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Evaluation of Retrocommissioning Persistence in Large Commercial Buildings

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Synopsis

Commercial Building Retrocommissioning activity has increased in recent years. This paper discusses LBNL's recently conducted study of 8 participants in the Sacramento Municipal Utility District Retrocommissioning program. We evaluated the persistence of energy savings and measure implementation, in an effort to identify and understand factors that can improve the longevity of retrocommissioning benefits.

The LBNL analysis included a whole-building and measure status analysis, incorporating elements of previous work by Texas A&M University and Portland Energy Conservation Inc. Included in the energy analysis were whole building calculated energy savings and consideration of effects from the 2001 energy crisis. The measure persistence analysis examined each recommended measure and it's current operational status. Results showed a 59% implementation rate of recommended measures. Some process findings were:

- Building engineers will tweak a measure that didn't work, instead of reverting to the pre-retrocommissioning settings
- A majority of the implementation costs were absorbed into regular operation and maintenance budgets
- The most frequently reported down side was the large time demands on the building engineering staff. However, all respondents thought it was worth the price.
- All the sites said that retrocommissioning is beneficial to their operations, due to on-going training and continuous improvement of system specifications
- Approximately 65% of the peak retrocommissioning savings persisted beyond four years

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Introduction

Project Goals and Objectives

Commissioning of existing buildings is an increasingly important tool for building owners and operators. Large commercial buildings have many energy consuming systems that will degrade or fail without preventative maintenance and attention. The retrocommissioning process is fast emerging as a cost effective method to fine tune or correct problems, often resulting in energy and cost savings. Although retrocommissioning is becoming popular, the question of how long the benefits will endure over time is not well understood.

The Sacramento Municipal Utility District (SMUD) is a public-power electric utility serving over 500,000 customers. The SMUD retrocommissioning program is designed to reduce overall building energy consumption through low-cost operational improvements and on-site training of building operators. A secondary goal is to guide the customer toward more far-reaching improvements that may become evident in the course of commissioning. Such improvements may include capital intensive energy efficiency retrofits, more advanced operator interface and software, and replacement of the entire controls system and associated equipment (Parks et al., 2003).

Retrocommissioning can be defined as follows.

> *Commissioning of existing buildings or "retrocommissioning," is a systematic process applied to existing buildings for identifying and implementing operational and maintenance improvements and for ensuring their continued performance over time. Retrocommissioning assures system functionality. It is an inclusive and systematic process that intends not only to optimize how equipment and systems operate, but also to optimize how the systems function together. Although retrocommissioning may include recommendations for capital improvements, the primary focus is on using O&M tune-up activities and diagnostic testing to optimize the building systems. Retrocommissioning is not a substitute for major repair work. Repairing major problems is a must before retrocommissioning can be fully completed (Oregon Office of Energy, March 2001).*

Obtaining an estimate for the energy savings persistence is difficult due to the many load and occupancy factors. Equally difficult is characterizing the measure settings persistence. Building operators often make modifications to system settings in response to ongoing occupant calls. Over time the changes might affect the implemented retrocommissioning measures. More understanding of these two persistence conditions will help retrocommissioning attain even more market penetration.

This paper discusses parts of a wider study on retrocommissioning persistence and retrocommissioning process issues conducted by LBNL for the Sacramento Municipal utility District (SMUD)(Bourassa et al, 2004). One of the objectives of this study was to examine a selection of buildings that participated in SMUD's retrocommissioning program and estimate the persistence of energy savings and measure implementation.

Previous Commissioning Persistence Studies

Two previous studies examined the persistence of savings from commissioning. The first study by Texas A&M was a quantitative examination of the persistence of savings in existing buildings. They evaluated whole-building energy use data for several years after commissioning (Turner et al., 2001). This research showed that 3 to 4 years after commissioning, about 80% of the energy savings were still present in the 10 buildings studied. In general, the persistence of savings was found to be quite good.

The second study by PECI looked at the persistence of savings in new building commissioning and focused on control system changes (Friedman et al., 2003). The PECI study used a qualitative approach based on interviews and site visits. Individual “Commissioning fixes” were tracked and evaluated. Fifty-five commissioning fixes were studied, and the large majority of the measures persisted. 14 of the 55 did not persist, or about one fourth.

Methodology

The project phases progressed as follows:

- A background review of persistence work,
- Development a of project plan and site selection,
- Data collection and analysis, and
- Development of recommendations and the final report.

SMUD provided LBNL with 12 BAS (Building Automation Systems) Retrocommissioning reports as well as SMUD’s Evaluation reports for the 1999 and 2000 Program participants. The Evaluation reports are SMUD’s official record of the measures thought to be implemented. Eight of the twelve sites had at least two years of post-retrocommissioning data. The 8 sites are listed bellow. Site visits and multiple telephone interviews were done to determine the retrocommissioning activities under taken by each site.

Retrocommissioning Participants in Year 1999

- Office1 (352,000 ft2) Construction year unknown
- Hospital1 (267,000 ft2) Const. in 1996
- Office5 (150,000 ft2) Const. in 1995
- Lab1 (94,000 ft2) Const. in 1997

Recommissioning Participants in Year 2000

- Office6 (308,400 ft2) Const. in 1965, complete renovation 1999
- Office2 (383,200 ft2) Const. in 1984
- Office3 (400,000 ft2) Const. in 1991
- Office4 (324,000 ft2) Const. in 1990

The energy analysis process was conducted in three phases: the analysis of local weather history, the production of weather normalized energy consumption data and the comparison of consumption history against a pre-retrocommissioning baseline year.

Weather data for Sacramento, CA were obtained from the Average Daily Temperature Archive website (U. of Dayton). A regression model was applied to each year of 1997 to 2003 data. This produced a "normal" weather year of average monthly dry bulb temperatures. Monthly electricity billing history was obtained for all eight sites.

All the energy use data were normalized to an average weather year and a common billing period of 30.5 days using EModel (Kissock et al., 1995). This is similar to the methodology used by Texas A&M (Claridge, et. al., 2003), with the exception that this study used the calculated average weather year as opposed to identifying an actual weather data year for the "normal" weather year. The key assumption in the analysis was that changes in annual energy use from the baseline year were considered to be a result of the retrocommissioning.

However, the post-retrocommissioning data are confounded by the 2001 California energy crisis. Four sites report that they responded to the crisis with operation changes such as de-lamping, turning off unnecessary hallway lighting and softening thermostat settings. The post-retrocommissioning data shows five sites have increased energy savings during 2001.

The savings estimates were calculated using the normalized consumption data as well as the retrocommissioning report savings predictions. Both sets of savings (columns C & D in Table 1) were calculated against the same normalized baseline.

Measure Persistence Analysis

The measure persistence analysis used site visits and interviews to determine the current status of the implemented retrocommissioning recommendations. A three-phase interview method was used to improve accuracy. The first phase consisted of a questionnaire provided prior to the initial site visit. At the site visit, if access to the BAS was available, the associated measure settings were checked. The second phase involved telephone interviews in which all the measure implementation questions were rephrased and posed again. The third phase was yet another round of telephone interviews, as well as email correspondence, but this time the questions were limited to the discrepancies uncovered between the first two phases.

After the current measure settings were determined, we identified each implemented measure as being in one of three persistence states: 1) persisting as implemented, 2) not persisting as implemented or 3) evolved from the originally implemented settings. The third category for measures that are 'evolved' was added to capture measures that were tried, but eventually changed to something fundamentally different than the original settings.

Results

The energy savings analysis shows an average of 7.3% (4.8% median) electricity savings per year across all eight sites. The retrocommissioning reports predicted an average electricity savings of 5.6% per year (4.0% median) for all eight sites.

Table 1: All Sites - Summary of Electric Savings

Building	A Predicted Avg Annual Elec.savings (MWh/yr)	B Post-RCx Avg Annual Elec.savings (MWh/yr)	C Predicted Avg Annual Elec.savings (%)	D Post-RCx Avg Annual Elec.savings (%)	E Baseline Electricity (MWh/yr)	B/A Percent of Post-RCx vs Predicted Elec. Savings
Office1	380	190	7.3%	3.6%	5,210	50.0%
Office2	490	360	7.1%	5.3%	6,896	73.5%
Lab1	520	620	16.1%	19.3%	3,190	119.2%
Hopsital1	460	430	4.7%	4.4%	9,850	93.5%
Office4	120	290	2.2%	5.4%	5,327	241.7%
Office5	170	220	3.4%	4.3%	4,996	129.4%
Office6	140	610	2.9%	12.5%	4,827	435.7%
All Sites	2,360	3,010	5.6%	7.3%	48,880	127.5%

Column B/A of Table 1 compares the difference between predictions and the calculated electricity savings. Post-retrocommissioning savings were on average about 27.5% higher than the report predictions. Three sites had predictions that were larger that the post-retrocommissioning energy use. The retrocommissioning reports predicted an average annual savings of 2,360 MWh per year and the actual energy use reductions are estimated at approximately 3,010 MWh. Table 2 shows the calculated post-retrocommissioning energy savings and Energy Use Intensities (EUI) for each year.

Table 2: **All Sites - Summary of Electricity Savings by Year**

Baselines are shaded		1998	1999	2000	2001	2002	2003
Office1 *	% Savings		**0%**		5%	2%	0%
	EUI **		**33.7**		32.7	33.2	34.6
	MWh/yr		**0**		270	130	10
Office2	% Savings			**0%**	15%	14%	19%
	EUI			**17.2**	14.7	14.8	14.0
	MWh/yr			**0**	970	700	990
Lab1	% Savings	**0%**	2%	16%	29%	26%	24%
	EUI	**33.9**	33.4	28.4	24.2	25.0	26.0
	MWh/yr	**0**	50	530	910	840	750
Hopsital1	% Savings		**0%**	4%	6%	8%	5%
	EUI		**37.4**	35.9	35.2	34.5	35.6
	MWh/yr		**0**	390	590	770	470
Office3	% Savings		**0%**	4%	5%	3%	-2%
	EUI		**21.7**	21.0	20.6	21.1	22.2
	MWh/yr		**0**	310	440	230	-180
Office4	% Savings				**0%**	4%	7%
	EUI				**16.4**	15.8	15.3
	MWh/yr				**0**	200	380
Office5	% Savings		**0%**	-1%	12%	6%	6%
	EUI		**14.7**	14.8	12.9	13.7	13.7
	MWh/yr		**0**	-60	620	330	330
Office6	% Savings			**0%**	13%	13%	11%
	EUI			**15.7**	13.6	13.5	13.9
	MWh/yr			**0**	620	650	550
All Sites - Total MWh			**0**	**1,170**	**4,420**	**3,850**	**3,300**

* Estimated Baseline from 1998 - 2000 data. ** Energy Use Intensity (kWh/sf^2 yr)

Figure 1 shows the energy saved when the data is arranged by years after the retrocommissioning baseline. Each curve represents an aggregate group of sites with the same amount of post-retrocommissioning consumption data. All the sites show increasing energy savings during years one and two. This is expected because the recommended measures are implemented over time. After the second year, the increasing savings trend appears to flatten during year three, then degrade in the fourth year.

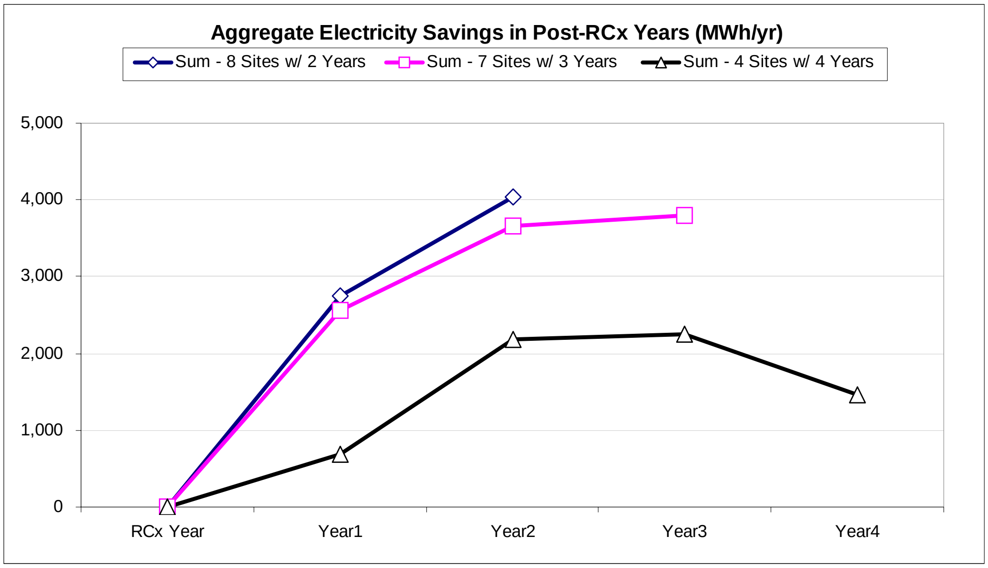

Figure 1: Aggregate Post-RCx Change in Electricity Use

Measure Persistence

The eight retrocommissioning reports recommended a total of 81 corrective measures and 48 were implemented. Air distribution related measures are the most frequently implemented with 43% of the component count. Cooling plant related measures are next with 26% of the count. The distribution of recommended strategies is even, with start/stop controls having a slight edge.

Measure persistence among the implemented recommendations was strong with 81% still persisting with the system settings that were recommended. The current persistence state of the implemented measures are listed in Table 3. Only four measures were identified as being abandoned and not persisting. All four of the not persisting measures were control recommendations for air distribution components.

Five implemented measures did not solve the identified problems to the building engineers' satisfaction and they chose to evolve the measures to find a better solution. Three are control settings on a cooling plant, and the other two are air distribution measures.

Table 3: Summary of persistence status for Implemented Measures

Code Key		
Cooling plant		C
Heating plant		H
Air distribution		A
Lighting		L
Plug loads		R
Whole Buidling		W
Design, installation	Change equip.	DI1
	Install controller	DI2
Control	Reset	CR1
	Start/Stop	CR2
	Scheduling	CR3
	Modify setpoint	CR4
	Calibration	CR5
O&M	Manual operation	OM1
	Maintenance	OM2

Office1	Office2	Lab1	Hopsital1	Office3	Office4	Office5	Office6
C-CR2(y)	A-CR4(y)	W-OM1(y)	A-CR3(e)	A-CR5(y)	A-CR5(y)	A-DI1(y)	A-CR2(y)
C-CR2(y)	L-DI2(y)	A-DI2(y)	A-CR4(y)	A-CR1(n)	H-CR2(y)	A-OM2(y)	H-CR2(y)
H-CR2(y)	C-DI1(y)	A-DI2(y)	A-CR3(y)	C-CR2(n)	A-CR5(n)	A-CR1(n)	C-CR2(e)
A-CR4(y)		A-CR4(y)	A-CR3(y)		H-CR3(y)	A-OM2(y)	C-DI1(y)
A-CR5(y)			C-CR4(y)		C-DI2(y)	A-OM2(e)	C-CR4(y)
L-CR3(y)			C-CR4(y)			A-DI2(y)	C-CR1(e)
			C-DI1(y)			H-CR2(y)	A-CR5(y)
			L-OM1(y)				C-CR1(e)
			L-OM1(y)				
			L-CR3(y)				
			L-DI2(y)				
			L-DI2(y)				
Category & Status ID (y = Persists, n = Not-Persisting, e = Evolved)							

Discussion

Seven sites reported that the retrocommissioning process inspired innovative analysis of their systems and they attempted to find more retrocommissioning style improvements. This important benefit is a direct result of a process that involves the building operations staff as much as possible. This survey supports the view that a properly executed retrocommissioning exercise can inspire a more creative approach to building operations and maintenance, one that might not have existed previously.

Table 4 lists answers, provided by the sites, to six questions about their retrocommissioning experience. The blank cells mean the site did not provide an answer.

Four sites listed training as the most important non-energy benefit from retrocommissioning. Many of the building engineers characterized the commissioning authority as a "teacher." The Table 2 results show that the four sites with a yes answer to a high level of training value, also have good energy savings and persistence. Conversely, Office 3 reported virtually no training value and it has the least persistent energy savings of the group. The most cited downside to retrocommissioning was the time intensive nature of the process. Also notable are two building engineers that could not find any negative aspects of retrocommissioning. Only one site identified inconvenience to the tenants as a problem.

Table 4: Answers to Survey Questions about retrocommissioning Process

Building	Primary non-energy impact of RCx	Most negative impact of RCx	Level of Training obtained	Plans to improve persistence	Will you RCx again	Do you have funds for RCx
Office1	Review of Sys. Specs.	None		Maintenance Manager program	Yes	No
Office2	Equip. life improvement	Time Req.	High	Utility Manage. plan	Yes	No
Lab1	Training	Time Req.	High	Improve WO process	Yes	Possible
Hopsital1	Training	Time Req.	High	Create an Energy Group	Yes	No
Office3	Training	None	None	Chief Eng. - approves all changes	Yes	No
Office4			Low	PM plan	Yes	No
Office5	Review of Sys. Specs.	Tenant interactions		PM plan	Yes	No
Office6	Training	Time Req.	High	BAS maint. Contract	Yes	Yes

All of the sites came out of the retrocommissioning process with ideas on how to retain the commissioning benefits over time. The most common solutions are preventative maintenance plans (not all the sites called it a PM plan). Office 6 hired a BAS expert with the task of providing small commissioning style reviews each month. The Hospital 1 site is creating an Energy Issues Group among their building operations staff. All the sites would undertake retrocommissioning again, but only two have potential internal funding. The other sites report that they are dependent on external funding for the cost of retaining a commissioning authority.

Summary

The energy analysis indicates that the post-retrocommissioning energy savings appear to turn towards degradation during the fourth post-retrocommissioning year. At four sites with four years of post-retrocommissioning data, the aggregate year 4 savings was at 65% of their peak post-retrocommissioning savings.

While not directly related to persistence, the retrocommissioning predictions for energy savings appear quite accurate. The energy savings persistence analysis shows that approximately 80% of the peak retrocommissioning savings have persisted beyond three years

The persistence of retrocommissioning benefits, both non-energy and energy related, are affected by the process style. Especially important is the conduct of the commissioning team during the field work phase. Some important retrocommissioning process factors that this study identified are:

- **Commissioning authority attitude –** A superior attitude can hinder information flow in the commissioning process. Commissioning authorities are most effective when they are both an expert and a teacher.
- **Identification of a retrocommissioning measure is just the start –** Retrocommissioning measures do not always work. Finding options that allow building engineers the opportunity to evolve towards a final solution is desirable.
- **Retrocommissioning can raise energy efficiency awareness –** Independent of whether the retrocommissioning effort was successful, all eight of the sites exhibited an increased awareness of energy efficiency and building diagnostics issues as a result of the retrocommissioning experience.
- **Funds for future retrocommissioning are constrained –** All of the sites want to do more retrocommissioning in the future, but internal funding is severely constrained at most of the sites.

Future Directions

Additional research is needed to examine whether the trends identified concerning the persistence of savings from retrocommissioning that occurred in this project are similar at other sites. The findings from this project are similar to the findings from previous research suggesting that most of the savings persist beyond three years. Longer multi-year studies are needed to examine five year savings rates and beyond. Additional research is also needed to develop tools and methods to allow building engineers and operators to obtain feedback on savings associated with retrocommissioning. Diagnostics tools and continuous performance monitoring systems are needed to assist in such tracking.

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