How Much Does Retrocommissioning Really Save?
Results From Three Commissioning Program Evaluations in California

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ABSTRACT

Energy-focused retrocommissioning has been and continues to be an important element of the energy savings portfolio in California. Rigorously quantifying the realized savings, though, is particularly challenging. Retrocommissioning programs often have complex implementation processes that span years, and assessing their impacts requires a high level of technical skill and evaluation judgment. This paper discusses the impact evaluations of three major programs that have taken place over the past several years, namely, the 2002-2003 Oakland Energy Partners Large Commercial Building Tune-Up Program, the 2004-2005 Building Tune-Up Program, and the 2004-2005 Monitoring-Based Commissioning element of the UC/CSU/IOU Statewide Energy Efficiency Partnership. A key objective of the state-funded evaluations of these three programs was to assess actual reductions in energy and peak demand savings, as well as the useful lifetime of these savings. The findings have helped determine how cost-effective retrocommissioning programs are, as well as ways in which they could be improved.

The Statewide Energy Efficiency Partnership evaluation is still in progress, but the two Building Tune-Up evaluations found that realized energy savings were significantly lower than program goals and claims. This paper discusses the reasons for this, why they varied, and the methods used to assess this. It also provides recommendations for improving savings estimation and results for future programs. These recommendations include improved program communication to support evaluation activities, additional measure commissioning, measurement and verification support throughout, and assistance to encourage savings persistence.

Background

Building commissioning is the systematic process of ensuring that building systems, such as HVAC and lighting, are designed, built, and operated according to the owner's operational needs. Commissioning existing buildings, often referred to as retrocommissioning, can dramatically improve building performance through renovation, upgrade and tune-up of existing systems. Typical commissioning measures include updating equipment scheduling, adding temperature reset schedules, and repairing malfunctioning dampers and valves. Such efforts can be attractive because in many instances, only minimal investments of time and effort are necessary to achieve large energy savings. Previous studies have highlighted the enormous energy savings potential that commissioning holds (Mills, 2004). Numerous energy utilities nationwide have developed retrocommissioning programs designed to capture some of these savings. Because of the recent vintage of such programs, coupled with the technical challenges inherent in evaluating them, few rigorous program-level evaluations of the actual results of these programs exist.

The state of California has funded several retrocommissioning programs since 2002. The California Public Utility Commission (CPUC) has placed high importance on rigorously assessing these new and potentially valuable programs to confirm their energy savings, and the persistence of these savings. Their experience to date suggests that retrocommissioning savings may not be as strong as predicted by the program implementers, and that savings may erode faster than predicted. To test this hypothesis, the CPUC approved multiple approaches for evaluating California's retrocommissioning programs, with some program evaluations consisting of reviews of calculations provided by the implementers, and other evaluations focusing on on-site reviews, testing and confirmation of savings using approaches consistent with IPMVP Option B[1]. The CPUC will use the results from different evaluation approaches to see if there is a significant difference between program-projected savings, and evaluation confirmed savings. For the studies that employed more rigorous evaluation approaches, the study findings will allow the CPUC to better understand the issues affecting measurement of achieved energy savings.

This paper presents the methodology, results, and conclusions from impact evaluations of three major retrocommissioning programs in California. The three programs are (1) 2002-2003 Oakland Energy Partners Large Commercial Building Tune-Up Program (referred to throughout the paper as "OEP"), (2) the 2004-2005 Building Tune-Up Program ("BTU"), and (3) the 2004-2005 monitoring-based commissioning element of the UC/CSU/IOU Statewide Energy Efficiency Partnership ("MBCx"). We also compare these evaluation results with those from the 2004-5 San Diego Retrocommissioning Program, which relied on a less rigorous impact evaluation methodology. These programs, and the corresponding evaluation, measurement, and verification (EM&V) efforts were ultimately funded through the CPUC public goods charge. The state of California and participating utilities plan to use the EM&V study results to obtain a complete picture of each programs' performance and cost-effectiveness. This information will provide useful feedback for improving subsequent programs of this nature. The three programs are briefly summarized below.

OEP: The Building Tune-Up portion of this 2002-2003 program targeted larger commercial buildings in Oakland, such as office buildings, hotels, colleges, hospitals, and retail customers. Facilities could be publicly or privately owned. The program implementer, QuEST, provided participants with a no-cost engineering investigation and analysis to identify and recommend improvements in building operations, such as control strategies and schedules that increased energy efficiency. The result of the investigation was a set of energy efficiency recommendations focusing on those that were low or no-cost, with quick paybacks. The program offered flexible financial incentives to further motivate potential participants. The program goals were to deliver services to 10.45 million square feet of commercial buildings in Oakland, resulting in 114,000 million Btu of energy savings annually.

BTU: This 2004-2005 program was very similar to OEP, although with a statewide, rather than citywide, focus. It targeted existing medium and large, public and private, nonresidential buildings in the service areas of Pacific Gas and Electric (PG&E) and Southern California Edison (SCE). For each participating building, the program implementer, QuEST, performed a comprehensive engineering investigation and analysis of key energy consuming systems to identify potential cost-effective, low-cost improvements in building operations and related hardware to reduce energy use while maintaining comfort and health objectives. In addition, the program recommended operations and maintenance, as well as capital improvements that would improve energy efficiency.

[1] International Performance Measurement and Verification Protocols, January 2001 version. Option B refers to *partially measured retrofit isolation*, in which savings for a measure are determined by field measurements of the energy use of the systems to which the measure was applied, separate from the energy use of the rest of the facility. Short-term or continuous measurements are taken throughout the post-retrofit period.

MBCx: This portion of the UC/CSU/IOU Energy Efficiency Partnership began in 2004 and concluded in early 2007. Its goal is not only to obtain energy and demand savings, but also to establish a framework for long-term, comprehensive energy management throughout the University of California and California State University system. Each participating campus selected buildings or systems to receive monitoring-based continuous commissioning. Installation of metering equipment and subsequent retrocommissioning could be done in-house, or through an independent contractor. Monitoring capability was permanently installed to capture data on energy use and other measurements needed to diagnose energy use problems. Campus facility staff, working with commissioning agents, used these data to diagnose and correct current problems. Campus staff received training in how to use these monitoring systems to continuously commission these building and, in theory, will subsequently apply this training and the monitoring system to maintain energy efficient operations in affected buildings.

Analysis Methodology

Between them, these three evaluations examined in detail retrocommissioning efforts in 36 large commercial facilities throughout California, encompassing hundreds of measures. These randomly sampled facilities represented significant fractions of their respective program's overall claimed savings. Each study relied on a variety of techniques and data sources, consistent with IPMVP Option B, to assess energy savings. These include short-term metering, one-time measurements, customer records, and on-site interviews and observations. In most cases, both baseline and post-implementation data were available to support developing and revising engineering calculations and building simulations. Although sampling strategies vary across the evaluations, they share a common characteristic: namely, the need for a high degree of flexibility to cope with the long timeframes and ever-changing scope of the retrocommissioning projects.

Table 1 summarizes the sampling and data collection strategies for each evaluation. All of them relied on random sampling of measures or projects, coupled with field observations and metered data that informed engineering analyses of realized savings. The subsequent text provides further details.

OEP Methodology

The EM&V effort for this program consisted of three major steps. The first was to sample implemented measures among the completed projects that would account for a significant portion of the expected savings. To support this effort, the program implementer summarized the implementation status and ex ante savings for each recommended measure at each participating site. This task was complicated by the extremely long timeframe for implementing measures (nearly two years), as well as the high degree of uncertainty as to whether a measure would actually be completed before the program end date. Measures with the largest savings were without exception included in the evaluation sample. Additionally, measures were selected that early on had been deemed large savers relative to the program and thus had been selected, and for which some baseline data collection activities had already begun. Remaining measures were randomly selected. In all, we sampled 26 of the 129 claimed measures, accounting for nearly 60% of the total program savings claim.

Table 1: Summary of evaluation methodologies

	Oakland Energy Partnership Building Tune-Up (BTU), Oakland Energy Partnership 2002-3	Building Tune-Up (BTU), PG&E/SCE 2004-5	Monitoring-Based Commissioning (MBCx), UC/CSU/IOU Partnership *[M&V still in progress]*
Sampling strategy	Stratified with largest measures selected with certainty, others randomly sampled, and smallest excluded.	Randomly sampled from three batches of projects with implemented measures. Analysis rigor for completed measures based on size of ex ante savings and other factors.	Select with certainty the largest savers among each type of MBCx project (lab, non-lab, and central plant), as well as the first project. Randomly selected one additional project from each group.
Baseline data collection	For sampled measures likely to be installed, reviewed implementer baseline data, and supplemented with evaluator field data (inspections, interviews, one-time measurements, trend logging) if necessary.	At sampled projects, reviewed implementer baseline data, and supplemented with evaluator field data (inspections, interviews, one-time measurements, trend logging) if necessary.	At sampled projects, reviewed implementer baseline data and supplemented with evaluator field data (inspections, interviews, one-time measurements, trend logging) if necessary.
Post-implementation data collection	For implemented measures, collected field data (inspections, interviews, one-time measurements, trend logging).	At sampled projects, collected field data. Level of data collection depended on magnitude of savings and other factors.	At sampled projects, reviewed implementer post-implementation data and supplemented with evaluator field data (inspections, interviews, one-time measurements, trend logging) as necessary.
Predominant IPMVP Option	B (partially-measure retrofit isolation)	B (partially-measure retrofit isolation)	B (partially-measure retrofit isolation)

Second, for sampled measures, we developed evaluation plans that included engineering and building simulation analyses consistent with IPMVP Option B: Partially Measured Retrofit Isolation. This required collecting the best available baseline and post-implementation data to support a recalculation of actual savings. After reviewing program implementer reports and calculations, we collected additional necessary baseline and post-implementation data. Data sources included short-term metering, one-time measurements, customer records, field observations, manufacturers' specifications, and self-reports from building operators and tenants at the sampled sites. We applied the most appropriate evaluation method on a case-by-case basis, based upon factors such as the information available from the ex-ante estimation process, available performance data, ease of further data collection, complexity of determining system performance, the relative savings contribution of an action to the overall program package, ease in working with facilities personnel, and budgetary limitations.

Lastly, we extrapolated our findings from the sampled measures to the program population, taking into account the various sample strata, to estimate total program savings and cost-effectiveness. We also estimated, based on the measure mix and measure life estimates shown in Table 2, the overall persistence of program savings.

BTU Evaluation Methodology

The evaluation approach was similar to OEP. One key difference is that we incorporated, based on our OEP experience, sampling at the project, rather than the measure, level. This approach did not allow us to optimize the sample through stratified random sampling focusing on large savers, but did eliminate the problems associated with high uncertainty over which measures customers would ultimately implement. The EM&V budget permitted us to randomly sample 17 of the 36 projects. Because we excluded projects with very small savings, this sample accounted for over 70% of the total program savings claim.

This evaluation employed techniques and data sources very similar to those for OEP. Because of the project-level sampling, though, we developed evaluation plans for all implemented measures at a project, with the degree of data collection and analysis rigor for each measure linked to the magnitude of claimed savings and the uncertainty in the ex ante analysis. Often, these plans were revised as the evaluation proceeded, and the evaluators encountered unforeseen complications that required flexibility to overcome. Examples of such complications included field visits revealing that a measure had been implemented differently than program documentation described, or customers unable to provide trend data they originally promised.

Table 2: Measure lives used in OEP, BTU evaluations

Measure life category	Assumed measure life
Tune up boilers	1
Program schedule changes to EMCS (setpoint, start/stop schedules)	3
Recalibrate terminal boxes	3
Program logic changes to EMCS (add reset control, optimum start/stop, control sequences)	5
Repair and recalibrate damper controls	5
Inspect and repair steam traps	8
Lighting occupancy sensors	8
Recharge Refrigerant in AC Units	8
Replace smooth belts with cogged belts	8
Add or replace control components	10
Add VFDs to supply fans	15
Duct heater	15
Eliminate air compressor	15
Replace cooling tower	15
Reduce lighting levels	16
Premium efficiency motor	18
Duct insulation material	20
High-eff centrifugal chiller replacement	20
Repair pipe and equipment insulation	20

Sources include: Approved EM&V plan (default lifetimes based on evaluator, implementer consensus), California Database for Energy Efficient Resources (DEER)

When we issued a draft evaluation report, the program implementer provided a detailed technical critique of many of the projects where we found significant differences between their claims and our results. Both the program implementer and evaluator spent a substantial amount of time investigating and resolving points of disagreement. These points ranged from different opinions of appropriate analysis methodology, alternative interpretations of findings, and follow-up data that suggested system performance had changed after the evaluation. The California Public Utilities Commission (CPUC) authorized additional evaluation funds to research some of the most critical issues. Ultimately, we concluded that realized savings were even lower than first evaluated. This process illustrates how the complexity of the affected systems and their dynamic nature makes establishing actual retrocommissioning results particularly challenging.

MBCx Methodology

The evaluation sample strove to maximize the claimed savings within the sample by eliminating the smallest savers, while also representing the three major project types (central plant, lab building, and non-lab building). Overall, the seven sampled projects account for nearly half of the MBCx energy savings. Typically, retrocommissioning these complex facilities and systems resulted in numerous customized, difficult-to-quantify measures. We engaged project team members (especially campus managers and commissioning agents) throughout the project to track developments. Because the program theory stresses the installation of permanent metering to monitor building performance, baseline and post-implementation data in some form were generally available for all projects. Quantifying the actual energy savings, however, in some case required that we install temporary data loggers to augment the permanent metering. It was sometimes advantageous to measure a particular end use system or component to aggregate the combined effect of multiple small commissioning changes, and accurately account for their interactive effects. We also recorded anecdotal information that might shed light on the expected persistence of commissioning measures.

As with the OEP and BTU programs, our procedure for estimating savings first involved reviewing program savings calculations and supporting data for the project. Next, we discussed projects further with campus contacts to determine appropriate methods to collect additional onsite data. We then developed EM&V plans describing how the additional data was integrated into the original spreadsheet or simulation model developed by the program implementer to estimate savings, or how a more appropriate savings estimation method was applied. Results from the detailed examinations of the sampled projects were applied to the program as a whole with a simple extrapolation.

Findings

Program-level savings

Table 3 and Figure 1 compare the savings goals, claimed savings, and evaluated results for the three programs. The significant disparities between goals and claims for the OEP and BTU programs reflect the challenges both programs faced recruiting candidate projects and then getting customers to implement measures before tight program deadlines. The OEP and BTU programs saw a high attrition rate among initially recruited projects, few of which ultimately were successfully completed. Those that were completed often only implemented a small number of the recommended measures. These facts illuminate some of the hurdles that retrocommissioning program implementers face. This paper does not address these particular programmatic issues, but focuses mostly on the large differences between the claimed and evaluated savings.

Overall gross energy realization rates were 49% for OEP and 68% for BTU (unfortunately, realization rates for MBCx were not yet available at the time of publication). These overall results obscure even more dramatic differences at the fuel level. For example, realization rates for OEP ranged from 45% for therms to 180% for kW. Contrast these results with those for BTU, where the therm realization rate was 149%, while the kWh rate was 35%. As a point of comparison, evaluated results for the San Diego retrocommissioning program, using only checks of implementer data and calculations to verify savings, showed realization rates of 158% for kWh and 188% for kW. The latter study report points out that these results are not to be considered as reliable as those that used independent, on-site M&V.

The varying realization rates for the OEP, BTU, and MBCx programs point again to the difficulty in estimating ex ante savings. When the evaluated savings for each program are normalized by building area, the program results are somewhat consistent, although it should be pointed out that the floor areas are in some cases rather indeterminate, and so normalization should be considered a very crude method of comparison (for example, the MBCx areas include all building areas affected by central plant projects, providing a somewhat different metric than the project savings for a given building).

Measure-level savings

Figures 2 and 3 compare evaluation savings to program claimed savings at the measure level for electricity and natural gas, respectively. These data are available for OEP and BTU only. The diagonal line represents a realization rate of one, i.e., instances where the evaluated savings matches the claimed savings. The plots show a tremendous amount of scatter, with actual savings often being much higher or lower than the program estimates. Two cases in point: (1) an electric measure where the predicted savings of 680,000 kWh/year ultimately yielded large negative savings of -1,400,000 kWh/year because another measure compromised HVAC performance, and (2) a gas measure where the actual savings of 270,000 therms/year far exceeded the ex ante estimate of 57,000 therms/year. The plots also reveal that a not insignificant number of measures yielded little or no savings.

For the OEP and BTU programs, one of the primary reasons why electrical savings fell short of claims was that in many cases, measures were only partially or ineffectively implemented, or were negated by subsequent changes. At times, it was uncertain whether program implementers and/or participants thoroughly checked whether recommended measures got implemented effectively, so many times the measures did not save as expected. In some cases, customers attempted to implement measures (such as retrofitting constant volume HVAC systems with variable speed drives and reducing fan speeds), but changed the measures back after getting complaints from building occupants. A number of projects did not investigate the interrelationship between measures and recommended repairs, so when the customer did not complete the repairs, it prevented the measures from yielding recommended savings. These observations point to the care that must be taken balancing energy savings from retrocommissioning against proper building function and comfort. In some cases, retrocommissioning measures can improve building comfort and function, but in doing so, increase overall energy use.

Savings Persistence

The bulk of savings for the OEP and BTU programs is expected to last about three to five years, as Figure 4 illustrates. The majority of measures implemented through the program consisted of HVAC control logic, set point, and schedule changes, as well as some control repair and recalibration. The expected lifetime for such measures ranges from three to five years, per the assumptions in Table 2. We deviated from these assumptions in cases where the evaluation uncovered clear evidence that a measure would not last as long as expected (for instance, if facilities staff told us they planned to raze a building or replace an air handler within a certain number of years). The overall savings from the program are expected to remain at first-year levels for the first three years, and then drop off by up to 30% for the next two years. By Year 6 and beyond, energy savings are expected to be less than 40% of first-year levels. The OEP and BTU programs originally estimated an effective useful life for measure savings of eight years. The MBCx program projects an average savings lifetime of 15 years—higher than the other two programs perhaps owing to the hope that permanent monitoring will help maintain savings. At this point in time, no additional data exist for updating this estimate.

Table 3: Comparison of projected, claimed, and realized program savings

		Oakland Energy Partners	Building Tune-Up	Monitoring-based Cx *[preliminary*]*
PROGRAM GOALS	Projects	44	150	35
	Area (sq. ft.)	10,450,000	36,000,000	17,500,000
	Energy savings (gross)			
	kWh/year	16,689,450	37,004,852	8,031,481
	kW	4,576	10,148	893
	therms/year	-	1,285,284	524,201
	million Btu/year	56,961	254,826	79,832
	Normalized savings			
	kBtu/ft2/year	**5.5**	**7.1**	**4.6**
CLAIMED RESULTS	Projects	19	36	51
	Area (sq. ft.)	9,293,300	16,058,469	17,500,000
	Energy savings (gross)			
	kWh/year	4,869,913	23,879,091	8,800,000
	kW	160	1,112	1,000
	therms/year	569,400	338,537	319,000
	million Btu/year	73,561	115,353	62,000
	Normalized savings			
	kBtu/ft2/year	**7.9**	**7.2**	**3.5**
EVALUATED RESULTS	Projects (evaluated only)	12	17	7
	Energy savings (gross)			
	kWh	3,084,191	8,326,068	*[PENDING]*
	kW	287	1,837	
	therms	256,599	504,265	
	million Btu	36,186	78,843	
	Normalized savings			
	kWh/ft2/year	0.33	0.52	
	therms/ft2/year	0.03	0.03	
	kBtu/ft2/year	**3.9**	**4.9**	
	Realization rates			
	kWh	63%	35%	
	kW	180%	165%	
	therms	45%	149%	
	million Btu	**49%**	**68%**	

* MBCx numbers are based on rough, preliminary tracking database and are likely to change.

Figure 1: Comparison of projected, claimed, and realized program savings

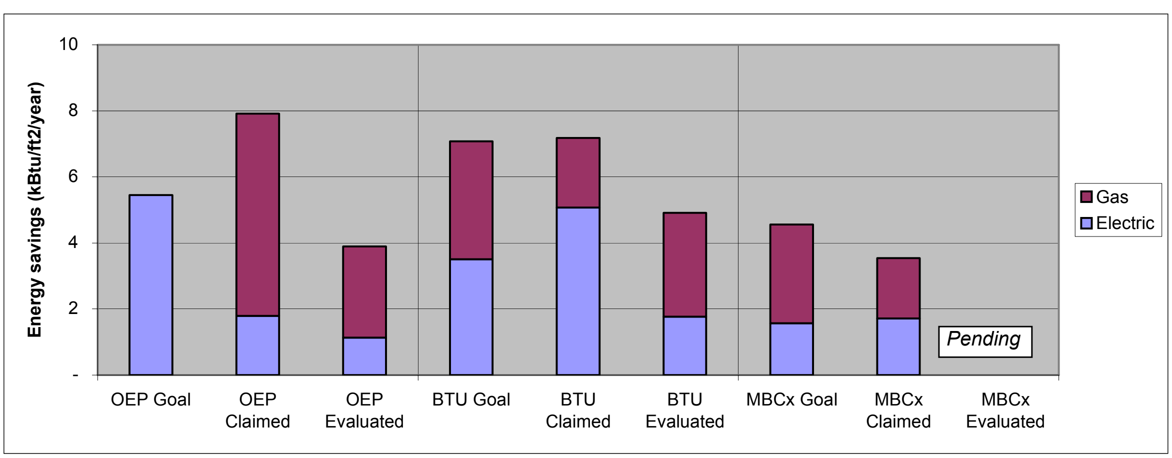


Figure 2: Claimed vs. evaluated electric savings for studied measures

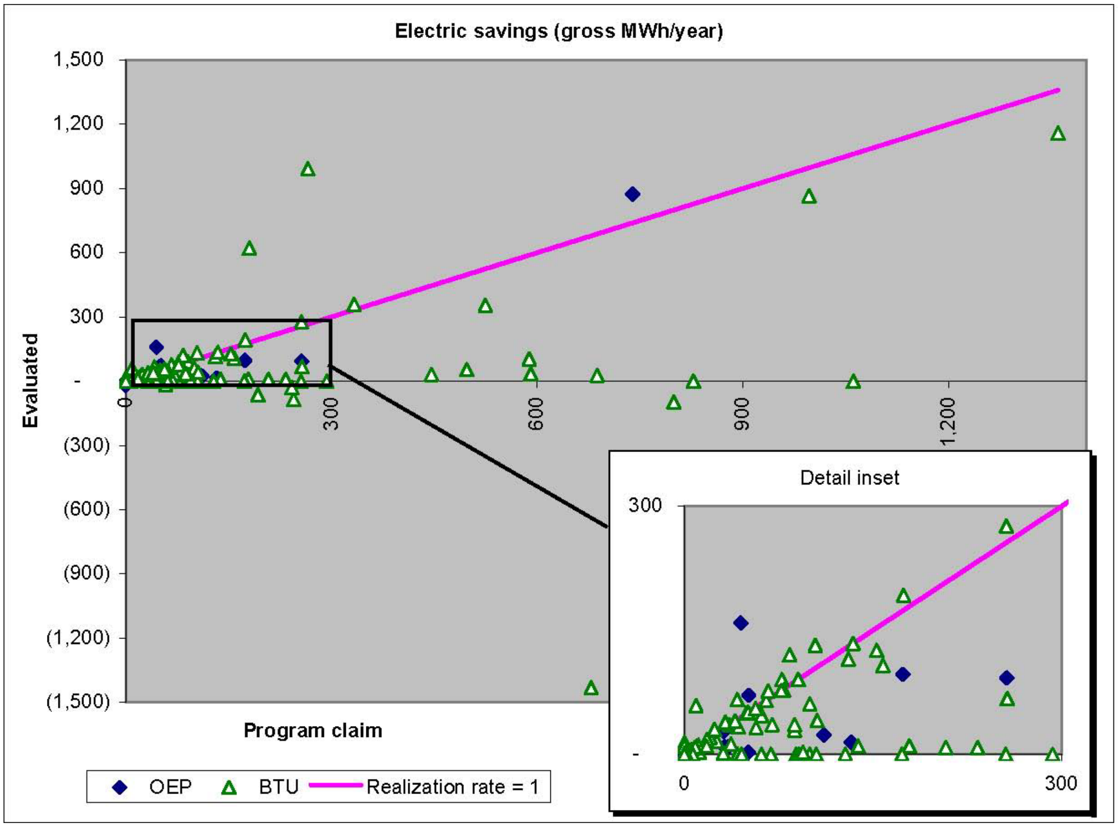


Figure 3: Claimed vs. evaluated natural gas savings for studied measures

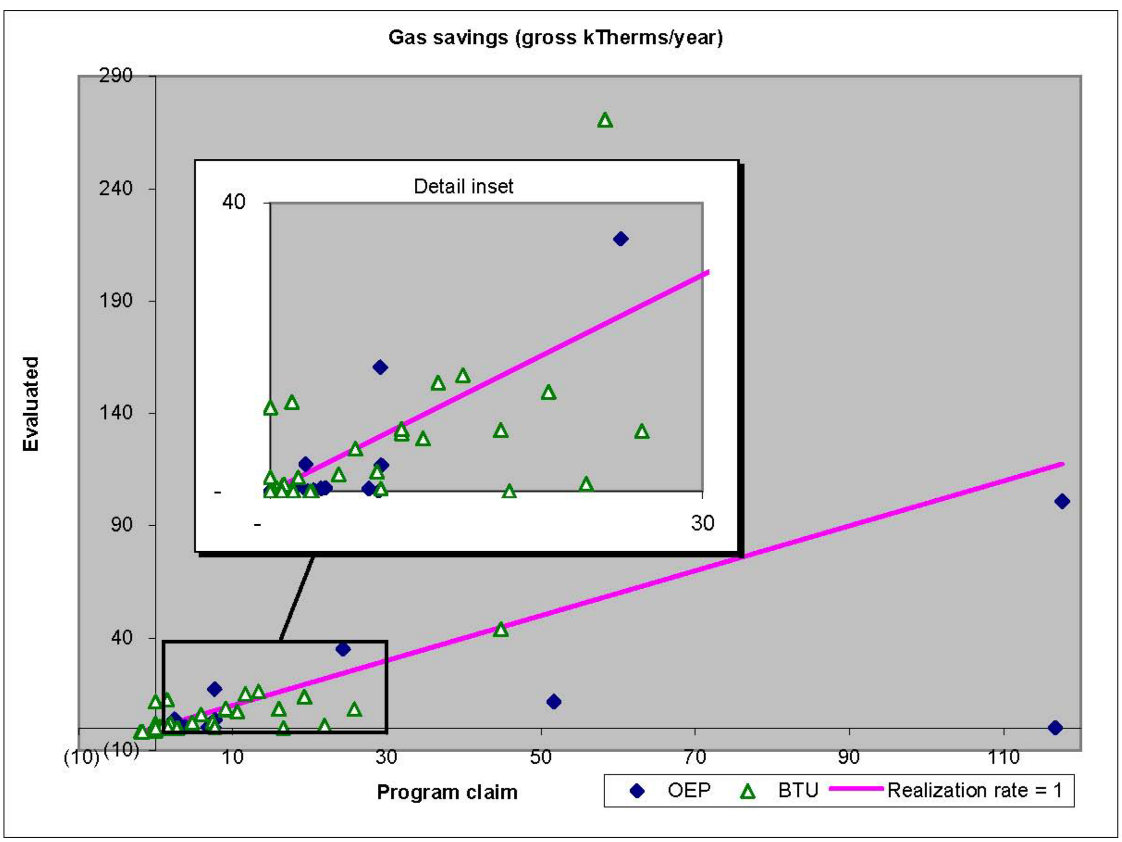
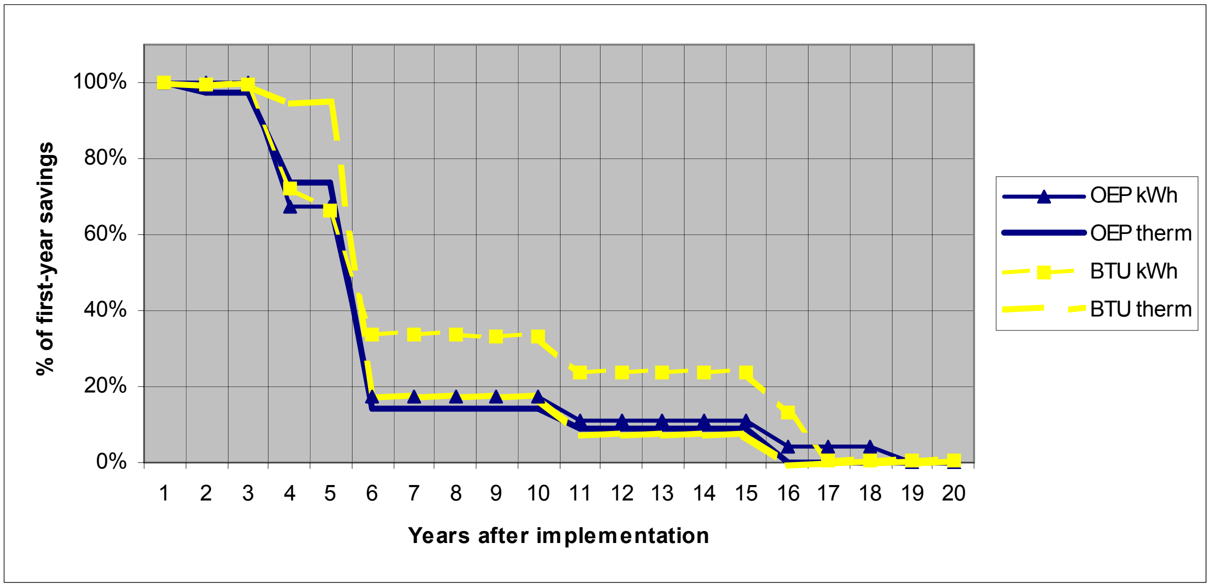


Figure 4: Evaluation projections of lifetime program savings



Conclusions and Lessons Learned

The advent of numerous utility- and publicly-funded retrocommissioning programs speaks to the enormous energy savings potential that large commercial facilities provide. The impact evaluations of the OEP, BTU, and MBCx retrocommissioning programs have shed some light on important aspects of these programs. Among the key conclusions we have reached are the following:

1. **Flexibility and cooperation between the implementer and evaluator can contribute to a successful, well-verified program**. The complexity and length of retrocommissioning programs pose special difficulties for both implementers and evaluators. These include the long duration of the RCx projects, with corresponding personnel turnover at sites, as well as the uncertainty over what problems will be found, what measures will ultimately be implemented, and the actual energy savings effect of those measures. These challenges in turn make impact evaluations of such programs particularly challenging for program evaluators. Implementation of commissioning projects or measures often takes much longer than expected, making it challenging to allocate evaluation resources appropriately. Ongoing cooperation and communication between the program implementer and evaluator are important during the evaluation process. In addition, the actual retrocommissioning measures observed onsite during evaluations often differ dramatically from what was recommended. Consequently, evaluators must be prepared to adapt the study approach in real time when evaluating these types of programs.
2. **Commissioning measures helps ensure savings are realized**. Meeting program savings goals can be difficult because of challenges getting customers to implement, as well as determining the actual impacts of the changes**.** Actual gross savings from these programs can vary widely from claimed savings, often because building operations are generally quite dynamic.

3. **“Commissioning the retrocommissioning” is an important step for programs to include, since system changes do not always work as intended**. Some, if not most, of the issues with poor measure performance or low savings might have been forestalled with careful checking and adjustment after implementation.

4. **Diligent M&V at all stages of the program can improve savings estimation**. Improved baseline documentation and measure tracking can improve the ability to evaluate tune-up programs. As the wide range of measure realization rates we found suggests, accurately estimating savings from common tune-up measures can be very challenging, as the measures are complex and the effects subtle. Such estimating can be confounded by difficulties collecting reliable data and challenges trying to predict how a facility might actually implement measures. Given these factors, the importance of on-site measurement and verification after measure implementation cannot be overstated. These verification activities should be consistent, yet adaptable to match specific site conditions and savings, so that the time and budget expended remain reasonable. Specific guidelines for improving predicted and realized savings include:

    a. Capture baseline conditions thoroughly: Meticulous documentation of baseline conditions is critical to good impact evaluations of retrocommissioning programs. Given the inherent uncertainty about whether facilities will ultimately implement measures, and the nature of evaluation sampling for such programs, it is unlikely that an evaluator will be in a position to collect adequate baseline data for evaluated measures. In addition, the complexity of many tune-up measures, and the oftentimes long delay between a measure being recommended and implemented, make it doubly important to clearly explain initial conditions and assumptions.
    b. Use best possible measurements and assumptions to estimate savings: Use measured true kW of power draws for electrical loads whenever practical. For variable loads, perform short-term monitoring for large-saver measures to establish load profiles and performance curves. If this is done, take care when extrapolating these results to a typical year. Be sure to apply part load efficiencies as appropriate for chiller measures.
    c. Take post measurements to verify performance and savings: Post-installation inspections should incorporate measurement and verification beyond simply checking that measures were implemented. Program implementers are already familiar with the project facilities and staff, as well as the savings analysis, so the incremental cost of doing so should be small. Such an investment could dramatically improve the accuracy of the final claimed savings estimates.

5. **More work is needed to see if savings last, and if not, how to make them last**. Although we have early predictions of program savings persistence, future studies should address whether certain program elements are effective as claimed at maintaining program savings levels for many years. Examples of these elements are operator training—educating facility staff on properly maintaining equipment so savings will persist—and permanently installed metering, so operators can easily diagnose and fix energy-wasting problems. These studies should also explore the effectiveness of various preventive or predictive maintenance strategies, such as regular monitoring and system checkups, for cost-effectively prolonging efficient building operations.

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