures are close to the ex ante and have standard errors that indicate that the EUL is not statistically significantly different from ex ante EUL.

4.6 FINAL RESULTS

Exhibits 4-5 and 4-6 summarize the estimated EULs for each approach and corresponding model for the studied Lighting and HVAC measures, respectively. The median EULs are provided, along with the upper and lower confidence bounds, based on the 80 percent confidence interval.

Exhibit 4-5
Comparison of Survival Model Results
Summary Statistics, Trendlines, LIFEREG, and Competing Risks Models
L23 T8, L19 Delamping, L81 HID, S160 CAC Measures[5]

			Lighting Measures			HVAC Measure
Approach	**Model**		**L19**	**L23**	**L81**	**S160**
		Ex Ante EUL	**16**	**16**	**16**	**15**
Summary Statistics	Exponential	Median EUL	269	53	60	190
		Upper Bound	-	-	-	-
		Lower Bound	-	-	-	-
Trendlines	Linear	Median EUL	120	27	37	123
		Upper Bound	126	28	38	137
		Lower Bound	115	27	35	110
	Exponential	Median EUL	216	41	60	252
		Upper Bound	224	42	63	229
		Lower Bound	208	40	58	275
LIFEREG	Exponential	Median EUL	235	42	44	148
		Upper Bound	330	48	56	186
		Lower Bound	139	35	31	110
	Logistic	Median EUL	83	20	15	18
		Upper Bound	164	26	17	22
		Lower Bound	2	15	12	14
	Log-Normal	Median EUL	205	38	17	27
		Upper Bound	471	53	21	35
		Lower Bound	-61	23	13	19
	Weibull	Median EUL	68	18	14	17
		Upper Bound	128	22	16	20
		Lower Bound	7	14	12	13
	Gamma	Median EUL	57	16	-	15
		Upper Bound	71	17	-	16
		Lower Bound	42	15	-	14
Competing Risks	Best Fit	Median EUL	-	17	14	21
		Upper Bound	-	21	21	26
		Lower Bound	-	13	6	16
	Min EUL	Median EUL	-	15	14	15
		Upper Bound	-	17	19	17
		Lower Bound	-	14	8	12
	Max EUL	Median EUL	-	42	44	149
		Upper Bound	-	54	74	181
		Lower Bound	-	30	15	116

[5] Although negative EUL values are a physical impossibility, the values are presented so that the reader may understand the magnitude of the standard error.

Approaches 1 and 2 discussed in Section 3 (summary statistics and trendlines) were implemented for all Lighting and HVAC measures. Approach 3 (survival modeling using LIFEREG) was also implemented for all measures. And finally approach 4 (competing risks modeling) was only calculated for the L23 T8, L81 HID, and S160 CAC measures since the remaining L19 delamping measure did not have competing event types (failures versus removals). The results based on the summary statistics are not recommended, as they based solely on the overall failure/removal rate observed during the study period. In addition, the results based on the trendlines are not recommended, as they are based on a number of assumptions, as discussed earlier.

The results from LIFEREG are recommended for measures L19 delamping since these measures had only one event type observed during the study period. The recommended LIFEREG log-normal distribution for the L19 delamping measure was chosen based upon the largest log-likelihood estimate. It is important to note, however, that the study results for the L19 measure were very large and not statistically significant. This is due to a very small number of failures having occurred during the study period.

The recommended results for the L23 T8, L81 HID and S160 CAC measures are based on the competing risks models built from classical survival analysis using the LIFEREG procedure. Of the three models constructed for each measure, the best fit model is the model of choice. Because the best fit model is based upon the fit of the distribution to all of the actual data, we believe that the competing risks model produces the most reliable results. The minimum and maximum EUL methods are not recommended because they seek to minimize/maximize the EUL at the expense of goodness of fit.

Exhibit 4-6presents the recommended ex post estimates of the EUL. Because the LIFEREG and competing risks models did not provide results that were statistically significantly different from the ex ante results, measured at the 80 percent confidence interval, all of the ex post EULs are based on the ex ante estimates. The ex post estimates are compared to the favored study results and the corresponding upper and lower 80 percent confidence interval, when available. Finally, the program realization rates are provided, which are the ratios of the ex ante and ex post estimates. For all measures, the realization rate is one.

Exhibit 4-6
Final Ex Post EUL Estimates

				Study Results				Realization
End Use	**Technology**	**Measure**	**Ex Ante**	**Upper**	**Median**	**Lower**	**Ex Post**	**Rate**
Lighting	Optical Reflectors w/ Fluor. Delamp	L19	16	471	205	-61	16	100%
	T8 Lamps and Electronic Ballasts	L23	16	22	17	11	16	100%
	High Intensity Discharge (251-400)	L81	16	23	14	4	16	100%
HVAC	Central Air Conditioning	S160	15	28	21	15	15	100%

APPENDIX 1

PROTOCOL TABLES 6B AND 7B

FOURTH YEAR RETENTION STUDY FOR THE
1996 & 1997 COMMERCIAL EEI PROGRAM
LIGHTING AND HVAC TECHNOLOGIES
PG&E STUDY ID #S 333AR2 & 333BR2

This Attachment presents Tables 6B and 7B for the above referenced study as required under the "Protocols and Procedures for the Verification of Cost, Benefits, and Shareholder Earnings from Demand Side Management Programs" (the Protocols), as adopted by the California Public Utility Commission (CPUC) Decision 93-05-063, Revised March 1998 Pursuant to Decisions 94-05-063, 94-10-059, 94-12-021, 95-12-054, 96-12-079, 98-03-063, and 99-06-052.

The Table 7B synopsis of analytical methods applied follows Protocol Table 6B.

Protocol Table 6.B
Results of Retention Study
PG&E 1996 & 1997 Commercial Energy Efficiency Incentives Program
Study ID #s 333aR2 & 333bR2

Item 1			Item 2		Item 3	Item 4	Item 5	Item 6		Item 7	Item 8	Item 9
PG&E Measure Code	Studied Measure Description	End Use	Ex Ante EUL	Source of Ex Ante EUL	Ex post EUL from Study	Ex Post EUL to be used in Claim	Ex Post EUL Standard Error	80% Conf. Interval Lower Bound	80% Conf. Interval Upper Bound	p-Value for Ex Post EUL	EUL Realizat'n Rate (ex post/ex ante)	"Like" Measures Associated with Studied Measure (by measure code)
L19	FIXTURE: MODIFICATION/REPLACE LAMPS & BLST, 4 FT FIXTURE	Lighting	16	Advice Filing & MDSS	205	16	207.3	-61	471	<0.0001	100%	L17, L18, L20, L76 - L77
L23	FIXTURE: MODIFICATION/LAMP REMOVAL, 4 FT LAMP REMOVED	Lighting	16	Advice Filing & MDSS	17	16	4.1	11	22	<0.0001	100%	L9 - L12, L21, L22, L24, L69 - L75, L117 - L124, L160
L81	HID FIXTURE: INTERIOR, 251-400 WATTS LAMP	Lighting	16	Advice Filing & MDSS	14	16	7.4	4	23	<0.0001	100%	L25, L78 - L80, L26, L27, L37
S160	A/C: CENTRAL, < 65 KBTU/HR, AIR-COOLED, SPLIT-SYS/SNGL PKG	HVAC	15	Advice Filing & MDSS	21	15	4.9	15	28	<0.0001	100%	S1, S2, S4, S160 - S163

PROTOCOL TABLE 7B

1996 & 1997 COMMERCIAL EEI PROGRAM
NINTH YEAR RETENTION STUDY
PG&E STUDY ID #333AR2 & 333BR2

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

1. OVERVIEW INFORMATION

A. Study Title and Study ID Number

Study Title: Ninth Year Retention Study of PG&E's 1996 & 1997 Commercial EEI Program.

Study ID Numbers: 333aR2 & 333bR2

B. Program, Program Year and Program Description

Program: PG&E Commercial EEI Program.

Program Year: Rebates Received in the 1996 & 1997 Calendar Year.

Program Description:

The Commercial Energy Efficiency Incentives Program for lighting and HVAC technologies offered by PG&E has three components: the Retrofit Express (RE) Program, the Retrofit Efficiency Options (REO) Program and the Customized Incentives (CI) Program.

The RE Program

The RE program offered fixed rebates to customers who installed specific electric energy-efficient equipment. The program covered the most common energy saving measures and spans lighting, air conditioning, refrigeration, motors, and food service. Customers were required to submit proof of purchase with these applications in order to receive rebates. The program was marketed to small- and medium-sized commercial, industrial, and agricultural customers. The maximum rebate amount, including all measure types, was $300,000 per account. No minimum amount was required to qualify for a rebate.

The REO Program

The REO program targeted commercial, industrial, agricultural, and multi-family market segments most likely to benefit from these selected measures. Customers were required to submit calculations for the projected first-year energy savings along with their application prior to installation of the high efficiency equipment. PG&E representatives worked with customers to identify cost-effective improvements, with special emphasis on operational and maintenance measures at the customers' facilities. Marketing efforts were coordinated amongst PG&E's divisions, emphasizing local planning areas with high marginal electric costs to maximum the program's benefits.

The Customized Incentives Program

The Customized Incentives program offered financial incentives to CIA customers who undertook large or complex projects that save gas or electricity. Customers may also participate under the APOS program. These customers were required to submit calculations for projected first-year energy impacts with their applications prior to installation of the project. The maximum incentive amount for the Customized Incentives program was $500,000 per account, and the minimum qualifying incentive was $2,500 per project. The total incentive payment for kW, kWh, and therm savings was limited to 50 percent of direct project cost for retrofit of existing systems. Since the program also applied to expansion projects, the new systems incentive was limited to 100 percent of the incremental cost to make new processes or added systems energy efficient. Customers were paid 4¢ per kWh and 20¢ per therm for first-year annual energy impacts. A $200 per peak kW incentive for peak demand impacts required that savings be achieved during the hours PG&E experiences high power demand.

Due to the significant documentation and analysis involved in Customized Incentives program measures, however, rebates for a number of 1994 and 1995 measures were delayed for payment until 1996 and 1997. This evaluation covers those measures where rebates were paid in 1996 and 1997.

As a result of program design, the measures installed were similar to or the same as those for the RE program, but were installed in larger and more complex projects.

C. End Uses and/or Measures Covered

End Use Covered: Indoor Lighting and HVAC Technologies.

Measures Covered: For the list of measures covered in this evaluation, see *Exhibit 2-3*.

D. Methods and Models Used

Our overall approach consists of five analysis steps that were used to estimate each of the studied measures' EULs:

1. ***Compile summary statistics*** on the raw retention data. Upon review of the summary statistics, it became clear that such a small percentage of failures and removals had occurred, that it would be difficult to model the equipment's survival function.

2. ***Visually inspect*** the retention data, by simply calculating the cumulative percentage of equipment that had failed in a given month, and plotting the percentage over time. This step clearly illustrated that for each studied measure, there was not enough data over time to support an accurate estimate of the survival function.

3. ***Develop a trend line*** from the survival plots. Using the plots developed in (2) above, a trend line was estimated using standard linear regression techniques. We modeled the trend as a linear and an exponential function. In each case, we used the resulting trend line to estimate the EUL, which was statistically significantly larger than the ex ante estimate.

4. ***Develop a survival function*** using classical survival techniques. We modeled the survival function assuming five of the most common survival distributions: exponential, logistic, lognormal, Weibull and gamma. In each case, we used the resulting survival function to estimate the EUL. In nearly every case, the resulting EUL was either statistically significantly larger than the ex ante EUL, or was not statistically significantly different than the EUL.

5. ***Develop competing risks models*** that incorporate different distributions for failures, removals, and replacements. Using the LIFEREG procedure in SAS from step 4 above, separate output was generated for failures, removals, and replacements. Then, the best fitting distributions for each event were combined to form one combined survival function. This additional analysis step provided valuable results that have not been previously utilized in retention studies.

The details surrounding each of these steps is provided in *Section 3.*

E. Analysis Sample Size

Exhibit 3-2 provides the final sample disposition used in the study analysis.

2. DATABASE MANAGEMENT

A. Key Data Elements and Sources

The MDSS, the original retention panels and the follow-up survey data were the only data sources used for this analysis.

B. Data Attrition Process

All data points that had follow-up survey data were utilized in the analysis. As discussed in *Section 3*, the SAS analysis procedures we implemented were able to handle interval censored data, in the cases when failure/removal dates were not obtainable.

C. Internal Data Quality Procedures

The Evaluation contractor of this project, Quantum Consulting Inc. (QC), has performed extensive data quality control on all retention and follow-up survey data. QC's data quality procedures are consistent with PG&E's internal database guidelines and the guidelines established in the Protocols.

Throughout every step of this project, numerous data quality assurance procedures were in place to ensure that all data used in analysis and all survey data collected was of the highest quality. On questionable responses follow-up phone calls or site visits were made.

D. Unused Data Elements

Without exception, all data collected specifically for the Evaluation were utilized in the analysis.

3. SAMPLING

A. Sampling Procedures and Protocols

Section 3.1 describes the sample procedures and protocols.

B. Survey Information

The data collection instrument is presented in the *Attachment 1. Exhibit 3-2* provides the final sample disposition, which contains the number of sites and units that were in the sample frame, and the number surveyed.

C. Statistical Descriptions

Statistics variables that were used in the survival models are also presented in *Section 3.*

4. DATA SCREENING AND ANALYSIS

A. Procedures for Treating Outliers and Missing Data

All data points that had follow-up survey data were utilized in the analysis. As discussed in *Section 3*, the SAS analysis procedures we implemented were able to handle interval censored data, in the cases when failure/removal dates were not obtainable.

B. Background Variables

Due to the nature of this analysis (survival analysis), background variables, such as interest rates, unemployment rates and other economic factors, were not considered to be a necessary component of the analysis.

C. Data Screen Process

Again, all data points that had follow-up survey data were utilized in the analysis.

D. Regression Statistics

The regression statistics for the models implemented are provided in *Section 3*.

E. Model Specification

The model specifications are presented in *Section 3*.

F. Measurement Errors

For the survival analysis, the main source of measurement errors is the survey data. Our approach has been to proactively stop the problem before it happens so that statistical corrections are kept to a minimum.

Measurement errors are a combination of random and non-random error components that plague all survey data. The non-random error frequently takes the form of systematic bias, which includes, but is not limited to, ill-formed or misleading questions and mis-coded study variables. In this project, we implemented several controls to reduce systematic bias in the data. These steps include: (1) thorough auditor/coder training; (2) instrument pretest; and (3) cross-validation between on-site audit data and telephone survey responses.

The random measurement error, such as data entry error, has no impact on estimating mean values because the errors are typically unbiased. For the measures that were modeled in the survival analysis, the impact of random unbiased measurement errors was accounted for as part of the overall standard variance in the parameter estimate.

G. Influential Data Points

No diagnostics were used to identify outliers.

H. Missing Data

As discussed in *Section 3*, the SAS analysis procedures we implemented were able to handle interval censored data, in the cases when failure/removal dates were missing. There were no other missing data points, other than failure/removal dates.

I. Precision

The SAS output provided the standard errors for the 50^{th} percentile (or median). Because the analysis was conducted on the unit of measure (e.g., a ballast) and not a site, the standard errors from SAS were grossly underestimated. SAS treats each observation in the dataset as independent. However, it is likely that there is significant correlation in the observations that are common to a single site (especially in the event that a removal occurs.) For example, when a removal occurs, it is likely that many measures are removed at once. To a lesser extent, failures are correlated since they may all come from the same manufacturing lot, they are all likely to be installed under the same circumstances, and they are also used in a similar manner.

If we believed that there was 100 percent correlation of failure/removal for all measures with a site, we could simply multiply the standard error calculated from SAS by the square root of the ratio of the number of units to sites. Therefore, if there were an average of 100 units installed per measure, we would multiply by 10.

We felt, however, that there were two components to our error: one caused by variation across sites, and another caused by variation across measures. The errors calculated by SAS correspond only to the error across measures.

To estimate the standard error associated with failures and removals, we first took the SAS output and backed out a standard deviation. This was achieved by multiplying the standard error from SAS by the square root of the sample size (in units.) We then assumed that this standard deviation was associated with the joint probability density function of failures and removals.

(1) $StdErr_{SAS} * \sqrt{N_{Units}} = StdDev_{Failures,Removals}$

Where,

$StdErr_{SAS}$ is the standard error around the median EUL projected with the SAS System;

$\sqrt{N_{Units}}$ is the square root of the number of sites that contributed to the regression model;

$StdDev_{Failures,Removals}$ is the standard deviation associated with the median EUL of failures and removals.

We then assumed that failures were independent of removals (Which is of course not true, since a high failure rate may cause a customer to decide to make removal. But we felt this was reasonable overall.) Therefore, the variance of removals and failures is equal to the variance of removals plus the variance of failures:

(2)
$$\begin{aligned} StdDev_{Failures,Removals}^{\;2} &= Var_{Failures,Removals} \\ &= Var_{Failures} + Var_{Removals} \end{aligned}$$

Where,

$StdDev_{Failures,Removals}^{\;2}$ is the square of the standard deviation associated with the median EUL of failures and removals;

$Var_{Failures,Removals}$ is the variance which is equivalent to the square of the standard deviation.

If we assume that failures are independent across units, and removals are independent across sites, then the standard error can be calculated as:

$$(3)\quad \begin{aligned} StdErr_{Failures,\mathrm{Re}movals} &= \sqrt{StdErr_{Failures}{}^2 + StdErr_{\mathrm{Re}movals}{}^2} \\ &= \sqrt{\frac{Var_{Failures}}{N_{Units}} + \frac{Var_{\mathrm{Re}movals}}{N_{Sites}}} \end{aligned}$$

Where,

$StdErr_{Failures,\mathrm{Re}movals}$ is the standard deviation associated with the median EUL of failures and removals;

N_{Units} is the number of units used for the regression models;

N_{Sites} is the total number of sites having those units.

Furthermore, if we assume that the underlying standard deviation of failures and removals are equivalent, then:

$$(4)\quad \begin{aligned} StdDev_{Failures,\mathrm{Re}movals}{}^2 &= Var_{Failures,\mathrm{Re}movals} \\ &= Var_{Failures} + Var_{\mathrm{Re}movals} \\ &= 2Var_{Failures,or\,\mathrm{Re}movals} \end{aligned}$$

So,

$$(5)\quad \begin{aligned} Var_{Failures,or\,\mathrm{Re}movals} &= 0.5*(StdDev_{Failures,\mathrm{Re}movals})^2 \\ &= 0.5*(StdErr_{SAS})^2 * N_{Units} \end{aligned}$$

Therefore, substituting equation (5) in equation (3), we get

$$(6)\quad \begin{aligned} StdErr_{Failures,\mathrm{Re}movals} &= \sqrt{\frac{0.5*(StdErr_{SAS})^2 * N_{Units}}{N_{Units}} + \frac{0.5*(StdErr_{SAS})^2 * N_{Units}}{N_{Sites}}} \\ &= StdErr_{SAS} * \sqrt{0.5 + 0.5*\frac{N_{Units}}{N_{Sites}}} \end{aligned}$$

It is interesting to note that if there was only one unit per site, the standard error would equal the standard error calculated in SAS. Our resulting standard error is somewhere between the standard error found in SAS, and the standard error from SAS multiplied by the square root of the ratio of the number of units to sites (the method discussed as the beginning of this section.)

Skinner and Kish[6] both offer a more theoretical approach to solving the problem of estimating a standard error when the data are not identical and independently distributed (IID). They define this problem as a design effect, which is the case when the sample is not a simple random sample that is IID, but rather is a cluster sample such as ours. In our case, each site contains a cluster of sample points.

Skinner developed a design effect factor, Deff, that can be used to adjust the standard error obtained from SAS to estimate the true standard error:

$$(7)\quad Deff = \frac{StdErr_{TRUE}^{\ 2}}{StdErr_{SAS}^{\ 2}}$$

Where,

$StdErr_{TRUE}$ is the actual standard error associated with the median EUL;

$StdErr_{SAS}$ is the standard error associated with the median EUL obtained from SAS;

Skinner estimated the design effect factor as:

$$(8)\quad Deff = 1 + (n-1) * \tau$$

Where,

n = the average number of sample points per cluster (or, in our case, per site)

$$= \frac{N_{Units}}{N_{Sites}}$$

τ = the intra-cluster correlation

[6] Skinner, C. J., "Analysis of Complex Surveys," John Wiley & Sons, 1989, pp. 23-46.
Kish, L., "Survey Sampling," John Wiley & Sons, 1965, pp. 162.

Skinner's design effect factor can be compare directly to the factor we developed in equation (6):

$$(9)\quad Deff\,(Eq.6) = 0.5 + 0.5 * (\frac{N_{Units}}{N_{Sites}}) = 1 + (n-1) * 0.5$$

Our method discussed above is identical to that developed by Skinner, with an intra-cluster correlation equal to 0.5. As discussed above, we believe that there are two types of events: removals and failures. Our assumption above was that removals are perfectly correlated and failures are totally uncorrelated. Therefore, an intra-cluster correlation of 0.5 is not unreasonable.

To calculate the intra-cluster correlation, it would require knowing the time of failure or removal for all units in our analysis. The intra-cluster correlation measures how correlated the failure/removal times are across all units within a site. Because our analysis is being conducted in such an early stage of the measures life, it is not possible to accurately estimate the correlation. However, given that (1) it is likely that removals are highly correlated, and failures are relatively uncorrelated; and (2) removals are expected to be as prevalent as failures over the life of the measure; then an intra-cluster correlation of 0.5 is a reasonable approximation.

Finally, relative precision estimated at the 80 percent confidence interval was calculated using the following equation:

$$RP = \frac{1.282 * StdErr}{EUL}$$

Where,

$StdErr$ = the standard error calculated using Equation 6, above.

APPENDIX 2

Telephone Script for 2005 Lighting Retention Study

Hello, this is <Auditor Name> calling from Quantum Consulting on behalf of Pacific Gas & Electric Company. May I speak with <Contact Name> OR the person in your organization who is responsible for decisions regarding construction, renovation, or operation of your physical facilities?

To get correct person, ask: Do you recall that there was a Lighting retrofit that occurred in <YEAR>, and that was subsidized by PG&E's program?

When correct person is on the phone:
We are not selling anything and this survey will only take a few minutes. We are assisting PG&E in evaluating their energy efficiency programs. We would like to ask you some questions regarding the success of the Lighting retrofit that took place at <Company> in <YEAR>. The goal of the study is to determine the lifetime of the lighting equipment installed through PG&E's rebate programs. PG&E conducts this study every few years, to track specific equipment over time. Are you the best person to talk to, for this study?

IF NEEDED: PG&E wants to better understand how long lighting fixtures typically last. Many of the energy efficient technologies installed through the rebate program are so new that there is still some uncertainty as to how long they last. PG&E may use this information to update their programs so that they better serve the needs of the customer.

Our records indicate that your facility is located at <ADDRESS> <CITY>. Is that correct?

If not willing to do survey over the phone or nobody can remember the retrofit AND if <Survey Cluster Nr. 1 or 3-6>:

With your permission, we would like to have one of our energy auditors drop by and verify the success of the HVAC retrofit that took place there in <YEAR>. It would require only a few minutes of your time. Would it be OK for one of our auditors to come on site?
If no: T&T.

If yes:
The way we like to schedule the appointments is to find out what weekday (or days) and times you would be available, and then for our auditors to call you to schedule the appointment. Let's start with the weekdays. In general, on what days would you be available to spend a few minutes with our auditor?

Around what time would it be best that the auditor arrive at the facility?

The auditor will have up to three specific locations for each HVAC measure installed. The goal is to determine how many of the noted items have failed, been removed, or been replaced in each area. Any repair orders or invoices that you have may facilitate the survey.

Fill out appointment sheet with the following info:
Weekdays Available
Hours Available
Company Name
Contact Name

Contact Phone
Address
City
Cross Street
Any directions that the auditor may need to get to the place

Confirm weekdays/times by reading back to customer. Remind customer that the auditor will call within two weeks to schedule the appointment.

If not in Cluster 1-6: T&T

If willing to do survey:

Our records indicate that your facility is located at <ADDRESS> <CITY>. Is that correct?

FOR EACH MEASURE AT SITE:

For HID Fixtures (measure code L81):
Our records indicate that in <YEAR> there were <retention quantity> high-intensity discharge (or HID) fixtures installed (at/on <location description>) at <site address>. Can you verify this information?

For Delamping (measure code L23):
Our records indicate that in <YEAR> some old fluorescent fixtures were replaced with <retention quantity> new 4-foot T8 fixtures with a reduced number of lamps (at/on <location description>) at <site address>. Can you verify this information?

For T8 fixtures (measure code L19):
Our records indicate that in <YEAR> 4-foot T8 fixtures with a total number of <retention quantity> lamps were installed (at/on <location description>) at <site address>. Can you verify this information?

For T8 also ask:
Focusing on the new T8 fixtures, can you tell me how many lamps are controlled by one ballast? [GET AN AVERAGE FOR ALL FIXTURES]
IF NEEDED: A ballast is the electronic control device for the fixture. It powers the lights, and when a ballast fails, all lights that it runs go out. It usually costs 50 to 100 dollars to replace and requires an electrician.
IF NEEDED: For example, when you flip a switch, you may have two lamps switching on at the same time – in this case, a ballast controls two lamps.

For all measures ask:
Have any of those <retention quantity> <quantity units> failed, been removed, or replaced?
FOR L19: ask BALLASTS instead of <retention unit> (which is 4 ft T8 LAMPS for the most part)

<If so, then get detailed counts.>
<If not, move to next measure for site or T&T.>

Overall, how many of the <quantity units> (BALLASTS for L19) installed in the <YEAR> HVAC retrofit have failed, been removed, or replaced?

< If respondent can't answer with a number, try with a percentage>:
What percent of ALL the <quantity units> (BALLASTS for L19) installed in the <YEAR> HVAC retrofit have failed, been removed, or replaced?

Let's now try to break this number down into failed, removed and replaced.

- If the fixture doesn't switch on, then it has FAILED. If a fixture fails and it is replaced by something else, then it is still considered a failure.
- A fixture is considered REMOVED if it has been taken out of its original location while it was still functional, and has not been replaced with something else. For example: taking out a light fixture during a remodel, because light is no longer necessary in the area.
- A fixture is considered replaced if another fixture has been installed in its place

FAILURES

How many <retention unit> (BALLASTS for L19) have failed?

IF NEEDED: If the fixture doesn't switch on, then it has failed. If a fixture fails and it is replaced by something else, then it is still considered a failure.

Can you recall when this failure FIRST occurred? What year was it? What month was it? (If the respondent cannot recall month, ask what season it was).

And can you recall what type of failure that was? Was it…

- Manufacturing Defect
- Improper Installation
- Improper Maintenance
- Accident/Human Error
- Other – RECORD VERBATIM
- Don't Know/Unable to determine

Were there other failures that occurred at other times? IF yes: can you recall when the LAST failure occurred? Year? Month? (at least Season?)

What type of failure was it?

- Manufacturing Defect
- Improper Installation
- Improper Maintenance
- Accident/Human Error
- Other – RECORD VERBATIM
- Don't Know/Unable to determine

Did you replace any of the failed <retention unit> (BALLASTS for L19)? Were they replaced with…

- Higher Efficiency <retention unit>
- Equivalent Efficiency <retention unit>
- Baseline Efficiency <retention unit>
- Other – Specify
- Don't Know/Unable to determine

And how many (OR what percentage) of the FAILED <retention unit> (BALLASTS for L19) were replaced under warranty?

REMOVALS

Let's now talk about <retention unit> that have been removed. Can you remember how many (OR what percentage) of the <retention unit> (BALLASTS for L19) were removed, if any?
IF NEEDED: A fixture is considered REMOVED if it has been taken out of its original location while it was still functional, and has not been replaced with something else. For example: taking out a light fixture during a remodel, because light is no longer necessary in the area.

Can you recall when this removal FIRST occurred? What year was it? What Month? (at least what season?)

And can you recall why they were removed? Was it…

- Unsatisfactory Performance
- Savings not worth the effort
- Remodeling disabled the installation
- Type of business changed
- Moved
- Equipment upgrade
- Other – RECORD VERBATIM
- Don't Know/Unable to determine

Were there other removals that occurred at other times? If YES:
Can you recall when the LAST removal occurred? What year was it? What Month? What season?

And can you recall why they were removed? Was it…

- Unsatisfactory Performance
- Savings not worth the effort
- Remodeling disabled the installation
- Type of business changed
- Moved
- Equipment upgrade
- Other – RECORD VERBATIM
- Don't Know/Unable to determine

Did you replace any of the removed <retention quantity> (BALLASTS for L19)?

If YES: Were they replaced with…

- Higher Efficiency <retention unit>
- Equivalent Efficiency <retention unit>
- Baseline Efficiency <retention unit>
- Other – Specify
- Don't Know/Unable to determine

T&T:

Those are all the questions I have for you today. On behalf of Pacific Gas & Electric Company, thank you very much for your time and cooperation.

CATI Telephone Script for 2005 HVAC Retention Study

Hello, this is <Interviewer> calling from Quantum Consulting on behalf of Pacific Gas & Electric Company. May I speak with <Contact Name> OR the person in your organization who is responsible for decisions regarding construction, renovation, or operation of your physical facilities??

To get correct person, ask: Do you recall that there was an HVAC retrofit that occurred in <YEAR>, and that was subsidized by PG&E's program?

When correct person is on the phone:
We are not selling anything and this survey will only take a few minutes. We are assisting PG&E in evaluating their energy efficiency programs. We would like to ask you some questions regarding the success of the HVAC retrofit that took place at <Company> in <YEAR>. The goal of the study is to determine the lifetime of the HVAC equipment installed through PG&E's rebate programs. PG&E conducts this study every few years, to track specific equipment over time. Are you the best person to talk to, for this study?

IF NEEDED: PG&E wants to better understand how long HVAC equipment typically lasts. Many of the energy efficient technologies installed through the rebate program are so new that there is still some uncertainty as to how long they last. PG&E may use this information to update their programs so that they better serve the needs of the customer.

Our records indicate that your facility is located at <ADDRESS> <CITY>. Is that correct?

If not willing to do survey over the phone or nobody can remember the retrofit AND if <Survey Cluster Nr. 1-6>:

With your permission, we would like to have one of our energy auditors drop by and verify the success of the HVAC retrofit that took place there in <YEAR>. It would require only a few minutes of your time. Would it be OK for one of our auditors to come on site?
If no: T&T.

If yes:
Is the HVAC equipment easily accessible? If the equipment is located on a roof, is there a permanent ladder for access?
If no: T&T

If yes:
The way we like to schedule the appointments is to find out what weekday (or days) and times you would be available, and then for our auditors to call you to schedule the appointment. Let's start with the weekdays. In general, on what days would you be available to spend a few minutes with our auditor?

Around what time would it be best that the auditor arrive at the facility?

The auditor will have up to three specific locations for each HVAC measure installed. The goal is to determine how many of the noted items have failed, been removed, or been replaced in each area. Any repair orders or invoices that you have may facilitate the survey.

Fill out appointment sheet with the following info:
Weekdays Available
Hours Available
Company Name
Contact Name
Contact Phone
Address
City
Cross Street
Any directions that the auditor may need to get to the place

Confirm weekdays/times by reading back to customer. Remind customer that the auditor will call within a few days to schedule the appointment.

If not in Cluster 1 or 3-6: T&T

If willing to do survey:

FOR EACH MEASURE AT SITE:

Our records indicate that your company installed: <retention quantity> <quantity units> (at/on <location description>) at <site address>. Can you verify this information?

Has any of those <retention quantity> <quantity units> failed, been removed, or replaced?

<If so, then get detailed counts.>
<If not, move to next measure for site or T&T.>

Overall, how many of the <quantity units> installed in the <YEAR> HVAC retrofit have failed, been removed, or replaced?

< If respondent can't answer with a number, try with a percentage>:
What percent of ALL the <quantity units> installed in the <YEAR> HVAC retrofit have failed, been removed, or replaced?

Let's now try to break this number down into failed, removed and replaced.

- If the installed HVAC measure breaks down and is beyond repair, then it has FAILED. Repair or maintenance are not considered a failure if the HVAC unit is still functional. If an HVAC measure fails and it is replaced by something else, then it is still considered a failure.
- An HVAC measure is considered REMOVED if it has been taken out of its original location while it was still functional. For example: taking out an energy management system during a remodel.
- An HVAC measure is considered REPLACED if another HVAC measure has been installed in its place.

FAILURES

How many <retention unit> have failed?
IF NEEDED: If the HVAC measure breaks down and is beyond repair, then it has failed. Repair or maintenance are not considered a failure if the HVAC unit is still functional. If an HVAC measure fails and it is replaced by something else, then it is still considered a failure.

Can you recall when this failure FIRST occurred? What year was it? What month was it? (If the respondent cannot recall month, ask what season it was).

And can you recall what type of failure that was? Was it…

- Manufacturing Defect
- Improper Installation
- Improper Maintenance
- Accident/Human Error
- Other – RECORD VERBATIM
- Don't Know/Unable to determine

Were there other failures that occurred at other times? IF yes: can you recall when the LAST failure occurred? Year? Month? (at least Season?)

What type of failure was it?

- Manufacturing Defect
- Improper Installation
- Improper Maintenance
- Accident/Human Error
- Other – RECORD VERBATIM
- Don't Know/Unable to determine

Did you replace any of the failed <retention unit>? Were they replaced with…

- Higher Efficiency <retention unit>
- Equivalent Efficiency <retention unit>
- Baseline Efficiency <retention unit>
- Other – Specify
- Don't Know/Unable to determine

And how many (OR what percentage) of the FAILED <retention unit> were replaced under warranty?

REMOVALS

Let's now talk about <retention unit> that have been removed. Can you remember how many (OR what percentage) of the <retention unit> were removed, if any?
IF NEEDED: An HVAC measure is considered removed if it has been taken out of its original location while it was still functional. For example: taking out a 5-ton packaged unit during a remodel.

Can you recall when this removal FIRST occurred? What year was it? What Month? (at least what season?)

And can you recall why they were removed? Was it…

- Unsatisfactory Performance
- Savings not worth the effort
- Remodeling disabled the installation
- Type of business changed
- Moved
- Equipment upgrade
- Other – RECORD VERBATIM
- Don't Know/Unable to determine

Were there other removals that occurred at other times? If YES:
Can you recall when the LAST removal occurred? What year was it? What Month? What season?

And can you recall why they were removed? Was it…

- Unsatisfactory Performance
- Savings not worth the effort
- Remodeling disabled the installation
- Type of business changed

- Moved
- Equipment upgrade
- Other – RECORD VERBATIM
- Don't Know/Unable to determine

Did you replace any of the removed <retention unit>?

If YES: Were they replaced with…

- Higher Efficiency <retention unit>
- Equivalent Efficiency <retention unit>
- Baseline Efficiency <retention unit>
- Other – Specify
- Don't Know/Unable to determine

T&T:
Those are all the questions I have for you today. On behalf of Pacific Gas & Electric Company, thank you very much for your time and cooperation.