Persistence in Energy Savings From Retro-Commissioning Measures

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Commissioning and retro-commissioning (RCx) are critical steps to ensure that a building performs at its best. But commissioning and RCx are truly effective only if their impacts last over time, which cannot be taken for granted. We took a deep dive into dozens of RCx projects in Illinois to determine long-term persistence of savings from RCx and what drives that persistence.

Retro-commissioning is the process of making low-cost adjustments to an existing building's operation to improve its energy performance. Most often, these adjustments are changes in sequences of operation in HVAC controls, such as temperature or airflow resets, or scheduling changes. Retro-commissioning is most often implemented over a period of time by a team made up of the RCx consultant, controls technician, and a building operator. Traditionally, once the period of RCx has passed, the consultant departs the team and the controls tech and building operator try to maintain building operation as adjusted by the RCx process. However, building operators and controls techs have objectives other than just energy performance: keeping occupants satisfied, maintaining equipment, and conducting retrofits and replacements. As a result, anything from comfort complaints to simple equipment maintenance can lead to altering or even disabling some RCx adjustments.

When RCx adjustments are altered or disabled, the energy-saving measure in question no longer fully *persists*. That is, the energy savings from that measure has decreased from what it was when it was first implemented. Persistence is the measure of how energy savings last years after a RCx effort is complete. It is an important consideration because many commissioning and RCx efforts, and often the energy-efficiency programs that support them, are justified based on maintaining the initial energy savings year after year. ComEd, an Illinois utility serving the greater Chicago area, was interested in understanding how well energy savings from its RCx program were persisting; how long they could depend on the savings to last for each customer that went through the program.

Considering the magnitude of energy savings at stake, there has been surprisingly little research on the topic of persistence of energy savings from commissioning

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or RCx. As a result, one of ComEd's independent energy-efficiency consultants, undertook a substantial primary data collection effort, ultimately visiting 28 separate buildings and investigating 167 individual measures.

The primary objectives of this study were to:

- Quantify the persistence of RCx measures.
- Identify operational factors and energy management characteristics that influence the persistence of savings.
- Determine how to improve program activities to promote persistence or determine whether RCx follow-up is needed after some amount of elapsed time.

TABLE 1 Prior literature measuring persistence of RCx and commissioning.

	PRIMARY AUTHOR	NUMBER OF BUILDINGS	BY MEASURE OR BUILDING	STUDY TYPE	TIME AFTER CX (YEARS)	RESULTS: PERSISTENCE
Measured Persistence	Bourassa	8	Building	Survey and On-Site	1 to 2	81%
	Eardley	2	Measure	On-Site	Not Stated	36% (Measure Count)
	Potter	10	Measure	Survey and On-Site	2 to 8	69% (Measure Count)
	Mills	362	Building	Energy Usage	3	88% (Measure Count)
	Peterson	3	Measure	On-Site	4	Electricity: 89%; Gas: 0%
	Roberts	32	Measure	Survey (Some On-Site)	1 to 3	Estimated Average EUL – 8 Years
	Selch	1	Measure	Usage Analysis, Reconducting RCx	8	Electricity: 83%; Gas: 100%
	Toole	10	Building	Usage Analysis, On-Site, Some Simulation	3	Overall: 83%
Evaluated or Published Assumptions	Cadmus-1 (2012)			Evaluation	1	Assumed EUL – 7 Years
	Cadmus-2 (2010)			Evaluation	1	Assumed EUL – 5 Years
	DEER			Established Assumptions	–	EUL (Years) – Economizer: 5, RTU Control: 5, Lighting Control: 8, Supermarket: 10, Ventilation: 10, Resets: 10
	SBW			Field Study and Evaluation	1 to 3	Varies by Utility – 3 to 20 Years
	Tetra Tech			Evaluation	–	Assumed EUL – 7 Years

Prior Research

In reviewing literature from the past twenty years, we found eight studies that had published quantitative results on the persistence of either commissioning or RCx (*Table 1*).

Of those eight, only three had quantified RCx persistence on a significant sample of buildings. And all the studies varied in type, time frame, and approach, preventing us from doing a substantial meta-study. In taking a simple average of persistence across all the studies, which ranged from one to eight years of post-RCx data, we find an average persistence of 76%. Little of the data, however, comes from longer time-frame studies; most are two to three years post-RCx.

Five studies in our literature were based on program evaluations and did not include any primary site data collection (*Table 1*, Evaluated or Published Assumptions). These five publications included estimated useful life (EUL) data on nine different utility RCx program assumptions.

Two studies departed significantly from that overall average of 76%. Peterson (2005) investigated three buildings about four years after RCx. The study found a typical rate of persistence with electric measures (83%), but the few gas measures that they studied had all been disabled or changed, resulting in a rated persistence of 0% for gas. Eardley (2007) also found lower than typical persistence. That study only investigated two buildings but found that roughly two-thirds of the measures in those buildings had been disabled or had their effectiveness significantly reduced. These studies are included in the averages above but represent less than 10% of the buildings studied in the eight publications.

The study by Roberts (2010) also stands out from the others based on the amount and granularity of data collected. It not only collected data on 32 buildings, it did so on a measure-by-measure basis. The majority of typical RCx measures (schedules, resets, setpoints, valves/dampers, etc.) were investigated, and most showed high persistence. Eighty percent of the measures persisted after three years while 20% did not. Specific measures that degraded more than others include HVAC scheduling (60% of measures persisted), temperature setpoints (38%), boiler controls (33%), and lighting occupancy sensors (0%). We also reviewed several reports that described ex ante regarding useful life of RCx measures in utility programs. Though they were not based on primary data, it is worth noting that most utility programs assume that these types of measures last about seven years.

Method

We collected data on measures in commercial buildings that had been retro-commissioned between 2009 and 2014. Our data collection protocol was comprised of three steps: a pre-visit measure review based on an existing RCx report, a site audit to quantitatively evaluate measure persistence and a personnel interview to qualitatively identify factors influencing persistence. We analyzed this information to determine measure persistence.

Our original sample set consisted of 80 buildings that participated in ComEd's RCx program in 2010/11 or 2013/14. These were mostly large commercial offices, hospitals, hotels and university buildings. We faced several challenges with recruiting sites due to personnel turnover and changes in building management. We finally recruited and audited 28 sites and collected data on 167 discrete measures. We identified 15 categories (*Table 2*) that comprised the measures that were most frequently implemented and accounted for 75% of total RCx program savings.

TABLE 2 List of measure categories analyzed.

MEASURE CATEGORIES	NUMBER OF INSTANCES
Airflow Adjustment	3
Airflow Adjustment (Zone)	2
Demand Controlled Ventilation (DCV)	2
Duct Sealing	0
Economizer and Outdoor Air (OA) Control	32
Filters	3
Lighting Control	1
Optimum Start for Air-Handling Units (AHUs)	1
Plant Control Optimization	32
Plant Sequencing and Isolation	8
Supply Air Temperature (SAT) and Reset	6
Static Pressure Control	23
System Schedule	29
Thermostat Setting	3
Other (Includes Measure Instances With a Negligible Sample Set, Such As Individual Unit Heater Controls, Fan Staging Modifications, Etc.)	14

Data Collection

Prior to each site visit, we reviewed the RCx service provider's reports to understand the measures that were implemented and the documented verified energy savings from each measure. We did not perform any interventions, such as sensor calibration prior to site data collection, since the intent of this study was to gather data on as-existing measure performance. To determine persistence in savings, we conducted field audits and used one of the four following data collection methods:

- Measure trends. For each installed measure, we reviewed specific data points that were adjusted during RCx to determine whether and how much the measure persisted. Ideally, we wanted three months of data prior to the site audit to see how the measure was trending. This was not always possible, though, particularly for seasonally dependent data points associated with heating and cooling equipment.
- Control logic. Each installed measure has setpoints and operational strategy coded in the BAS. When data trending was not available, particularly in BAS without long-term trending capability, we reviewed the controls programming to determine measure persistence.
- Functional testing. When both BAS trends and control logic resulted in ambiguous measure performance results, we manually changed measure setpoints and observed if the system responded as intended at installation. Although this was a very reliable method of data collection, it was not feasible to manually adjust measure setpoints while buildings were fully occupied and operational, or when measures operated in critical zones such as in hospitals and labs.
- Setting up new trends. When measures did not have historical data trends, we set up new data trends during the site visit and followed up with the facilities staff to observe the trends once enough data was collected.

Data Analysis and Results

We analyzed data for persistence at the building level and at the measure level. All data was analyzed using R statistical computing software.

Our first step was to evaluate all 167 observed measure instances across all sites to identify overall persistence in savings. From this analysis, persistence based on measure count alone (not the weighted electric energy savings) was found to be 58.1% (±8.6%). Sites analyzed six years after RCx and three years after RCx showed 63% (±15%) and 52.8% (±8.9%) persistence, respectively.

More significantly, we found a 60.8% (± 8.9%) persistence in weighted electric energy savings across the program (*Table 3*). The 2010/11 and 2013/14 data sets showed 76.4% (± 9.1%) and 49% (± 11.2%) persistence respectively.

We expected 2013/14 to have higher persistence compared to the 2010/11 data set since RCx energy savings will degrade over time. But our results showed higher persistence for 2010/11 compared to 2013/14. Our investigation into the 2014 data set revealed that the low persistence was driven by two very large commercial facilities that had very low persistence at the building level (0.09 and 0.34). Since these two buildings contributed to the highest kWh savings in the year 2014, it negatively influenced the overall persistence for the year 2014.

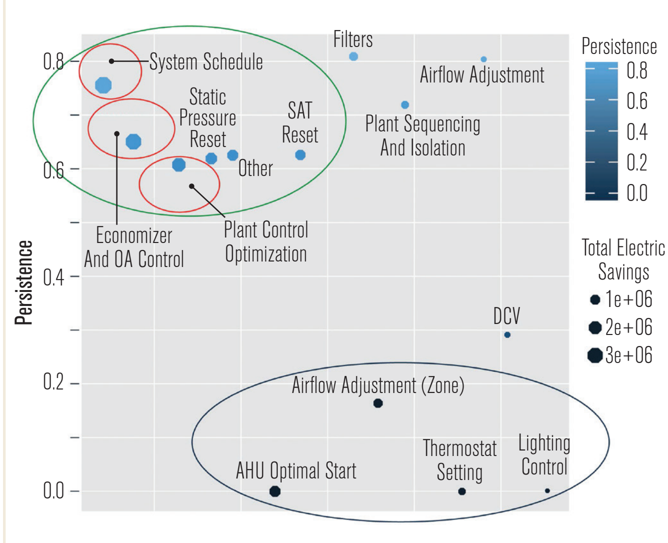
A persistence higher than 50% reflects that a measure is still within its useful life. We reviewed all measures in each measure category for persistence by measure type. The number of data points we were able to collect varied by category. Some measures such as economizer and OA control, and plant control optimization had 32 observed instances each, while a few other categories did not have any available data points.

Filters and airflow adjustment measures showed the highest persistence. Lighting controls, optimum start for AHU's and thermostat settings had the lowest performance with zero persistence. The sample size for these categories was very small, and we only calculated 90% confidence interval for measure categories with more than 14 instances.

TABLE 3 Overall persistence weighted by electric energy savings per measure.

PERIOD	PERSISTENCE (ELECTRIC ENERGY SAVINGS WEIGHTED)	STANDARD ERROR	90% CONFIDENCE LOW	90% CONFIDENCE HIGH
All	0.61	0.09	0.46	0.76
PY3	0.76	0.09	0.61	0.92
PY6	0.49	0.11	0.30	0.68

FIGURE 1 Persistence by measure category.



Factors Influencing Persistence

We tested our data set for several correlation factors that could potentially impact savings persistence. At each site, we interviewed and gathered responses from the facilities personnel on building operation and maintenance. Based on this data, we identified key metrics against which to test correlations with energy savings persistence. Some factors showed a clear correlation with persistence, such as sites that have had a major retrofit since RCx, training for site personnel and BAS management type (*Table 4*).

RCx Training. Training site engineering staff to operate and maintain RCx measures is critical to preserve savings from installed measures. Our analysis showed that staff who received training immediately following the RCx process were more knowledgeable about RCx measures and made continuous efforts to preserve energy savings. It is important to incorporate post RCx building operation training as part of the RCx process.

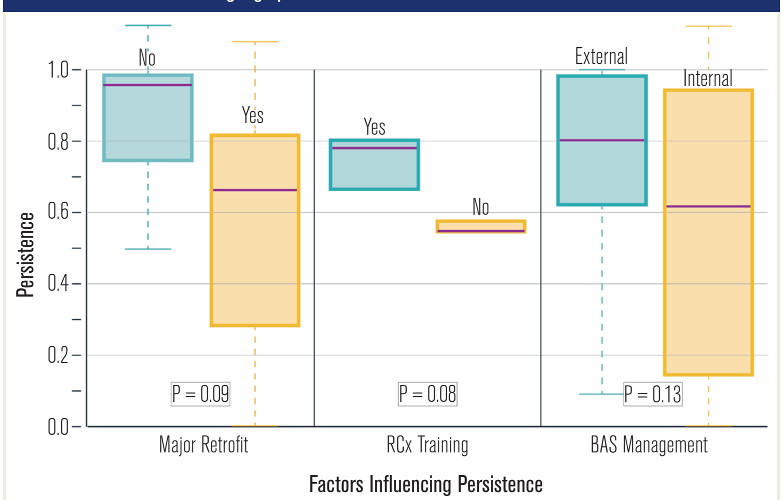
Major Retrofits. When significant retrofit activity or building additions followed RCx, persistence suffered. After major retrofits, buildings were often zoned differently, had variations in space use or occupancy. All these factors made the building operation deviate from the post-RCx building management plan, causing a loss in RCx savings. Outreach discussions could identify when building retrofit, significant HVAC equipment retrofit, or BAS hardware or software retrofit are occurring.

Internal BAS Management. We found that persistence was more likely to decrease when the BAS was managed

TABLE 4 Correlation coefficients and P values.

Factors Affecting Persistence	Correlation Coefficient	P value
Year of Retro-Commissioning	–0.25	0.20
Building Type	0.15	0.44
Building Area	–0.17	0.39
Major Retrofit	**–0.33**	**0.09**
Energy Management (Internal/External)	–0.05	0.80
BAS Management (Internal/External)	**0.29**	**0.13**
RCx Training	**0.34**	**0.08**
Staff Turnover	0.16	0.44
Age of the Building	0.14	0.49
BAS Upgrades	0.01	0.96
BAS Hardware Age	0.04	0.88
Major Control Repairs or Upgrades	0.00	0.99
Operator's Job Title	–0.05	0.82
Service Provider's Continued Involvement	0.10	0.60
On-Site Evaluation	–0.02	0.92
Scale of Project Impact (In Total Cost Savings)	–0.36	0.06

FIGURE 2 Factors influencing high persistence.



primarily internally, without substantial intervention from an outside contractor. External vendors were more likely to monitor the building operation and site performance closely and were less prone to override measures without a thorough investigation. We observed less frequency among external vendors in overwriting measures in immediate response to comfort complaints from occupants compared to internal management. Sites with internally managed BAS could be watched more closely.

Staff Turnover. Building turnover was one of the factors that correlated most clearly to persistence. Outreach activities should identify when key personnel who were present for RCx are no longer operating RCx sites; when that occurs follow-up activities may become more worthwhile.

We analyzed data for several other factors (*Table 4* and *Figure 2*) for additional insights on savings from RCx, but the findings were not statistically significant. Large projects showed some slight correlation to lower persistence in the data. Bigger commercial facilities typically have multiple building use types, HVAC systems and are managed by more than one site engineer. These factors made it harder to streamline building operation and preserve RCx measure, leading to low persistence. Since large projects represent a larger share of the program's impact, it is worth more effort to ensure persistence.

From the study, we also found that RCx measures contributed to significant gas savings. We observed a mean persistence of 42% across all measures with gas savings. Although the RCx program is administered by an electric utility and primarily focuses on electric energy savings, the gas savings contribute significantly to improved building performance.

Spillover

We also attempted to quantify savings from spillover: recommendations made by the RCx program that were not implemented immediately but could potentially result in additional energy savings when implemented later. Out of 39 such measures, we found four that had been implemented sometime later than the initial RCx. From our study, we found success rate for spillover energy savings to be roughly 10%. Our analysis of interview data also showed that 64% of participants had made additional energy efficiency improvements to their buildings that were not incentivized by a utility energy efficiency program. Most commonly implemented non-incentivized measures are adding VFDs to pumps, central plant equipment or AHU replacements, and some envelope improvements like window replacements.

Conclusions

From our study of 28 sites that were retro-commissioned over a period of six years, we found the average persistence in that savings at the end of 2017 to be 61%, with a higher persistence from projects that were retro-commissioned in 2010/2011 (76%) than projects retro-commissioned in 2013/2014 (49%). Results are inconclusive as to whether persistence between program years is significant; there was significant variability in persistence from site to site.

We also considered which factors in the building had the biggest effect on persistence and the following factors showed the highest correlation:

- Sites with an external contractor handling building automation changes had higher persistence.
- Sites with lower staff turnover, where building managers had retained positions longer, had higher persistence. Formal training of these staff also improved persistence.
- Sites that had not undergone significant system retrofits had higher persistence: whenever a site had undergone some type of significant system retrofit, persistence was generally lower.

Recommendations

- These results, especially the correlations, suggest ways to improve persistence in RCx efforts (some of which would also be applicable to new building commissioning):
- Building operator training (union, BOC program, etc.) had some positive impact on persistence. The most conscientious building operators seemed to make a direct connection between their training and the RCx project.
- Utility programs that promote RCx should include persistence in all conversations with customers, and even provide incentives for activities that promote persistence.
- Persistence could be increased significantly with even minor follow-up activities, which could be applied to all sites or just to those that exhibit the problem factors discussed above. Follow-up activities include:
- Brief re-visits to sites to spot check implemented measures. Similar to the site visits conducted for this study, spot checking requires less time than RCx and can result in identifying measures that haven't persisted but could easily be readjusted to improve performance.
- Full monitoring-based commissioning generally solves the persistence problem although it adds expense and possibly security issues. A lighter-touch to a monitoring-based Cx approach would still have value in many buildings. Projects with significant enough savings to track via utility bills or main-meter readings (e.g., chilled water) would be good candidates for this approach.
- There is value in conducting RCx again three to six years after the initial RCx in buildings where it can be identified that measure performance may have degraded (based on either a significant number of degradation factors being present or increase in metered energy).

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