Results from a Comprehensive Impact Evaluation of the 2006-08 California Retro-Commissioning Portfolio

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ABSTRACT

This paper presents the results of the California Public Utilities Commission's (CPUC) statewide evaluation of all retro-commissioning (RCx) activity in the 2006-08 program cycle. This effort is the largest primary study of RCx undertaken to date. The activities studied included over 22 programs—including partnerships, general-purpose programs, and those targeting specialized market segments—and over 220 projects. This paper presents the methodology and results of the rigorous evaluation of portfolio gross and net savings. Information from this evaluation has provided policy-makers with useful feedback on the cost-effectiveness of RCx as an energy efficiency strategy, as well as information on ways to improve future programs.

The gross impact evaluation examined in detail RCx efforts in 50 facilities. Facility energy savings analyses relied on a variety of techniques and data sources, including short-term metering, one-time measurements, customer records, and on-site interviews and observations. These analyses findings were compared to the utility claimed savings. Across all utility RCx programs, the evaluation determined that 62% of the gross claimed total energy savings (MMBTU/year) were realized.

Evaluation of net impacts for 123 projects relied on a self-report approach consistent with CPUC guidelines. Project-specific, measure-weighted net-to-gross ratios were calculated for each RCx project using information from reviews of secondary and program data, as well as in-depth interviews with decision makers, program managers, account representatives, and others. The net analysis found low levels of free ridership, with NTGRs generally above 0.80, indicating that most improvements would not have happened without the interventions of the utility programs.

Introduction

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 retro-commissioning (RCx), can dramatically improve building performance through custom-engineered, site-specific combinations of recommended actions designed to optimize all or a portion of a facility's energy systems. Utility-sponsored RCx programs, as a rule, naturally focus on saving energy while maintaining satisfactory operation. 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, with estimates of savings averaging 15% of pre-commissioning usage (Mills, 2004). Numerous energy utilities nationwide have developed retro-commissioning 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 evaluations of the actual results of these programs exist.

Since RCx emerged as a viable energy efficiency strategy over a decade ago, California utilities have increasingly incorporated it into their portfolios, and numerous third-party programs have sprung up to tap the savings potential. In the California 2006-08 program cycle, ten programs were initially identified as focusing primarily on RCx for energy savings. In addition, numerous other programs included a substantial RCx component—most notably the University of California/California State University/Investor Owned Utility (UC/CSU/IOU) Partnership and the Los Angeles County Partnership. Furthermore, once all programs in the cycle concluded, the evaluation team discovered other programs had included small numbers of RCx projects as well. Ultimately, we identified 28 programs, which collectively claimed 260 completed RCx projects over the 2006-08 program cycle, for inclusion in our comprehensive evaluation. These programs are listed in Table 1, along with the number of RCx projects completed through each. Programs offered by different IOUs that had very similar design and markets are listed as a group.

The CPUC Energy Division's original objective for this evaluation was to develop results specific to each program. Many of these programs, however, ended up falling far short of their initial project completion goals, rendering program-level results of less value. Because of this, as well as other reasons affecting the entire energy efficiency portfolio, the evaluation approach shifted to a utility-specific focus, where all RCx activities completed by a given utility, regardless of program, were grouped together for evaluation purposes.

Analysis Methodology

Below we discuss how the evaluation team sampled projects for the net and gross savings evaluations, and briefly describe the methods by which we conducted these efforts. Note that the overall study also included an investigation of effective useful life for RCx measures, but this topic is addressed in a separate paper (Roberts, 2010).

Sampling

Depending on the program design, some programs supported projects that encompassed low-cost RCx actions, such as changing control setpoints, as well as conventional retrofit measures, such as installing efficient light fixtures. Of the 260 claimed projects, 35 projects that consisted mainly of retrofit actions were excluded from the evaluation. Our samples were drawn from a list of the remaining 225 completed RCx projects. Samples were designed to provide separate estimates of savings for each investor-owned utility (IOU). Stratified random sampling was used to minimize sampling error. Stratification was based on the program's initial (ex ante) estimates of gross savings (MMBTU/year), on the assumption that these estimates would serve as a good predictor of the associated actual (ex post) savings. The net sample included all projects in the gross sample, as well as additional sites so that overall, half of the population was included in the evaluation.

Table 1. Summary of Evaluated Programs

Programs Included in this evaluation*		#/% of RCx Projects**	
PGE2036, SCE2530, SCG3520, SDG&E3029	UC-CSU-IOU Partnership (state universities and investor-owned utilities, retrofit and monitoring-based Cx projects and education)	54	21%
SCE2528, SCG 3527	County of Los Angeles Partnership	53	20%
PGE2007	Office Buildings (Large Commercial)	28	11%
SCE2508	Retro-Commissioning (general)	22	8%
PGE2094	Macy's Comprehensive Energy Management	18	7%
PGE2091	Retrocommissioning Services and Incentives	15	6%
PGE2015	Partnership - Association of Bay Area Governments	10	4%
PGE2002	Schools and Colleges	10	4%
PGE2052	Lodging Savers	9	3%
PGE2072	Hospitals Pilot	7	3%
PGE2070	Data Centers	5	2%
PGE2032	Partnership - Sonoma County	4	2%
PGE2005	Hi-Tech Facilities	4	2%
PGE2088	State Leased Facilities	3	1%
PGE2071	Hospitality Energy Efficiency Program	3	1%
PGE2056	Monitoring-Based Persistence Commissioning	3	1%
PGE2035	Partnership - Silicon Valley Leadership Group Energy Watch	3	1%
SCE2526, SCG 3518	California Community Colleges Partnership	2	1%
PGE2025	Partnership - Marin County	2	1%
PGE2006	Medical Facilities	2	1%
SDGE3010	Energy Savings Bids	1	0.4%
PGE2090	Airflow and Fume Hood Control Systems Re-Commissioning	1	0.4%
PGE2001	Ag & Food Processing	1	0.4%
Total		**260**	**100%**

* PGE=Pacific Gas & Electric, SCE=Southern California Edison, SCG=SoCalGas, SDGE=San Diego Gas & Electric.
** Some of these projects consisted predominantly of standard retrofit-type measures, and thus were not included in the RCx study.

The final sample frame was developed to clearly define the population of RCx projects. Although information was available about most of the measures comprising the projects, we opted to sample projects, because measure savings are so highly interactive within a project. Another complication was that the utilities defined measures very differently. As shown in the results section, we were, however, able to disaggregate savings for some individual recommendations in the sample projects and draw some general conclusions about which types of recommendations yielded the most savings, to inform future program planning efforts.

Gross Savings Evaluation

The evaluation approach ultimately implemented called for the development of evaluated savings estimates by utility, rather than by program. The resulting cross-program samples were designed to be large enough to provide utility-level estimates of RCx performance. These estimates can inform statewide RCx realization rates that may be applied generally. This approach provided more robust assessment of RCx performance across each utility's RCx portfolio, but less information about program performance.

Our gross impact evaluation approach ultimately focused mainly on project-level analysis. While in many cases, we developed savings estimates for each RCx measure, only project-level results were used to extrapolate gross results to the population. Site-specific M&V plans were developed for each project, using a combination of engineering analysis and building simulation methods (the latter were used in instances where the program had already developed a workable simulation model). These plans detailed the RCx measures, algorithms, data elements, sampling strategies, and other key factors in the savings analysis. Both engineering and building simulation analyses were supported by extensive on-site data collection as specified in the site M&V plan, including, as appropriate, inspection, metering/trend logging and interviews with building operators and the commissioning (Cx) agent who performed the RCx study, thus allowing evaluation analysts to understand each site's systems, as well as the proposed and implemented measures. Analysts maintained flexibility to adjust site plans as needed to deal with field contingencies and other unforeseeable circumstances.

Net Savings Evaluation

Our net analysis of the RCx efforts utilized the same self-report approach developed and applied to all Large Nonresidential measures and programs in the CPUC 2006-08 portfolio. The self-report option involves asking one or more key participant decision-makers a series of structured and open-ended questions about whether they would have implemented the same measures in the absence of the program. We chose this approach because alternative methods of estimating the net-to-gross ratio (NTGR), such as discrete choice or billing analysis were not practical in light of the limited number of projects, the heterogeneity of participating customers, and the small impacts relative to overall energy usage.

In applying the self-report approach, we used two levels of rigor in the net analysis. The higher rigor level, which was used for the 50 gross impact sites, integrated information from other sources besides the customer interview, including utility program managers, program staff and, vendors, thereby allowing us to tell the full story behind each organization's decision to proceed with RCx recommendations and the role that the programs played in causing the work to occur. The lower rigor level was used for the projects that were not in the gross impact sample. We used the same standard data collection instrument and algorithm to calculate the NTGR for these projects, but did not bring in the additional noncustomer viewpoints to support the analysis.

Findings

Table 2 and Figure 1 summarize gross and net evaluation results by utility and across the statewide portfolio. These results include sample sizes, realization rates, net-to-gross ratios, and savings per project.

Gross Impact Results

The gross impact analysis resulted in overall gross realization rates of about 0.62 for peak kW, annual kWh and therms, and corresponding net-to-gross ratios ranging from 0.80 to 0.88.

The number of RCx projects varied widely between the utilities. PG&E claimed 135 projects, or 60% of the RCx population of 225 projects. In contrast, SDG&E claimed four projects, all of which occurred at the same university campus. Figure 1 illustrates how, on an energy basis, the PG&E RCx projects accounted for about half of the claimed and evaluated savings. PG&E projects as a whole had relatively low realization rates for both electric and gas energy savings (0.45 and 0.53), compared to SCE and SDG&E, which had realization rates that varied between gas and electric savings. The sole gas-only utility, SCG, had a therm realization rate of 0.93. These differences may reflect the diversity of programs and program delivery models at PG&E. By comparison, the savings claims for SCE and SCG were dominated by two local government partnership programs, UC/CSU/IOU and Los Angeles County.

Reasons for differences. To investigate major reasons why the claimed and evaluated gross savings were different, we reviewed the site M&V reports and calculations for all gross impact sites and identified 83 significant reasons for differences between the program and evaluation savings in the sample. Over 75% of these reasons tended to reduce savings. Critically, nearly half of these savings-reducing reasons were instances where the RCx measure was no longer operational. Put simply, the most common reason why savings fell short of the claim was that measures were not working anymore. Other common reasons for differences included discrepancies between program calculation assumptions and actual conditions, changes in building operation, and measures being only partially implemented.

Measure classification. We also developed a scheme to standardize RCx measures by the building system and general strategy. This helped us understand the classes of measures and systems that yield RCx savings. Extrapolating the sample to the RCx population, we estimated that the 225 projects comprised 623 measures, or slightly less than three per project. This includes unclassifiable projects, where individual measures could not be broken out for analysis purposes and the project was counted as having one unclassified measure. As shown in Tables 3 and 4, the most common system class was HVAC air distribution systems; the most common measure class was improving control strategies, with each accounting for more than one-third of measures installed. Generally, though, the measures and savings appeared distributed fairly evenly among the systems and classes, so that no one system or class dominated.

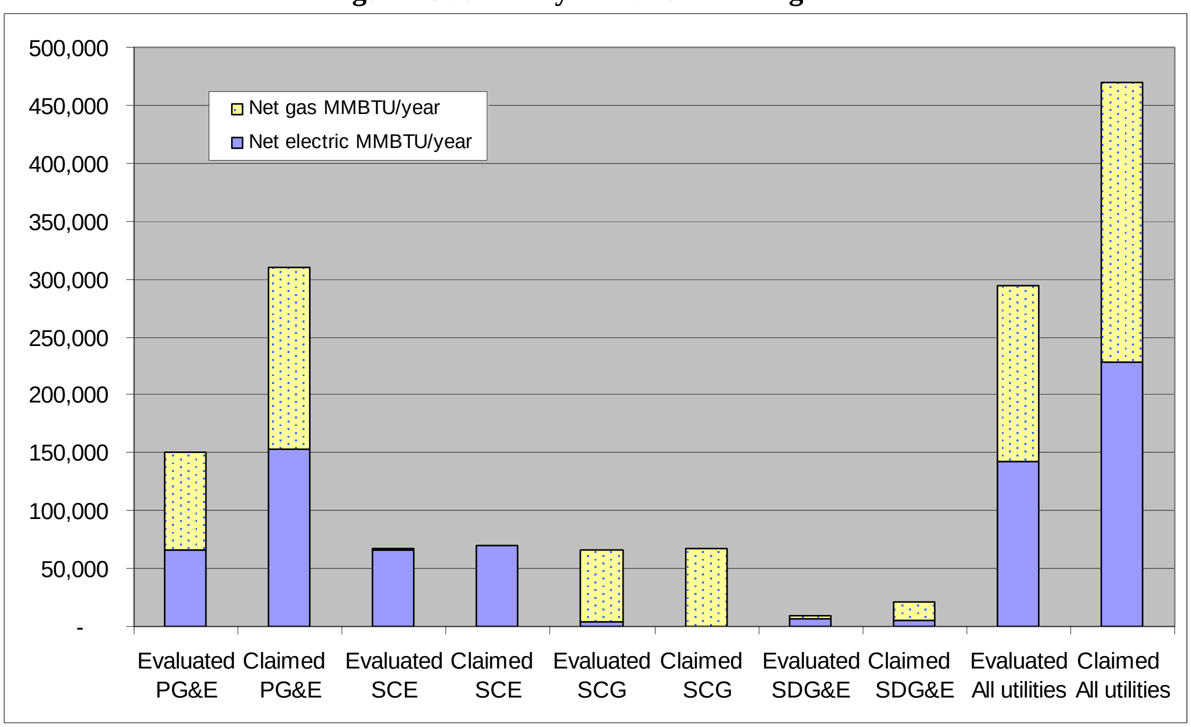
Table 2. Summary of Evaluated Programs

Utility (a)	Number of projects			Gross savings realization rate (b)				Evaluated gross savings per project (c)			
	Popu-lation	Net sample	Gross sample	Peak kW	kWh /year	Therms/ year	MMBTU/ year	Peak kW	kWh /year	Therms/ year	MMBTU/ year
PG&E	135	73	24	0.31	0.45	0.53	0.49	13	178,355	7,334	1,342
SCE	58	29	13	2.07	0.94	N/A	0.97	30	383,712	462	1,356
SCG	28	15	10	N/A	N/A	0.93	0.97	6	28,781	23,735	2,472
SDG&E	4	3	3	2.60	1.23	0.21	0.45	129	606,849	11,454	3,217
All (d)	225	120	50	0.62	0.63	0.62	0.62	23	227,543	9,075	1,684

Utility (a)	Evaluated net to gross ratios			Net savings realization rate (b)				Evaluated net savings per project (c)			
	kW	kWh	Therms	Peak kW	kWh /year	Therms/ year	MMBTU/ year	Peak kW	kWh /year	Therms/ year	MMBTU/ year
PG&E	0.76	0.80	0.86	0.28	0.43	0.54	0.49	10	142,684	6,307	1,118
SCE	0.78	0.86	0.91	1.86	0.93	N/A	0.96	23	329,992	420	1,168
SCG (e)	N/A	N/A	0.92	N/A	N/A	0.91	0.94	5	23,121	21,836	2,263
SDG&E	0.75	0.75	0.68	2.64	1.25	0.19	0.44	97	455,137	7,789	2,332
All (d)	0.80	0.84	0.88	0.59	0.62	0.63	0.62	15	180,816	6,862	1,303

(a) PG&E: Pacific Gas & Electric; SCE: Southern California Edison; SCG: Southern California Gas; SDG&E: San Diego Gas & Electric.
(b) The realization rate is the ratio of the evaluated savings divided by the savings claimed by the utility.
(c) For evaluation purposes, some projects for individual customers were treated as separate SCE and SCG projects, lowering the per project average somewhat.
(d) Based on savings per project multiplied by project counts. Utility results with N/A values cause calculated values to appear skewed.
(e) Although no NTGRs were developed for SCG kW and kWh, we applied average NTGRs from the other utilities to estimate net savings.

Figure 1. Summary of Evaluated Programs



We had hoped through this analysis to identify particular measure or system classes that might be particularly ripe targets for achieving RCx savings—if, for instance, we had observed that 60% of the kWh savings resulted from the 10% of central plant measures. The numbers in these tables, however, revealed no such obvious targets for future programs.

Analysis approaches. Table 5 below summarizes the analytical approaches used for the gross sample projects. For most sites, we relied upon extensive trend and/or logger data, coupled with a custom spreadsheet-based engineering analysis. For about a quarter of the projects, the program had created a calibrated building simulation (eQUEST®) model, which we subsequently modified with evaluator-collected post-implementation data. In one instance, the evaluation team created a new building simulation model. Five projects required analyses structured around whole building or whole system (e.g., chilled water use, hot water use) metering data provided by the customer or utility. Of the remaining three projects, two had poor baseline data, so the analyses were simply verifications that the measures had been installed and were operational, and one project had been completely disabled, and thus required no analysis.

Net Impact Results

Overall, NTGR scores were relatively high, reflecting the continued influence of a variety of programs on the motivation and ability of organizations to pursue RCx projects. Project NTGR scores averaged more than 0.50 for almost all fuel type and size strata, and the overall mean was significantly higher for all IOUs, as shown in Table 2.

Table 3. : Percent of Evaluated Savings, by Building System Class

Type of System	% of Measures	kW	kWh	Therms
Central plant	19	22	20	19
HVAC (general)	29	18	12	41
HVAC (air distribution system)	36	18	37	34
Other/unclassified	17	41	32	6

Table 4. : Percent of Evaluated Savings, by Measure Class

Type of Measure	% of Measures	kW	kWh	Therms
Improve control strategies	36	38	29	48
Improve outside air use	13	9	14	4
Improve scheduling*	18	-3	11	28
Other/unclassified	17	40	29	12
Install/replace variable speed drive	16	15	16	7

*The negative demand savings are driven mostly by a single measure at a single site, where revised chiller schedules led to higher demand over the 3-day peak period.

Table 5. Gross Analysis Approaches

Evaluation Gross Analysis Approach	# of projects
Detailed monitoring / custom analysis	28
Building simulation - updated program model	13
Building simulation – created new model	1
Whole building/system analysis	5
Verification	2
None needed	1
Total	**50**

Reasons for the NTGR scores include the following:

- Programs that cover all or part of the cost of the RCx study reduce the risk associated with an RCx project significantly and lead many organizations to proceed with the project. Incentives that cover the cost of the study received the highest mean rating for all program influences cited by respondents—even higher than incentives for implementing recommended measures.
- RCx programs also make projects possible by helping offset funding cutbacks, staffing shortages, and reductions in maintenance budgets, particularly in public institutions, but also in hard-hit private sectors such as office buildings and the hospitality industry.
- The most significant non-program influences in the decision to pursue RCx projects appear to be government or corporate policies that require or encourage implementation of energy efficiency or other "green" measures.

Recommendations and Conclusions

Key recommendations and conclusions from the net and gross elements of the evaluation are presented below. For gross impacts, recommendations are organized by whether they have implications for program design and implementation, evaluation, or future research.

Based on our findings and observations from the gross impact evaluation, some potential improvements that could benefit future RCx programs include:

1. <u>Provide program participants with adequate follow-up RCx services</u>. Once RCx service providers have identified RCx opportunities, maintaining the value of those findings requires sustaining a long-term relationship with customers to make sure the measures are implemented correctly and maintained properly over time. We found frequent examples where measures failed soon after implementation, such as with economizer repair measures. Future programs might consider if there are cost-effective interventions and sustained follow-up strategies that might mitigate such failures.
2. <u>Reduce RCx service providers' burden for quantifying energy savings</u>. The corollary to the recommendation above is that programs should be designed to minimize the RCx service provider's responsibilities to perform rigorous calculations and analysis to back up utilities' claimed savings. Estimating savings to the level of rigor necessary for a utility claim is a complex, challenging endeavor that requires specialized analytical skills.

It might make more sense to have utility staff or their consultants perform separate, more rigorous, post-implementation M&V studies to back up their savings claims.

3. Provide RCx service providers with simple, straightforward tools to quantify costs and savings. The quantification only need justify projects to customers. This is particularly true for well-established, clearly cost-effective measures such as changing HVAC setpoints or schedules. These tools might include broadly accepted methods for estimating complex parameters that are critical to good estimates of savings, such as boiler and chiller efficiencies, and the effect of cogeneration systems.
4. Give program staff primary responsibility for collecting baseline data. Program staff and the RCx service providers are in the best position to collect all-important baseline data. Program implementers should bear primary responsibility for collecting and clearly documenting and archiving baseline information for future savings verification. This data collection would mainly consist of information RCx service providers naturally come across during their investigations, such as photos, notes, EMS trend data and screen shots, and one-time measurements.

Improvements that could help future RCx program or technology evaluations include the following:

5. Improve baseline data collection. Good baseline data is critical to accurate savings estimates, particularly for measures where the baseline is inherently uncertain, such as those involving broken dampers, stuck valves, or sequencing strategies. As noted above, it is generally most expeditious to have customers and/or RCx service providers collect this information, and then record and maintain it in program tracking systems.
6. Specify post-only sample designs. With RCx programs, it is nearly impossible until after the program ends to know which projects, and which measures within those projects, will be claimed as complete. A pre-post sample design requires tracking projects throughout the cycle and collecting baseline data for projects that ultimately fall away, and thereby result in wasted evaluation resources. Switching to a post-only design would redeploy those resources towards increasing the sample size, reducing the sampling error.
7. Balance the need for accurate first-year savings against the need to track savings over time. While it is important to develop rigorous estimates of first-year gross savings for RCx projects, it is equally important to understand how those savings change over time. A significant number of RCx measures fail within a year or two of implementation, making it imperative to track how RCx savings degrade and how programs might be designed to minimize this degradation through appropriate interventions.
8. Maximize time allotted for onsite data collection. The evaluation schedule should allow as much calendar time as possible for field data collection, to support seasonal analyses and the oftentimes iterative process of data collection, analysis, and quality control.
9. Minimize the use of whole-building analysis. Using billing records or interval data to estimate savings, per IPMVP Option C, can be appropriate in limited circumstances. But since this approach does not analyze how individual devices and systems are functioning, it makes it nearly impossible to (a) determine whether particular measures are functioning well and the reasons why, or (b) to adjust for external factors that could also be changing facility-level energy use. This leads to a high degree of uncertainty in the analyzed savings. Partially- or fully-measured retrofit isolation (IPMVP Options A and B) provide

more definitive results, but some of the prior recommendations would need to occur to make such an approach practical.

Areas that could benefit from additional research in the future include:

10. Continue refining the measure classification scheme. This evaluation developed a general scheme for grouping RCx measures. This scheme filled a need, since RCx measures are fundamentally different from conventional retrofit program measures for which other classification schemes already exist. Further analysis of these data, along with data from future programs, could determine the amount of savings that a particular measure at a particular size or type of site might yield. This in turn could help program implementers and evaluators focus their resources on the most attractive measures. Lawrence Berkeley National Laboratory recently underwrote a detailed study of RCx measure cost effectiveness (PECI, 2009)--integrating findings from that work with data from this evaluation could yield additional insights.
11. Study the relative effectiveness of different programmatic approaches. The programs in this evaluation used diverse approaches and delivery strategies. A combined process and impact evaluation that compared results for different RCx approaches could yield insights into best practices and effective designs for future RCx programs. It is also advisable to link the process and impact evaluations of RCx, when possible. The highly technical and complicated nature of RCx projects often requires process evaluators to work closely with gross impact evaluators with strong engineering backgrounds to assess the programs.
12. Compare Retro- and Monitoring-based Commissioning. A related research issue is the comparative efficacy of monitoring-based commissioning (MBCx) and standard RCx in creating and maintaining savings. On the one hand, MBCx provides facility managers with powerful tools to sustain energy savings; on the other hand, utilizing those tools effectively may require more time and training than building professionals typically have available.

Conclusions and recommendations related to net impacts are listed below. They reflect the finding that, in the current economic climate, businesses and non-profit organizations face very limited funds to pursue RCx projects in the absence of assistance from utility or other programs. We believe customers will continue to need incentives and technical assistance to make these projects happen.

13. Specifically, incentives to cover the cost of the RCx study and remove the risk associated with initiating such a project are critical to encouraging RCx activity and were rated higher than any other factor for their influence on the decision to RCx. Such incentives should remain the foundation of RCx programs.
14. Requiring implementation of all measures that meet specific payback criteria (e.g. one year) with no additional incentive also helps ensure that recommended measures are actually implemented. This requirement could also be modified so that if more of the initial study cost is covered, measures with a somewhat longer payback period could be required.
15. Partnership programs appear to have a powerful influence in promoting projects that otherwise would not happen; as such they should be continued in order to sustain high net

savings for RCx projects. The current financial status of partner organizations should continue to be monitored, but it seems unlikely that budget concerns will disappear and enable universities and local government to pursue RCx projects using only their own resources in the near future.

16. A project screening process before the RCx study is initiated is strongly recommended to ensure that the proposed project is not already scheduled for a similar review and analysis.
17. Sustainability and green policies help encourage organizations to pursue RCx projects through utility sponsored programs, but may also represent a potential source of free ridership. Their growth and application by both private and public sector organizations should be monitored as it affects the RCx market, particularly if evidence arises—either in California or elsewhere—that such policies are causing organizations to pursue RCx outside of utility programs.
18. In addition, we recommend consideration of using other aspects of the interaction between decision makers and program staff, such as observation of standard operating and maintenance procedures, to help establish a solid understanding of baseline practice with regard to RCx.
19. As part of the program application process, customers could be asked to provide information on their knowledge of and experience with RCx, including corporate or organizational policies, payback and other investment decision criteria, and practices at facilities elsewhere in the country, particularly in areas without utility programs in place. Documenting this information at the time of the application would provide program managers and evaluators with a detailed picture of actual organizational practices and provide context to help judge the extent of program influence.

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