Do Savings from Retrocommissioning Last?
Results from an Effective Useful Life Study

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ABSTRACT

Retrocommissioning (RCx) of large commercial facilities plays an increasingly important role in many energy efficiency portfolios. Yet there is little data on how long the savings from RCx measures actually persist. This paper presents the methodology and results of a study of effective useful life (EUL) for RCx measures implemented in past California RCx programs.

The California Public Utilities Commission (CPUC) requested this study in large part because of the high level of uncertainty surrounding RCx program EUL claims. The study examined over 100 measures from three California third-party RCx programs implemented between 2002 and 2005. These measures were studied in previous impact evaluations and, as a result, substantial information was available for most measures from those evaluations.

The study methodology entailed reviewing project documentation from the implementation and evaluation files and then scheduling and conducting a site visit. The purpose of the site visit was to determine the RCx measures' functionality through inspection of equipment and control systems, along with interviews with building operators. Analysis of these field data yielded an estimated average RCx measure EUL of eight years, albeit with some uncertainty. A follow-up study of this group of measures and the addition of a study of 2006-08 RCx program measures is recommended.

This retrospective study provided valuable, empirical data on RCx EULs. It is a key step toward developing comprehensive future efforts to determine how long RCx savings last.

Introduction

Retrocommissioning (RCx) of large commercial facilities plays an increasingly important role in many energy efficiency portfolios. Yet there is little data on how long the savings from RCx measures actually persist. This paper presents the methodology and results of a study of effective useful life (EUL) for RCx measures implemented in past California RCx programs.

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The goal of this EUL investigation was to examine measures from early RCx programs in the 2002-03 and 2004-05 CPUC program cycles and, based on available evidence, determine if measures were still in place, operational, and yielding savings. The programs studied included the following:

- Oakland Energy Partnership (OEP) - Large Commercial Building Tune-Up Program – 2002–03
- Building Tune-Up Program (BTU) – 2004–05

- UC/CSU/IOU Partnership’s Monitoring Based Commissioning (MBCx) – 2004–05

The OEP and BTU programs funded investigations by commissioning agents of low/no-cost measures, and provided implementation support. The UC/CSU/IOU Partnership’s MBCx program was similar, but also emphasized a whole building approach, including adding monitoring to permit facility staff to continue optimizing energy use.

This EUL investigation was part of a much larger effort, the CPUC’s 2006-08 Commercial Retrocommissioning Impact Evaluation (SBW, 2010). However, this EUL investigation was not a formal, protocol-based study designed to comply with the California Energy Efficiency Evaluation Protocols for EUL studies, but was undertaken as a preliminary effort to address the need for RCx measure life information. EULs for RCx measures varied widely across programs in the 2006-08 program cycle. This study enhanced understanding of EUL evaluation issues and can serve as the basis for future EUL investigations.

The intent of this study was to take a fresh look at EUL estimates for RCx measures through building owner/operator interviews and field inspection. The on-site investigations provided a snapshot of measure performance but did not include methods such as trend logging or metering. This study provides observation and interview-based RCx measure persistence data based on measures from three third-party RCx programs from previous program cycles.

Methodology

Sample Design and Selection

SBW Consulting performed the original EM&V for the three RCx programs between 2004 and 2007. Samples were drawn for each of these evaluations and those same samples used again for this EUL investigation. The EM&V results for these samples were reviewed and measures were eliminated if they originally yielded no savings, or were retrofit-type measures, similar in nature to conventional capital projects, e.g., installing a cooling tower or replacing motors[1]. Collectively, the EUL sample spanned 32 projects and 101 measures.

Table 1 groups the most common types of measures, each of which constituted 8% or more of the total number of identified RCx measures. Three measures (improving outside air use, improving reset schedules and improving control strategies) accounted for almost half the measure count, while other measures each accounted for 8–11% of the total. The remaining less-frequently-occurring measures were aggregated into a miscellaneous classification[2].

[1] One capital-type measure, variable speed drive installations, was not removed because they are common in many RCx programs and allow the implementation of common RCx-type control strategies.

[2] Miscellaneous category included improvements in boiler, sensor, and damper performance, and variable speed drive installations.

Table 1. Measures Investigated in EUL Study

Measure name	N	% of N
Improve outside air use	16	16%
Improve temperature / pressure reset schedule	16	16%
Improve control strategies – general	16	16%
Improve scheduling	11	11%
Improve sequence of operation	10	10%
Improve setpoints	8	8%
Improve valve performance	8	8%
Improvements, miscellaneous	16	16%
TOTAL	**101**	**100%**

The original plan was to evaluate EULs by each of the eight categories in Table 1. However, because the differences in percentages of measure failures between these categories were inconclusive, we opted to combine the measure results to develop more robust findings for RCx as a whole.

Field Data Collection

Prior to beginning field data collection, the evaluation team developed a subset of RCx measures to study,[3] classifying the measures according to the scheme shown in Table 1 and identifying approximate measure installation dates from implementation reports and original database summaries. Site contacts and former evaluation monitoring and verification (EM&V) engineers were identified. The evaluators prepared a survey tool, as well as a recruitment script explaining the purpose of the visit and soliciting cooperation.

The evaluation team proceeded with the field data collection as follows:

- **Project file review:** The EUL investigator reviewed all project documentation from the implementer and the follow-up EM&V to become familiar with the site and measures implemented and the EM&V results. These investigators were seasoned professionals with many years of direct experience with energy efficiency in HVAC systems. In some cases, the investigator contacted the EM&V engineer for supplemental information.
- **Recruitment:** The investigator contacted project site personnel to schedule a site visit to inspect the condition and functionality of equipment and associated control strategies for the RCx project measures.
- **Site visit:** The investigator visually verified the presence of measure equipment and functionality. These verification inspections generally included a census of affected systems and equipment. Where practical, photographs and/or EMS screenshots were collected as documentation. Building operators were informally interviewed on the performance of the measure, probing for any difficulties with the measures' performance or modifications made to the measure since its implementation. Particularly if the measure was not functional or had been modified, building operator recollection of the events leading to measure modifications sometimes provided valuable anecdotal background. The focus was to determine the timing and rationale for any changes that

[3] Measures were eliminated which were not functioning at the time of the original EM&V. Also eliminated were standard retrofit measures, such as new premium efficiency motors.

may have significantly impacted the measure EUL. In cases where the measure was functioning partially, a judgment call was made by the EUL project manager, in consultation with the field investigator, that if the measure likely was realizing less than 50% of the impact evaluation documented savings, the measure was deemed to be not operational. Some measures were found likely to be achieving greater savings than the impact evaluation savings such as more aggressive temperature setbacks than originally observed.

- **Post site visit:** The investigator documented the site inspection findings for each measure in as much detail as possible. The three potential outcomes for each measure were: (a) measure is fully operational as described in the impact evaluation, (b) measure has been modified with a description of the changes, or (c) measure is disabled or otherwise not functioning to achieve the savings determined by the EM&V.

Once all field data collection was complete, data were aggregated, quality control checks performed, and inconsistencies resolved through discussions with the field investigators. Subsequently, measures were grouped according to the observed findings, and recommendations developed.

Findings

All 32 sites targeted for the study were successfully recruited for participation in the EUL investigation. The study team conducted on-site inspections from July through September 2009. The field work required ingenuity to assess measure performance in a wide variety of facilities and with site contacts having varying degrees of technical expertise and knowledge of past RCx projects.

Oakland Energy Partnership (OEP) sites in particular proved challenging because of the longer time period since measure implementation. The OEP was part of the 2002–03 program cycle, and even though many measures were actually completed in 2004, a number of sites had experienced staff turnover such that no one onsite had knowledge of the OEP retrocommissioning effort. Sites from other programs had also experienced personnel turnover, but usually to a lesser degree. Nevertheless, all consented to a site visit, and everyone did their best to help with the measure investigation.

These two examples illustrate typical situations encountered by the field investigation team:

(1) Large hotel. Five measures were installed in 2006 at a luxury hotel in Northern California. The measures included economizer repairs, control sequencing for the cooling towers, installation and tuning of fan variable frequency drives (VFDs), guestroom corridor supply air temperature setback and lighting control scheduling for hotel conference rooms. Key aspects of the site inspection were as follows:

- The hotel operating engineers were helpful, but initially had difficulty recalling the RCx project due to their company’s frequent participation in utility conservation programs.
- Through interviews, energy management system (EMS) assessment and equipment inspections, the investigator concluded the economizers, cooling towers and VFDs were all operating well and likely achieving the saving determined by the evaluation engineer.

- The guestroom corridors setback had been disabled. There was no recollection of the measure by the chief engineer.
- Shortly after implementation, the conference room lighting controls shut off the lights during a meeting. As a result, the lighting control strategy was immediately abandoned.

(2) Large commercial office building. Three measures were installed in 2004 at a high-rise office building in Northern California. The measures consisted of scheduling the boiler (rather than 24/7 operation), reduction of the outside air temperature at which the boiler is locked out, and a boiler tune-up. The outcome was:

- Due to staff turnover, no one on site remembered the RCx project.
- The building engineer said the boiler scheduling was operational, but the investigator's review of the control system settings found that the boiler scheduling had been disabled.
- EMS review revealed the boiler was not locked out when the outside air temperature exceeded 70^{o}F, as the measure was specified to do.
- The boiler had not had a tune-up in at least three years. At a minimum, annual tune-ups are needed to maintain optimum boiler efficiency.

Across the study population, the measures contained a broad mix of RCx actions with a total of 96 measures evaluated out of 101 originally implemented. The five measures omitted were declared "indeterminate" due to lack of adequate data and high uncertainty as to the outcome. The remaining measures were classified by measure group and measure system, as shown in Table 2.

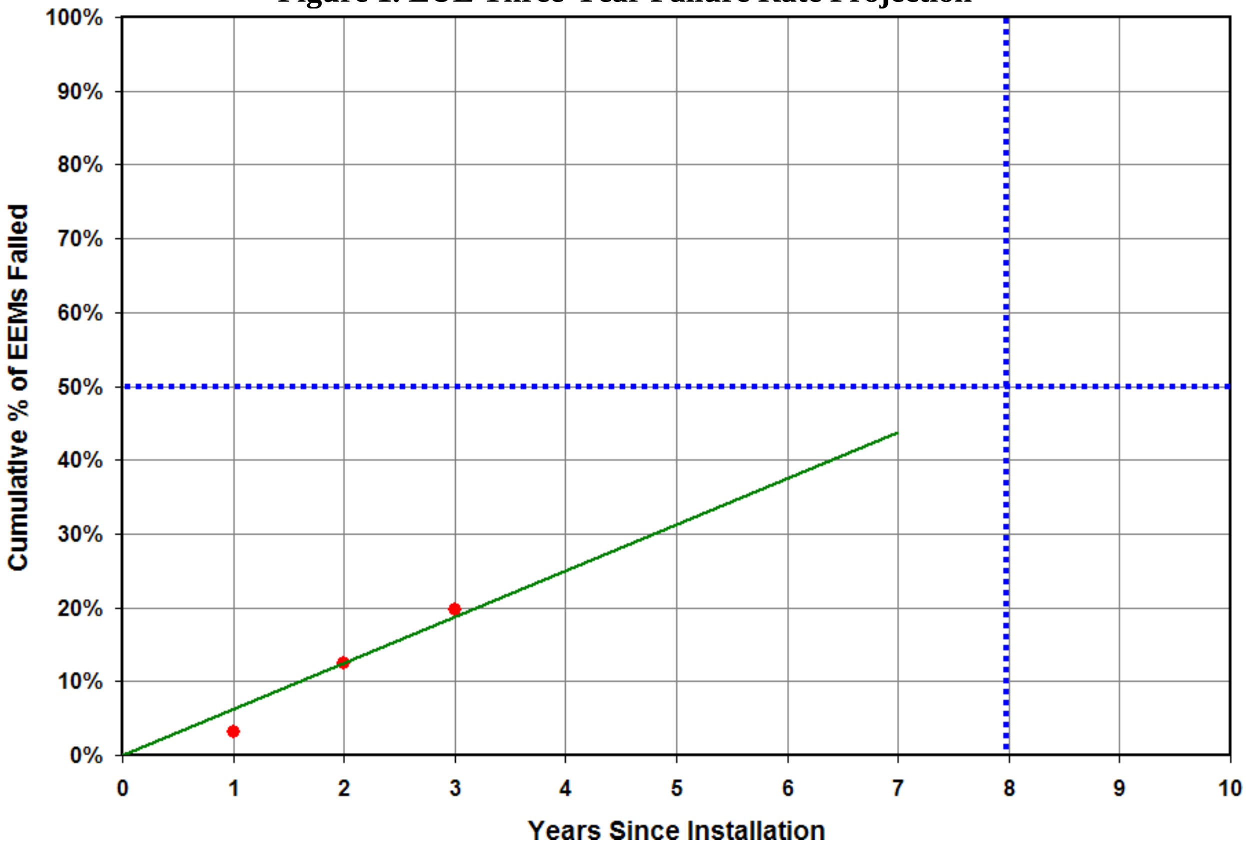
Table 2. EUL Measure Classification

Measure Name	N	Still Working	%
Improve boiler performance	3	1	33%
Improve building warm-up / cool-down	2	2	100%
Improve control strategies - general	10	8	80%
Improve damper performance	1	1	100%
Improve maintenance practices - general	1	1	100%
Improve outside air use	12	9	75%
Improve scheduling	10	6	60%
Improve sensor performance	5	5	100%
Improve sequence of operation	10	10	100%
Improve setpoints	8	3	38%
Improve temperature / pressure reset schedule	15	12	80%
Improve valve performance	8	7	88%
Install / replace variable speed drive - HVAC air handler	2	2	100%
Install lighting occupancy sensors	1	0	0%
Install miscellaneous efficiency improvement	3	2	67%
Install VFD	5	5	100%
All Measures	**96**	**74**	**77%**

The study results provided insights into both the timing of measure failures and the reasons for failures. The following were among the key findings:

- In all, there were 22 failures out of the 96 measures. Of these, three failed in the first year after measure installation, nine in the second year, seven in the third year, and for the small number of measures that had been installed four years ago, three more failed.
- Cumulatively, this represented failure rates of 3%, 13%, and 20% for the first three years, respectively. Using simple linear extrapolation, these results lead to an EUL of eight years – defined as the point at which half the installed measures have failed. Note, however, that there is a large uncertainty band around this estimate. Nonetheless, the results are consistent with previously published results in this area (Bourassa et al, 2004; Turner et al, 2001).

Figure 1. EUL Three-Year Failure Rate Projection



Although there were not enough measures in any category to provide statistically significant results on the comparative failure rates of different measure types, the results do provide the basis for a comparison to RCx measure EULs for program groups claimed by IOUs in the 2006-08 program cycle, summarized in Table 3.

Table 3. RCx Measure EULs Claimed (Years)

RCx Program Group	Pacific Gas & Electric	Southern California Edison	Southern California Gas	San Diego Gas & Electric
Partnership-University/Utility (UC/CSU/IOU)	15	14	10	10
Partnership-Los Angeles County	-	10	15	-
Partnership-Other	3-15	14	20	-
General purpose (administered by third party, PECI)	3-12	10	-	-
PG&E Core	3-12	-	-	-
Other	3-15	-	-	10-15
All Programs Range	**3-15**	**10-15**	**10-20**	**10-15**
All Programs Average	**7**	**11**	**14**	**10**

Overall, average EULs for RCx measures in Table 3 range from 7 years for Pacific Gas & Electric (PG&E) to 14 years for Southern California Gas (SCG). Note that ranges are shown in cases where IOUs assign different values to different measure types. For example, PG&E applies EULs of 3 years for control-setting changes, 8 years for equipment repairs, and 12 years for new equipment installations.

One notable disparity is the Los Angeles County Partnership program with gas savings claimed by SCG and electrical savings claimed by Southern California Edison (SCE); measure EULs claimed by the two utilities are respectively 15 and 10 years.

The UC/CSU/IOU Partnership's MBCx EULs range from 10 years for the Sempra Utilities (Southern California Gas and San Diego Gas & Electric) to 15 years for PG&E. Additionally, PG&E has substantially higher EULs for UC/CSU/IOU MBCx projects than for the rest of its RCx portfolio.

Generally, these inconsistencies between utility EUL claims point toward the need for a more uniform and defensible basis for future EULs. Moreover, they highlight the need for more research into whether RCx programs with special features—such as installation of permanent monitoring (such as MBCx), or repeated tune-up visits over ensuing years—substantially improve RCx measure EULs.

In addition to indications of measure life, the study also offered some interesting and potentially significant anecdotal findings regarding the reasons for measure failure. Of the 22 measures for which site contacts responded "no" to the question "Is the affected hardware still in place and operational?" The following reasons were offered for the measure failure:

Table 4. Reasons for Measure Failure

%	Reason for Failure
35	Control sequence changed due to perception that the RCx measure compromised occupant comfort
22	Control sequence changed – reason unknown
22	Lack of maintenance compromised the measure
9	Facility operating hours extended
12	Miscellaneous

Despite the small sample size, particularly in terms of the breakdown of reasons for premature measure failure, it appears that human factors are generally more responsible for the failure of these measures than actual technical issues. Measures recommended and implemented by the RCx implementer are usually selected based upon anticipated energy savings, but potential occupant comfort issues appear to raise the risk of manual overrides or control sequence changes reverting to the original condition.

Similarly, after RCx implementation, many measures require a preventive maintenance program if savings are to persist. In the study, the measures most at risk for losing savings due to lack of maintenance appear to be economizers and boilers. That one in five measures in the study failed from lack of maintenance suggests the need for more explicit instructions about required maintenance, or perhaps regular tune-ups for critical measures.

Reliability of Results

The primary source of uncertainty in the analysis was the development of criteria for determining functionality. In some cases, a measure clearly was not functioning; in others there was evidence that the functionality had been diminished but not completely eliminated, as when one of several setpoints had been overridden but others remained in their post-RCx state. In this latter case, if the investigation team felt that at least 50% of the previously evaluated measure savings were being delivered, the measure was counted as functional, if less than 50%, the measure was deemed to have failed.

There was, for many measures that were found to have failed, significant uncertainty around the time of failure. There was a reasonable certainty as to when a measure was installed, when the initial evaluation of the previous program had found the measure functional, and when the site investigation for this study discovered the measure was no longer working. We asked facility staff when the failure occurred, but in many cases, they could not recall (sometimes because they were new to the facility) or could only recall in very vague terms, e.g., "We disabled that a long time ago."

The EUL investigation team used their best judgment to establish a lifetime range, and then used the midpoint of that range in the analysis.

Because the site investigation was a one-time snapshot of the measure condition, the lack of detailed monitoring of measures at the study sites, such as power metering or other data trend logging, increased the level of uncertainty surrounding the percentage of savings still being achieved.

There is also significant uncertainty in the estimation of EULs from the observed failure rate. In Figure 1, the simple linear function projects the past failure rate into the future to determine at what point in time half the measures would have failed and half would still be working, and used that as our estimate of the EUL for all the measures studied. This projected overall EUL of about eight years does approximately correlate with the average of PG&E's three-tier RCx EUL system.

Conclusions

This study has developed a rich set of empirical data for program planning purposes, as well as serving as an important initial step, which can inform future, more comprehensive efforts to determine RCx EULs.

For the 2006-08 program cycle, the CPUC has taken the EUL estimated by this study under advisement, but does not plan to use them to adjust the ex ante EULs claimed by the IOUs for RCx measures. There are clear indications, however, that the average EULs claimed for some utilities are higher than indicated by this study.

Two options for solidifying the EUL estimate are described briefly below. Both of these, however, would require a number of years to complete. One option could be selected, or both options could be pursued simultaneously.

- **Continue the 2002–05 study**: Perform a similar measure failure investigation on the same panel after three more years have elapsed in 2012 or beyond. If the failure rates observed to date continue over the next few years, then around that time, the panel should be approaching a 50% failure rate, which would establish the EUL by definition.
- **Establish a new 2006–08 study:** The results of a preliminary statistical power analysis to determine the minimum requirements for statistical validity established that the EUL study would have to observe about 250 failures to obtain results with 90% confidence. Assuming the observed failure rate of 20% every three years, it would take a panel of over a thousand measures several years or more to reach a point where the requisite number of failures would be achieved. It is unclear at this point what the total number of observable measures in the 2006–08 program cycle is.

One advantage of the second recommendation above is that the larger pool of RCx measures from the 2006-08 programs may support multiple-tier RCx EULs similar to that practiced by PG&E for many of their RCx programs. This could also help determine whether monitoring-based commissioning as practiced by the UC/CSU/IOU Partnership (and other programs) supports longer measure life than other models for RCx implementation. The corresponding drawback, though, is that such segmentation would increase the number of failures that needed to be observed.

Confirmation of the EUL value developed by the current study on the relatively small sample suggests a much larger study will be required and we recommend that such research be pursued aggressively and on a large scale. RCx measures and programs have become a valued part of many utility portfolios and a well-supported standard for RCx EULs will contribute to the growth and credibility of this important resource.

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