Retrocommissioning and Opportunities for Natural Gas Savings

Energy Solutions Center
Washington, DC

Michaels No.: E9611AAN

November 2011

400 Main Street, Suite 200
La Crosse, Wisconsin 54601
Phone 608-785-1900 Fax 608-784-2270
www.MichaelsEnergy.com

Table of Contents

Executive Summary

The Energy Solutions Center contracted with Michaels Energy to share its experiences, lessons learned, project data, and recommendations for retrocommissioning (RCx) programs with specific emphasis on natural gas savings potential.

The natural gas savings potential for retrocommissioning is very attractive and significant. Natural gas savings dominate five of the top six and six of the top eight measure categories in the 22-building RCx sample of Michaels projects analyzed in this study. The five major gas-saving measures are summarized as follows:

- Reduce or eliminate simultaneous heating and cooling in buildings. This garners by far the greatest savings for natural gas and, to large extent, electricity. Measures in this category account for nearly 60 percent of natural gas savings among the sample projects. Michaels has found that if systems can waste energy by heating and cooling simultaneously, they are, at least to some extent. It must be noted that this measure type is not limited to cold climates. Buildings with the highest percent savings potential include many buildings in the desert southwest. Please note that this category is represented by two different measures and thus there are four bullets for five measures.
- Reduce ventilation levels to meet indoor air quality needs only. In many cases, Michaels has found ventilation to be excessive or not needed, and eliminating this large heating load can save significant natural gas.
- Implement demand-controlled ventilation to automatically minimize ventilation levels continuously as occupants fill and exit meeting spaces.
- Implement night setback scheduling. Many times this is due to avoiding a problem or a complaint to facility staff at some point. Retrocommissioning measures generally fix the sources of problems, rather than cover them up by further wasteful operation of facility systems.

For buildings served by natural gas, monetary natural gas savings account for about 43 percent of the total savings for all fuels, even during periods of low natural gas prices.

Rather than using the industry standard of minimum building size for RCx program eligibility, Michaels uses screening and benchmarking to estimate savings potential and program cost, maximizing return on program dollars. Therefore, costs per square foot are somewhat high for some smaller, energy-intensive buildings when compared to other programs, but cost per unit of energy saved, which is the ultimate metric, is low by industry standards.

Michaels’ cost per square foot for study, implementation, and total combined, are $0.10, $0.40, and $0.50, respectively, compared to a combined total of $0.30 per square foot among other programs. Unfortunately, granular secondary data are sparse and direct comparisons of natural gas savings in other programs are not available. However, Michaels’ projects achieve 15 percent electric savings in commercial buildings versus 9 percent for the comparison Lawrence Berkeley National Laboratory (LBNL) study of many buildings. The LBNL study does not include natural gas measure detail, but natural gas savings are likely greatly less because top measures are electricity dominated.

Michaels is delivering a RCx program to a mid-size Midwest utility. Program costs include 2.7¢ per therm for marketing, 38.7¢ for the study, and 38.0¢ for post-implementation training, functional testing (real-time verification), and bill monitoring, for a total program cost of 79.4¢ per therm. Note these costs are derived based on the percent dollar savings attributable to natural gas. The rest of the cost is carried by electricity savings.

Another key objective of this paper is to address attribution and whether RCx measures would occur anyway in the absence of a program. Addressing this issue most succinctly, end users are not going to pay consultants or contractors to look at their clock to tell them what time it is. Other points and recommendations for attribution include:

- Top natural gas-saving opportunities are "invisible" to building owners and occupants. One cannot tell simultaneous heating and cooling is occurring without metering over time.
- Programs must use knowledgeable consultants/contractors and train them to properly document as-found conditions for evaluation purposes. The conventional pre-approval process to demonstrate attribution is a turn-off to customers because they want to start saving energy on the spot during the investigation when possible.
- Evaluation of RCx programs has demonstrated the importance of the program-sponsored investigative study and post-implementation bill monitoring to get customers to act.

Finally, persistence of savings for RCx projects is a concern to many portfolio managers. Key points and recommendations for persistence include:

- Customers invest in retrocommissioning to reduce operating cost and fix system performance problems. Internal champions at both facility management and upper management levels typically ensure persistence by tracking performance and protecting their investment. They do this by monitoring their energy use/cost over time.
- Consultants and contractors must improve or maintain the indoor environment. Many times, opportunities are present because someone treated the symptom rather than curing the cause of problems, whether related to comfort or maintenance. Contractors cannot leave symptoms behind.
- Follow-up reporting of post-implementation energy consumption after 12 months is key to reminding customers they are hitting their impacts, and if not, it serves as a way to determine or report why that did not happen. Twelve-month post-implementation reporting is standard in Michaels' program.
- Training facility staff on how their systems use energy, what was done, and why it saves energy is critical to maintaining savings over time. Studies have shown program savings actually increase over time when training is effectively implemented. It must be very specific to customer systems and equipment, however.
- Engineers and contractors should recommend modest system and control component changes when possible to ensure savings persist. For example, if a boiler needs an air-fuel ratio adjustment, consider installing automatic controls such as "O_2 trim" rather than simply tweaking the linkages on the conventional control. This both maximizes savings and ensures it will be maintained over the long term.

In conclusion, retrocommissioning is cost effective for both customers and utilities, and potential natural gas savings are great when using knowledgeable investigative engineering with appropriate screening and project selection. Due to the nature of retrocommissioning, attribution should be high, and with sound engineering and logical financial decisions coupled with training, savings should persist and even increase over the long term.

1. Introduction

This paper presents typical findings, savings, typical measures, study costs, and implementation costs of 22 recent retrocommissioning (RCx) projects completed or in progress by Michaels Energy. In addition to information of interest to natural gas customers, this paper includes cost effectiveness for the interests of utilities and/or utility program implementers, with the primary metric being total program cost per unit of energy saved.

Michaels' background includes hundreds of investment-grade feasibility studies, most of which include some RCx and operations and maintenance measures for general facility improvements, including improved comfort and reduced operating cost. Michaels Energy also provides impact evaluations for all sectors, with an emphasis on commercial and industrial sectors. Michaels is currently evaluating over 20 utilities in 13 states at this time. Current and past evaluations include evaluation of building automation system programs and RCx programs. These program categories have very similar characteristics with respect to implemented measure types, documentation, and engineering analysis.

Michaels has participated in several RCx programs as an engineering services (studies) provider, and more recently launched a program that breaks with the RCx program status quo in order to avoid inherent barriers with those programs. Data and analyses in this report originate from studies conducted under this innovative approach to RCx.

The architect and lead author of this paper is Jeff Ihnen, Managing Principal of Michaels Energy. Mr. Ihnen holds professional engineering licenses in Wisconsin, Iowa, Minnesota, Colorado, Montana, and California. Early in his energy efficiency career, he provided over 100 investment-grade feasibility studies and about twice as many ASHRAE Level 2 audits. He has many years reviewing internal reports and engineering analyses and models, including building simulations such as those provided by DOE-2 and Trane Trace. He has been active in program evaluation for nearly 10 years as well. In total, he has 16 years of experience in the energy efficiency engineering and program business. Finally, he developed the RCx program approach detailed in this report.

Co-authors include Sean Weitner and Gary Ambach. Mr. Weitner provided secondary research and assisted with data analysis from secondary sources and from Michaels' projects. Sean has 10 years experience in the energy efficiency industry, mostly with Energy Center of Wisconsin where he developed energy efficiency plans for communities, developed biomass pilot projects and planning, and provided engineering and policy analysis for National Resources Defense Council and Wisconsin Focus on Energy's deemed savings database.

Mr. Ambach is Michaels' Director of Energy Programs. He has over 30 years experience in utility demand side management including account management, program management and portfolio management for many years for utilities including Alliant Energy, Hawaiian Electric Company, and Imperial Irrigation District in Southern California. He is Michaels' lead for program development, marketing, launch, and management.

Also contributing RCx program evaluation findings are Mike Frischmann and John Flotterud, both of whom provide impact evaluation for utilities nationwide.

2. Retrocommissioning Impacts

Retrocommissioning is an approach to existing building energy savings focused on optimizing existing systems. Most buildings fall well short of performing as designed in every dimension, including energy use. Retrocommissioning refers to the process of identifying these variances, implementing solutions, and, when done properly, teaching building operators why their systems had been underdelivering so that the building does not stray from its design specifications in the future.

One study refers to RCx as "a risk-management strategy that … ensures that building owners get what they pay for when constructing or retrofitting buildings, provides insurance for policymakers and program managers that their initiatives actually meet targets, and detects and corrects problems that would eventually surface as far more costly maintenance or safety issues."

This paper will discuss the complexities of RCx buildings, beginning by considering common RCx measures and impacts.

2.1 Michaels Findings

Retrocommissioning is the furthest thing from a one-size-fits-all approach to energy efficiency. Retrocommissioning studies begin with a thorough investigation of the facility in question, looking for the particular ways its performance falls short.

That said, Michaels' experience as an RCx provider has shown that many buildings share the same faults, and the most common characteristic of energy-wasting commercial facilities is excessive simultaneous heating and cooling. Michaels has performed numerous commercial and industrial energy efficiency training sessions for utilities, professional organizations, and consortia, and the common message is, if a system *can* wastefully consume heating and cooling energy simultaneously, it is. There is almost always opportunity to reduce this anywhere it could happen.

What is simultaneous heating and cooling?

Central air handling systems serving a single floor of an office building or a wing of a school building need to have capability to cool some zones and heat others at the same time. A common means of temperature control includes a variable air volume system. Generally speaking, the system varies the amount of cool air delivered to the temperature control zone as needed for cooling. Once the cooling air flow is minimized, the air is heated by means such as baseboard heating or terminal reheat in the ductwork.

Minimizing simultaneous heating and cooling in a variable air volume system involves setting the central air handler discharge temperature as high as possible and setting the minimum flow to each zone as low as possible. However, great complexity enters the equation when engineers must ensure:

- Sufficient ventilation (outdoor air) is supplied to each zone.
- Humidity levels are maintained within acceptable limits.
- Air flow is sufficient to avoid stratification and occupant discomfort.
- Air flow is also sufficient to prevent cooling coil freezing in direct expansion cooling systems.

Excessive simultaneous heating and cooling is also commonly seen with distributed single-zone heating and cooling systems, which can include a fan coil unit served by hot water and chilled water, or a water source heat pump—typically one for each temperature control zone. These systems are usually served with a central makeup air unit with or without heat recovery. This unit supplies tempered fresh air to each zone, and it is not unusual to have these units constantly delivering dehumidified air at 70F. Zones served downstream may need cooling, however, including year round cooling in some instances, even in cold climates. The most efficient operation is to treat fresh air as little as possible to avoid simultaneous heating and cooling. As with variable air volume, there are critical issues to consider:

- Fresh air traveling through ductwork indoors must be maintained above the dew point of the building to prevent condensation and water damage.
- Warm, humid outdoor air must be sufficiently dehumidified such that zone temperature requirements can be maintained.
- Sufficient minimum air flow to zones is necessary to meet occupant ventilation needs.

Even single-zone systems that contain both a heating coil and cooling coil and serve one space can waste significant energy all year. This can be seen particularly in manufacturing facilities where process loads overwhelm space conditioning loads and are not perceptible by viewing energy bills or using benchmarking techniques.

Impacts by Measure Type

Per Michaels' findings, a program to minimize simultaneous heating and cooling alone could result in impressive facility and program impacts. These results are demonstrated in Figure 1 and Figure 2. Salient points regarding Figure 1 include:

- Data in Figure 1 represent measures from 13 facilities with a combined payback of 1.37 years.
- Measure categories are sorted in order from greatest dollar savings to least.
- The measure "HVAC – Supply Air Temp Reset" represents another form of simultaneous heating and cooling.
- Measures with substantial natural gas savings are concentrated at the high end of the chart.
- Natural gas savings account for 42 percent of the total dollar savings during a period of low natural gas prices. While most program activity is sponsored by electric utilities, natural gas savings are critical to achieving return on investment for those measures end users have committed to implement.[1]
- Facilities include three manufacturing plants[2], a large office building, public assembly, hospitals, libraries, schools and colleges, and a grocery store in the upper Midwest.

[1] Michaels' administered programs provide full reimbursement for in-depth investigation once customers implement a package of measures with a combined payback of two years or less.

[2] Manufacturing facility studies limited to HVAC only at this time.

Figure 1: Gas and Electric Savings by Measure Category—Buildings Served by Natural Gas

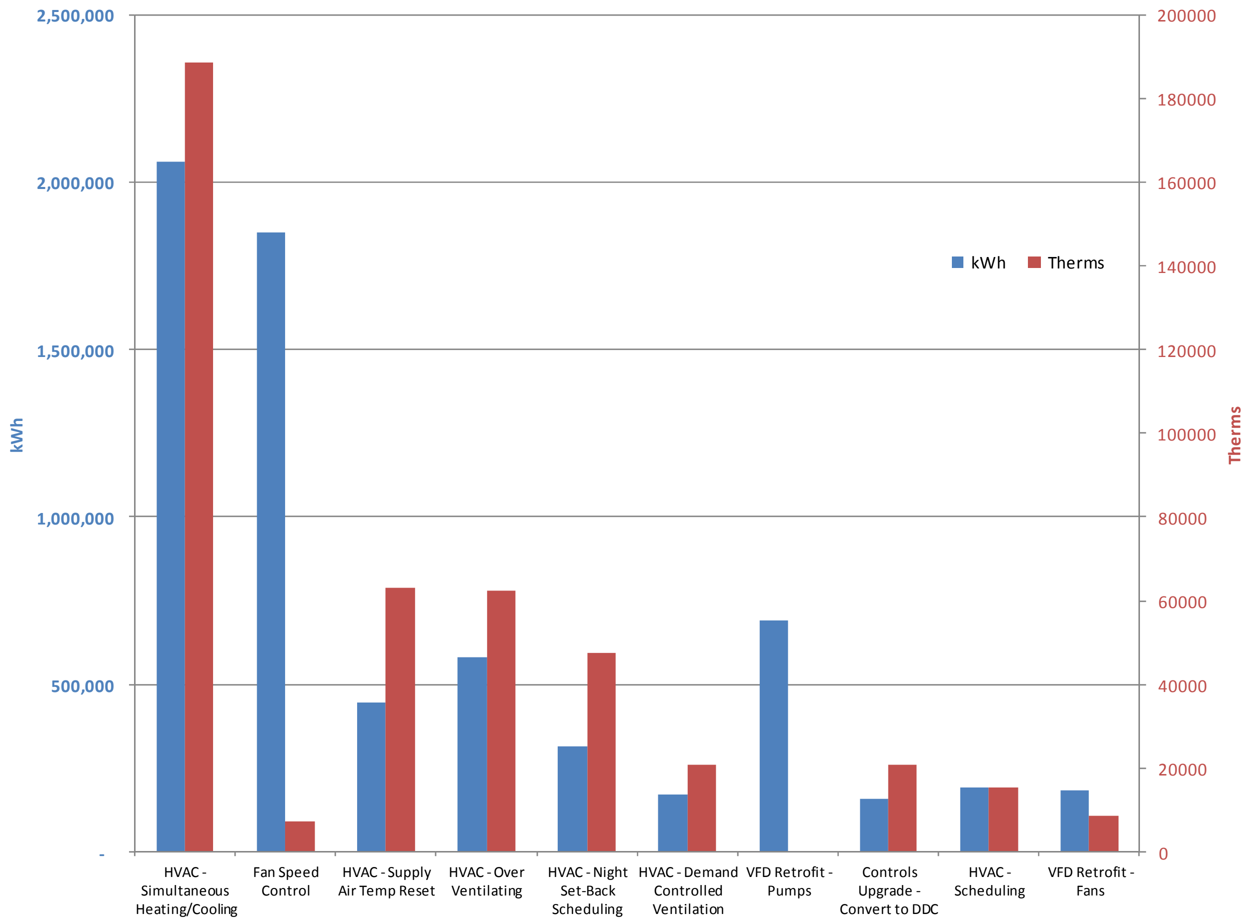
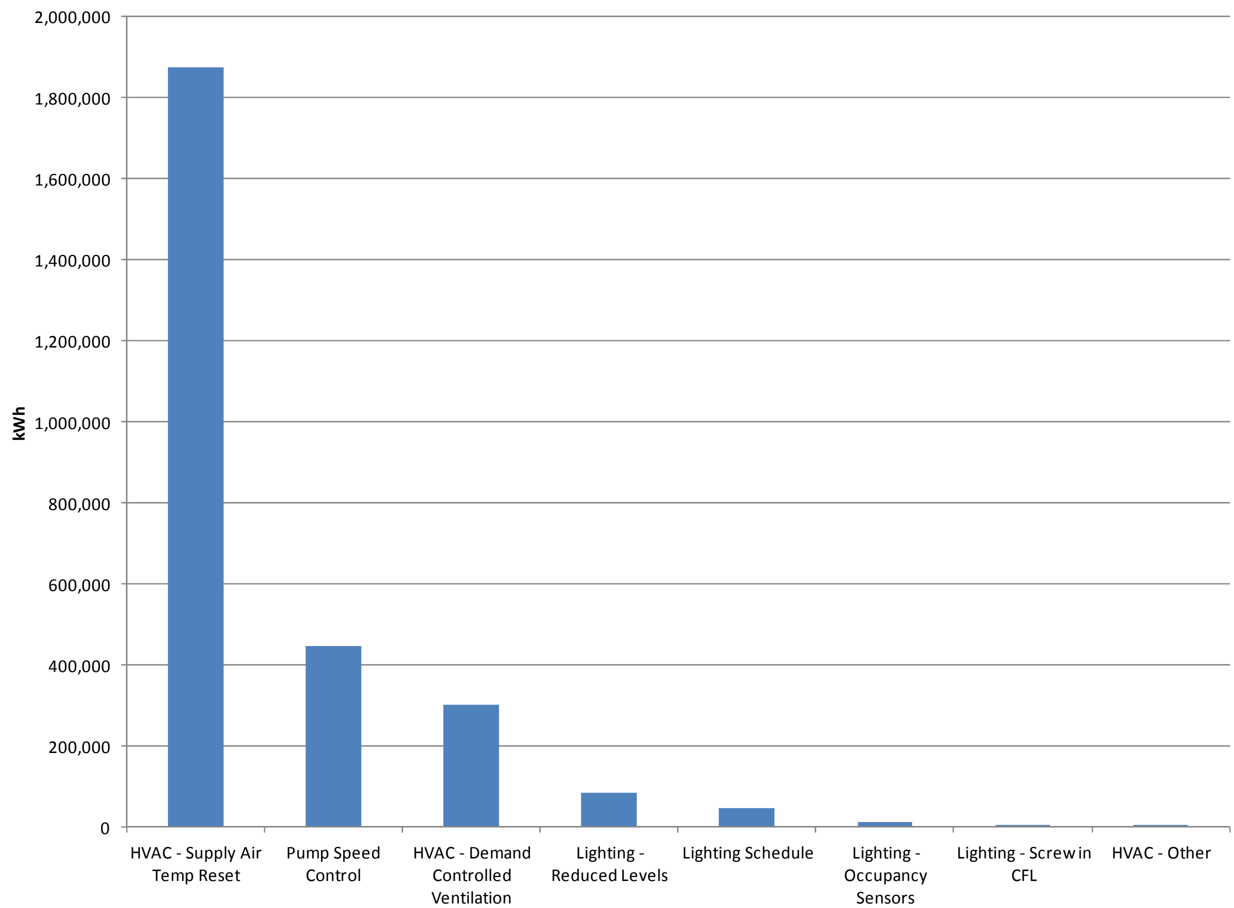


Figure 2 includes impacts of RCx for nine facilities not served with natural gas. The results from electric-only buildings once again emphasize the opportunities available by minimizing or eliminating simultaneous heating and cooling. Many of the electric-only facilities are quite small, but they included savings potential of approximately 10 kWh per square foot, which is the typical *consumption* of electricity in a commercial facility. Savings of this magnitude are atypical, but demonstrate how significant this energy waste can grow to be.

Facilities in Figure 2 include small commercial facilities in Arizona and a school in Minnesota.

Figure 2: Electric Savings by Measure Category—Electric-Only Buildings



Michaels is not the only RCx provider to notice the prevalence of HVAC measures in RCx projects. We sought up-to-date evaluations of RCx programs from across the country to survey their findings. The number of retrocommissioned buildings that have been studied remains relatively small, however, and it is possible that the samples used in the studies cited below overlap.

Additionally, comparing RCx measures and energy savings was difficult because the evaluation reports used dissimilar frameworks, descriptions, and methods. This issue is well documented within the industry; as one study said, "Much better practices are needed in the documentation of commissioning projects and creation of case studies. … The current literature is fraught with ambiguities and non-standard definitions." (Mills 2009)

Four external studies of RCx impacts are reviewed in this section: Two consider programs nationwide, and two consider the many programs in California.

- A Lawrence Berkeley National Laboratory (**LBNL**) study from 2009 considers "643 buildings, 99 million square feet [90 million in retrocommissioned existing buildings and 9 million in commissioned new construction], and $43 million invested in the commissioning work." (Mills 2009)
- A Portland Energy Conservation, Inc. (**PECI**) study from 2009 considers "commissioning measures implemented under utility programs [from] 11 utilities …. Data on 122 commissioning projects and over 950 commissioning measures was received." (Haves 2009)

- A California Public Utility Commission (CPUC) study from 2010 considers “statewide evaluation of all retrocommissioning activity in 2006-08 program cycle … over 22 programs and over 220 projects … The gross impact evaluation examined in detail RCx efforts in 50 facilities.” (Tso 2010)
- Another Portland Energy Conservation, Inc. study from 2008 (**PECI-Cal**) considers “21 projects with combined savings potential of 11.1 million kWh at first submission of investigation findings” from California’s 2009-08 program cycle. (Moore 2008)

2.1.1 Deficiencies

Three of the studies step back from measure-level analysis to highlight the building systems that require RCx. Table 1 shows these deficiencies, ranked by frequency. While each study categorizes the deficiencies slightly differently, making direct comparison across the studies difficult, each list is clearly dominated by HVAC measures.

Table 1: Deficient Systems in RCx Buildings by Resulting Number of Measures

Rank	LBNL	PECI	CPUC
1	Thermal distribution	Air handing unit	HVAC (air distribution)
2	Combined heating and cooling	Pumps	HVAC (general)
3	Terminal units	Chiller plant	Central plant
4	Lighting	Cooling tower	
5	Cooling	Boiler plant	
6	Heating	Interior lighting	
7	Controls/energy management	VAV terminal unit	

2.1.2 Measures

Measures are also difficult to compare directly across studies, both because each study offers a different metric for measure impact, such as kBtu versus therm or MMBtu or kWh, and because they are described differently. For instance, simultaneous heating and cooling does not emerge as prevalently in these reports, until you realize it is likely to be rolled up into such measures as “revise control sequence” and “calibration.” Michaels’ measures, and the measures from three other studies, are presented in Table 2, along with associated paybacks.

Table 2: Measures in RCx Buildings, including Payback

Rank	Michaels[1]		LBNL[2]		PECI[3]		PECI-Cal5	
	Measure	Pay- back [yrs]	Measure	Pay- back [yrs]	Measure	Pay- back [yrs]	Measure	Pay- back [yrs]
1	Simultaneous heating/cooling	0.5	Installation modification	1.9	Revise control sequence	0.4	Economizer	0.6
2	Supply air temperature reset	1.2	Calibration	0.8	Reduce equipment runtime	0.6	Fan speed variation	1.6
3	Fan speed control	1.2	Implement advanced reset	0.7	Optimize airside economizer	0.6	Condenser H_2O reset	0.8
4	Over-ventilating	2.5	Scheduling (occupancy determined)	0.3	Add/optimize SAT reset	1.4	VFD reset, pumps	0.8
5	Demand-controlled ventilation	2.6	Equipment staging	0.5	Add VFD to pump	0.8	Equipment schedule	0.6
6	Night setback scheduling	0.9	Start/stop (environmentally determined)	0.4	Reduce coil leakage	0.1	Chilled water reset	1.4
7	Pump speed control	4.6	Behavior change/ manual operations change	0.4	Reduce/reset DSP setpoint	0.7	Lighting schedule	1.1
8	VFD retrofit: pumps	3.3			Add optimum start/stop	1.1		
9	Controls upgrade: convert to DDC	2.9			Add/optimize CWST reset	1.1		

3. Return on Investment

Michaels' program is designed to minimize barriers of study cost, risk, implementation cost, uncertainty of savings, and time. As a result, the program is successful in getting customers to agree to and act on a measure package with a combined payback of two years while other programs struggle to sign customers with commitments to implement measures of one year and in some cases even nine months. Elements that mitigate these barriers include:

- Benchmarking against peer facilities and screening to estimate savings when drafting the proposal. While they are rough, these cost estimates provide an "order of magnitude" estimate to give customers confidence.
- Capping end-user implementation costs based on twice the savings estimate, i.e. a two-year payback, which limits the capital needed to implement the requisite project package. This removes uncertainty as customers know how much capital they are committing.
- Full study reimbursement once the customer completes all measures in the two-year package. At worst, the customer only has to implement with a ROI predicated on the two-year payback.
- Logging of key data over two weeks to ensure the actual operation and control sequences are known with confidence. This again mitigates risk in achieving projected savings.

- Specific implementation documents, which commit the contractor to completing a designated scope of work. These are provided if the customer so chooses, although Michaels recommends them to ensure study intent gets implemented as planned.
- Functional performance testing of the measures to ensure they were incorporated per the intent of the study and in compliance with implementation documents. This minimizes risk that design concepts from the study will not be implemented as intended.
- Monitoring for savings at approximately three months and again once a full year's data are obtained, post-implementation.
- Training that includes a discussion of how the customer's systems use energy, how they were wasting energy prior to implementation, and what we did to reduce energy consumption. If customers understand these things and buy in, chances are much greater savings will persist over time.

Michaels' process improves on the standard approach throughout the project. We bypass the application and planning phases that frequently bog down projects (see Section 4.1), enabling all involved to progress quickly without starts, stops, and delays. The two-year payback criterion and analysis is designed to include the cost of the implementation documents, which provide the control sequences and system modifications needed to achieve the savings. Rather than after-the-fact verification of implementation, Michaels provides real-time verification with functional testing before the contractor completes the job; deficiencies are typically fixed on the spot. Finally, Michaels stands behind its savings estimates and reports 12-month savings to the customer. Table 3 shows the impact of this thoroughness on project costs.

Retrocommissioning provides the utility an excellent return for its program investment. The cost per unit of energy savings is competitive or lower than most other program types. This is especially true when considering the high "close rate" for marketing to project implementation. Table 3 presents typical program costs for this unique program design. In addition, this program design presents an opportunity to replace measures that are becoming marginalized by changing standards and codes.

Table 3: Typical RCx Program Costs per Energy Saved

	Electric ($/kWh)	Gas ($/therm)
Marketing	$0.002	$0.027
Study	$0.031	$0.387
Post-implementation services[3]	$0.031	$0.380
Total	$0.064	$0.794

Evidence of the viability of this approach is provided in close rates achieved by the program design. For our purposes, close rate is defined as the percentage of customers that commit to the program

[3] Projected costs. If not available by measure, breakdown between electricity and natural gas achieved by a ratio of electric or natural gas dollars to total dollars saved.

after receiving a proposal that outlines the study cost, their implementation commitment, and program-provided follow-on services.

Our experience to date indicates that of the hospitals to whom Michaels provided a proposal, close to 80 percent have opted for the study and committed to the program.

Michaels' close rate with K-12 schools is about 25 percent, although customer feedback indicates that more will accept given more time to secure approval and budgeting—the sales cycle for schools is much longer. However, schools generate more studies per customer as the district is typically the customer, yielding multiple studies from one initial proposal. Another fertile opportunity for RCx is universities and colleges. Thus far, Michaels has seen significant savings with this group of customers. Although there are fewer customers, they tend to have multiple facilities and be driven to save energy. Michaels' close rate with these customers is about 75 percent. Similar to schools, feedback from the remaining customers indicates they will proceed with the program but need time for internal communication.

The overall close rate is 43 percent. Including customers who have committed to the program but are waiting for internal approval, this close rate increases to 67 percent. Michaels attributes its high close rate directly to the program elements that remove barriers to participation noted above.

Other programs have begun to realize the importance of requiring implementation of study findings for reimbursement. Some California programs have begun to use a legally binding agreement with RCx clients which "requires that owners will implement any measure that has a payback of one year or less, or else repay the program's investigation costs." Studies confirm that Michaels' model works: "Program experience has shown that although the level of commitment required initially represented a challenge in getting owners to sign up, it is a key component of program success." (Moore 2008)

Michaels is also not the first to recognize that not all RCx providers deliver projects equally well. "Projects with a comprehensive approach to commissioning attained nearly twice the overall median level of savings and five-times the savings of the least-thorough projects," one study said, adding, "Payback times showed little correlation with how much money was spent to conduct the commissioning, suggesting that skill plays a large role." (Mills 2009)

3.1 Savings

Michaels does not use typical guidelines such as minimum square footage to qualify RCx candidates. Rather, screening and qualification for program participation is based on savings potential for the facility. Small buildings can represent a gold mine of savings; this is indicated in Figure 2, which includes small buildings averaging 10 kWh/sq.ft. in savings.

A summary of recent Michaels project findings is provided in Table 4. Things to note include:

- This includes all facilities—facilities served by natural gas and facilities served by electric only.
- The industrial projects include only HVAC, and thus the savings as a percent of use is small relative to process-dominated consumption. The intent is to continue on with process-supporting systems including compressed air and industrial refrigeration.
- One comprehensive study of RCx programs, giving an example of program criteria, noted that a utility excluded buildings smaller than 75,000 sq.ft. (Mills 2009) By contrast, 11 of the 19 commercial RCx projects in Table 4 were smaller than 75,000 sq.ft.

- We use the Lawrence Berkeley National Laboratory study cited earlier as a benchmark. Note that this study only deals with commercial facilities.

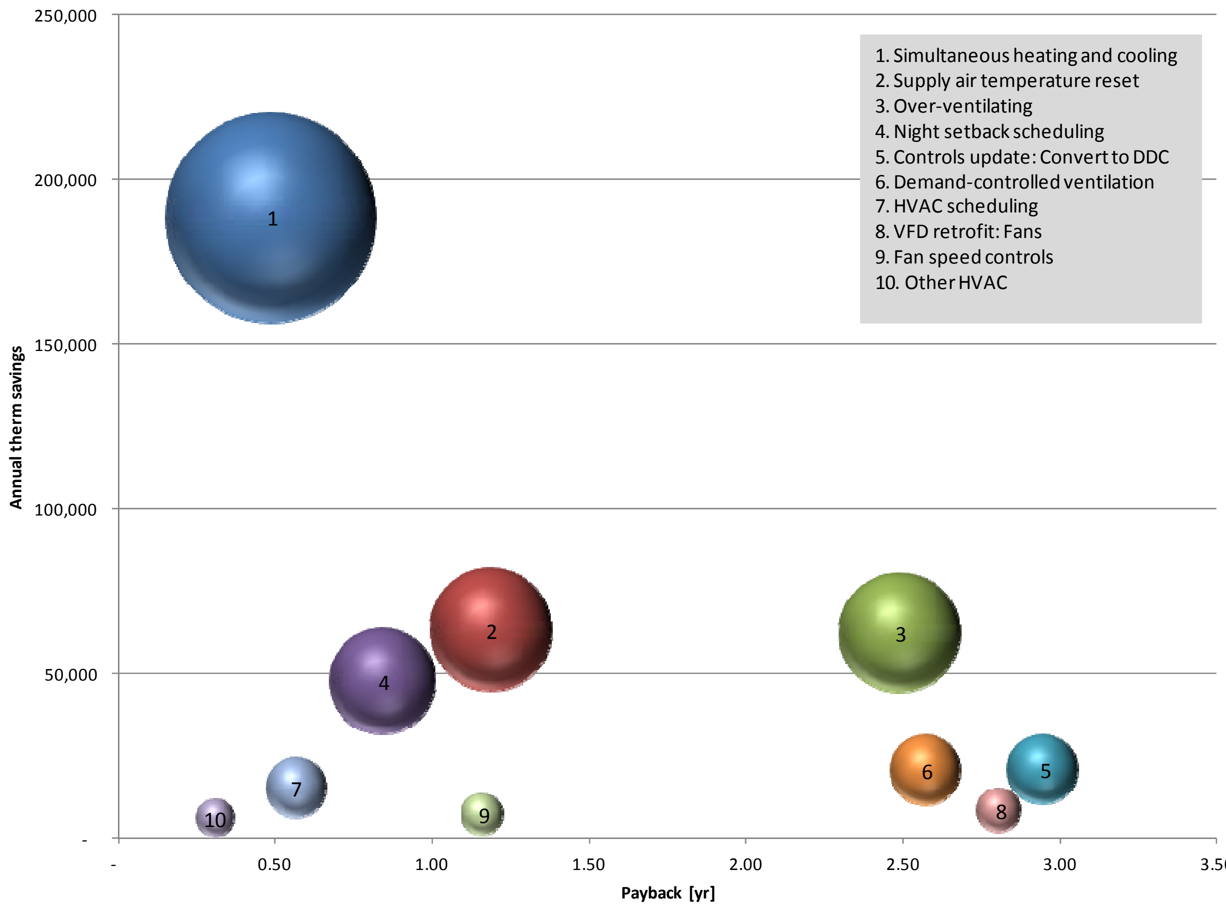
Table 4: Michaels Overall Results, with LBNL Benchmark

Metric	Commercial	Industrial	Totals	LBNL (Mills 2009)
Study Cost	$280,420	$95,900	$376,320	
Implementation Cost	$1,239,390	$295,571	$1,534,960	$28,562,970
kWh Saved	7,034,224	4,014,896	11,049,119	
Therm Saved	249,830	194,535	444,364	
$ Saved	$728,863	$412,772	$1,141,635	
Square Feet	1,733,833	2,075,422	3,809,255	90,410,884
Study $/sf	$ 0.16	$0.05	$0.10	
Implementation $/sf	$ 0.71	$0.14	$0.40	
Study & Imp. $/sf	$ 0.88	$0.19	$0.50	$0.30
kWh Saved/sf	4.06	1.93	2.90	
Therm Saved/sf	0.14	0.09	0.12	
$ Saved/sf	$ 0.42	$0.20	$0.30	
Customer Payback	1.70	0.72	1.34	1.1
Customer Cash on Cash Return	59%	140%	74%	91%
Number of Buildings	19	3	22	561
Median % energy saved/bldg	32%	2%	30%	16%
Study $ / Save $	38%	28%	33%	
Base kWh Use	46,138,379	149,291,803	195,430,182	
Base Gas Use	1,399,448	8,626,829	10,026,277	
% kWh Reduced	15%	3%	6%	9%
% Therm Reduced	18%	2%	4%	

3.2 Measure-Level Payback

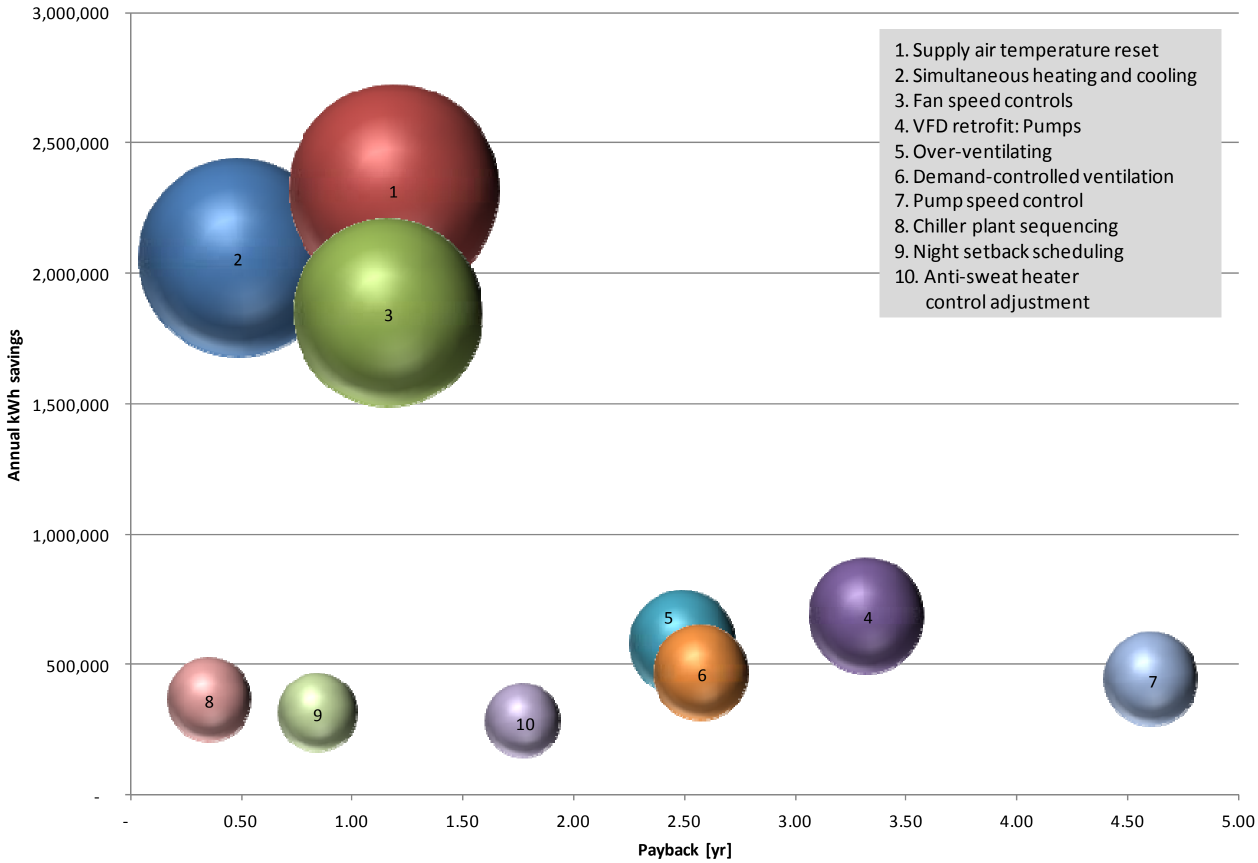
Michaels' promise to customers to deliver RCx packages with a payback window under two years is borne out in the following figures, which show both measure paybacks (x-axis) and annual fuel savings (both the y-axis and the size of each bubble).

Figure 3. Measure-Specific Net Gas Savings versus Payback



As previously discussed, simultaneous heating and cooling is the most significant opportunity we capture in RCx projects, but many other measures pay back just as quickly or nearly so.

Figure 4. Measure-Specific Net Electric Savings versus Payback



4. Attribution

Some DSM program elements for measuring program effectiveness are attribution and free ridership. Some evaluators and program managers believe these elements cast uncertainty on RCx programs because savings rely not on efficient new equipment but existing equipment operating more efficiently. Thus, it amounts to providing incentive dollars for activities that building operators *could* do themselves.

Michaels believes the opposite is true. Retrocommissioning likely has some of the highest attribution rates of any energy efficiency programs because end users are directly paying for services that reduce operating cost. This, in most cases resolves some lingering performance and comfort problems as well. Unlike most programs, customers are not buying shiny new equipment to replace poorly performing or problematic equipment—in those cases, there are *many* reasons for doing the project, raising attribution questions of whether end users are replacing equipment unnecessarily or buying an efficient model they would buy anyway. Furthermore, it is perfectly common to use energy-efficiency equipment to waste energy, essentially because of a lack of commissioning.

By comparison, attribution for RCx is straightforward. End users are simply not going to hire consultants or contractors to look at their clock and tell them what time it is. If it's obvious how to reduce energy consumption, they are not going to pay someone to tell them.

Studies from around the country that attempt to adjudicate RCx attribution confirm that the energy waste would continue in perpetuity without RCx intervention:

- "The net analysis found low levels of free ridership, with Net-to-Gross ratios (NTGs) generally above 0.80, indicating that most improvements would not have happened without the interventions of the utility programs," one study of California programs said. "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 sole gas-only utility … had a therm realization rate of 0.93." (Tso 2010)
- "DSM programs that are evaluated on attribution and free ridership have found RCx programs helpful as they tend to have high attribution rates," another study said. "The corrective measures that are identified as part of RCx studies either change the practices of facility operators, incorporate new strategies for existing equipment or fix problems that require testing and diagnostics to identify all of which does not take place under normal operation in most facilities." (Wall 2011)
- "Spillover is also common in RCx programs as customers will take the lessons learned from RCx and apply them to all of the facilities in their portfolio," the same study said. "Additionally, some facilities will incorporate commissioning practices into their operations and identify and implement additional measures after the utility has stopped tracking the facility." (Wall 2011)

An additional element of attribution is whether a customer would have pursued RCx in the absence of a program, but those elements of program evaluation are not a topic under discussion.

4.1 Michaels Experience

Attribution by Fixing the Unknown

As shown in the results of recent Michaels RCx projects in Section 2, the greatest savings by far are achieved through the elimination of simultaneous heating and cooling, which Michaels has found not just in the eastern half of the country but in the arid southwest as well. This is an exemplary RCx measure because end users do not realize this is occurring, most likely because they do not physically perceive it via comfort conditions.

In one instance, Michaels was performing routine measurement and verification for the installation of variable frequency drives for a cereals manufacturer and noticed substantial opportunity for drive optimization. While the end user was convinced there was not much opportunity for savings via controls optimization/RCx, they have a long history with implementing energy efficiency and decided to proceed with an RCx study of 72 of these air handlers. The results included over 1 million kWh and about 330,000 therm savings annually, mostly by eliminating simultaneous heating and cooling with humidity override control. These savings would never be realized without the RCx study.

Attribution Concerns Become a Barrier

Ironically, the very ease of achieving RCx savings can be an attribution roadblock for business-as-usual energy programs. As discussed in Section 2, energy waste can occur with makeup air units controlled to preheat air to 70F when the most efficient setting would be significantly lower when outdoor air conditions permit. Upon sharing this finding with a customer, they would want to delete "70F" on their building automation system and replace it with "55F" and start achieving savings at that instant, and this is what they did—implementation of many measures can and do occur as the investigation is underway.

Program administrators however, may want the entire process to unfold with completion of the study prior to implementation to take credit for the savings. Retrocommissioning programs often require an application phase, planning phase, investigation phase, and verification phase. In order for the program to take credit for savings, they have to occur in the right phase, and so the customer is asked to hold off, despite the fact that the program is responsible for the impacts, right there in real time with no cost. What could be better?

Waiting for program bureaucracy is deadly to individual projects and programs as a whole. In a recent evaluation of an RCx program on the eastern seaboard, Michaels' found that three of four program "trade allies" were telling current and future customers to avoid the program because of excessive delays and hassle associated with approval, applications, and preliminary reporting. Clearly, programs offer financial incentives to help motivate customers to act, but if the incentive fails to outweigh the cost of delay and expenses associated with trade allies doing substantial administrative tasks, customers would be money ahead by avoiding the program. Otherwise the program itself is a barrier, driven by conventional evaluation concerns about attribution.

In another instance, after the application phase and planning phase were completed for one end user, the investigation phase was competitively bid to prospective firms. Michaels was the successful bidder for the detailed investigation and upon commencement of the investigation, the customer had believed that Michaels was actually beginning the implementation process. The customer did not understand what seemed like an illogical program process and was disappointed with further delay.

Black Box Documentation Can Greatly Damage Programs

The very nature of RCx projects in optimizing rather than replacing existing equipment makes complete and descriptive documentation critical to avoid frustration to both internal and external evaluation. Michaels' RCx evaluation experience has shown that some documentation for RCx projects ranges from bad to horrible. Project documentation often includes:

- An executive summary-style report that contains little useful technical information regarding the system, its operation, and the proposed changes.
- "Black box" calculation files that cannot be deciphered, frequently containing hard coded values with no equations.
- Limited, if any, justification or description regarding whether or how the energy savings were calculated according to regulatory or quality control requirements.

This presents many problems, not least of which is that verifiable programs are important for utilities to demonstrate their cost effectiveness and goal achievement. Inability to verify these savings could mean the removal of the program from the utility's profile, making it that much harder for area customers to realize potential RCx savings.

Programs cannot make documentation requirements so stringent as to become a barrier to the program; however, project descriptions need to include enough information so that the pre-RCx conditions can be quantified. Saying a particular sensor has failed and will be replaced merely describes the project. Anyone looking at the project after the fact will have no way to determine how much energy this failed sensor was wasting, calling into question their calculation—at best, they were too lazy to record their work, and, at worst, they are guessing or fudging.

Utilities are finding greater value in programs from which they can sell their reduced capacity on forward capacity markets, but these markets bring even more stringent levels of evaluation. Adopting a standardized, fully vetted calculation tool that meets third-party approval, as some programs have done, would yield critical consistency and detail; at the same time, providers must be careful not to impose a “deemed” quality onto RCx, whose value comes from the specificity of its solutions.

Effectiveness of Studies and Attribution

While evaluating Midwest/Mountain efficiency controls and RCx programs, Michaels learned via direct surveys that customers clearly associate comprehensive studies, which include measures and cost and savings estimates, with their ability to achieve substantial energy savings with building automation systems. This evokes the classic energy-efficiency barriers of not enough time, expertise, or actionable information. Retrocommissioning programs should certainly offer expertise beyond end-user capabilities, minimize their time commitment to the project, and provide decision-makers with return-on-investment information necessary to trigger projects to move forward.

One study cited this same observation as the first of three factors that affected their net-to-gross ratio adjustments:

Attributable program influence increases as degree of RCx study funding increases. “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.”

Program influence also increases when the RCx provider can demonstrate that implementing the study findings will reduce operating budgets.

Existing “green” policies were the non-program factor most likely to cause facilities to pursue retrocommissioning. (Tso 2010)

4.2 Recommendations for Attribution

The energy efficiency industry stakeholders, including utilities, regulators, implementers, and program evaluators, must in part abandon the typical program mindset with respect to attribution and free ridership for RCx. A major benefit of RCx is that savings can be realized very quickly at little or no cost, but the structure of many programs works against this expediency.

Michaels recommends the following “best practices” to improve program penetration rates while maintaining high levels of attribution:

- Trust but train consultants to document the as-found conditions. Documentation may include screenshots of building automation systems or photos of system operating characteristics via handheld meters. Of course, logged parameter data over time is sufficient documentation of as-found conditions.
- Program evaluators providing measurement and verification of projects should use consultant-provided documentation of as-found conditions. If those conditions are not documented, customer interviews will be required to help estimate as-found conditions.
- Program quality control and quality assurance should not entangle the end user. Documentation should be reviewed by program quality control engineers for completeness for purposes of determining and evaluating savings.

5. Persistence

5.1 Michaels Experience

Because the ongoing benefit of RCx hinges on future behavior and controls that often go unmonitored, there is instinctive fear that these savings have little *persistence*—one day someone will decide that it's too warm in the office and all of that careful work will be overridden by bad old practices. This mischaracterizes the nature of RCx—the setpoint they might change is not the source of the problem; something else that is wasting energy is. As discussed in Section 4 Attribution, customers engage in RCx programs for one overarching reason: to reduce operating costs, with secondary benefits of improving indoor environment. They are not getting much, if anything, new. Like properly inflating one's tires, the benefit is predominantly energy savings. Everything looks the same. Everything should feel and sound the same or better.

Michaels has been deploying the RCx program approach outlined in this paper since 2007 and performance beyond one year is available for the first two projects.

Figure 5: Persistence of Savings, High School in Minnesota

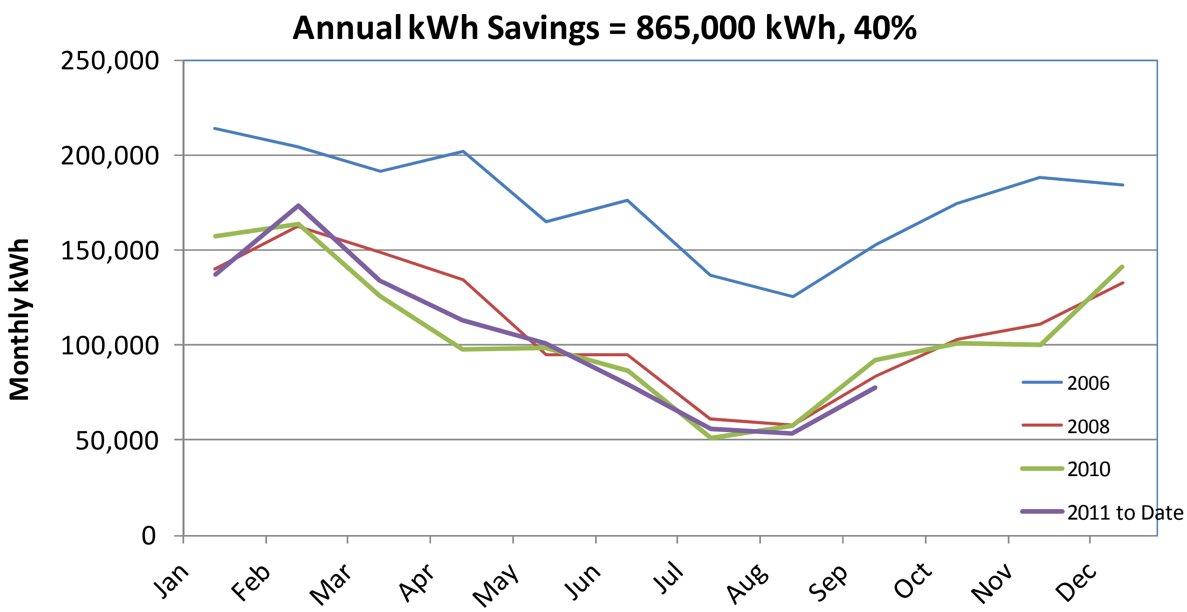
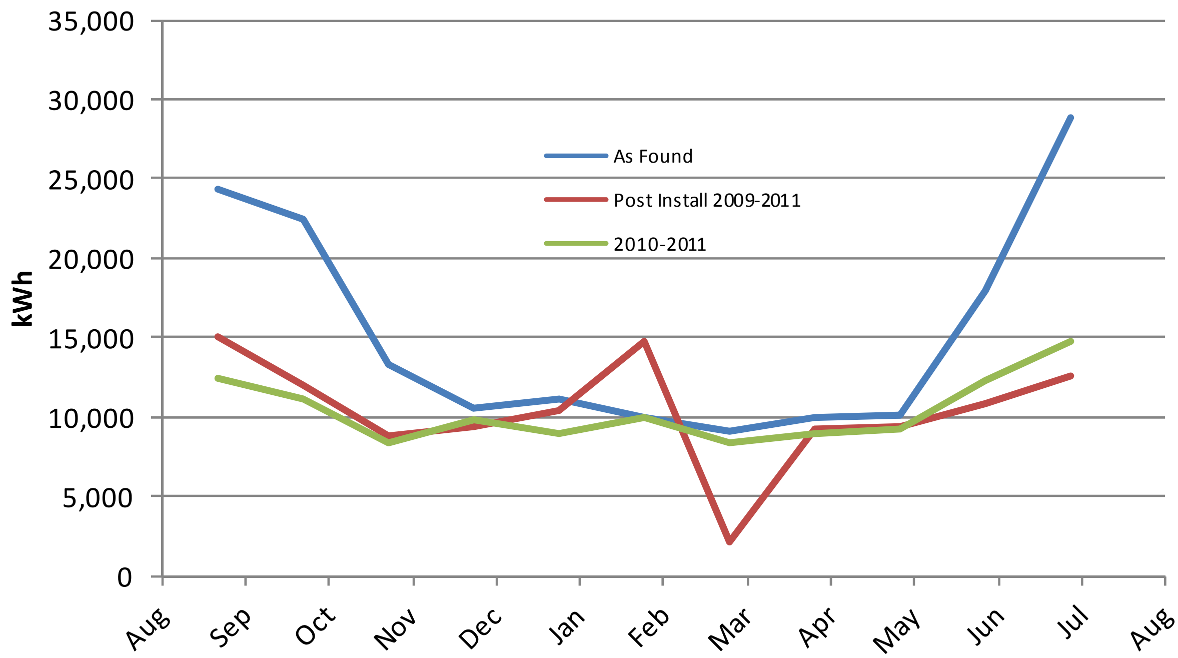
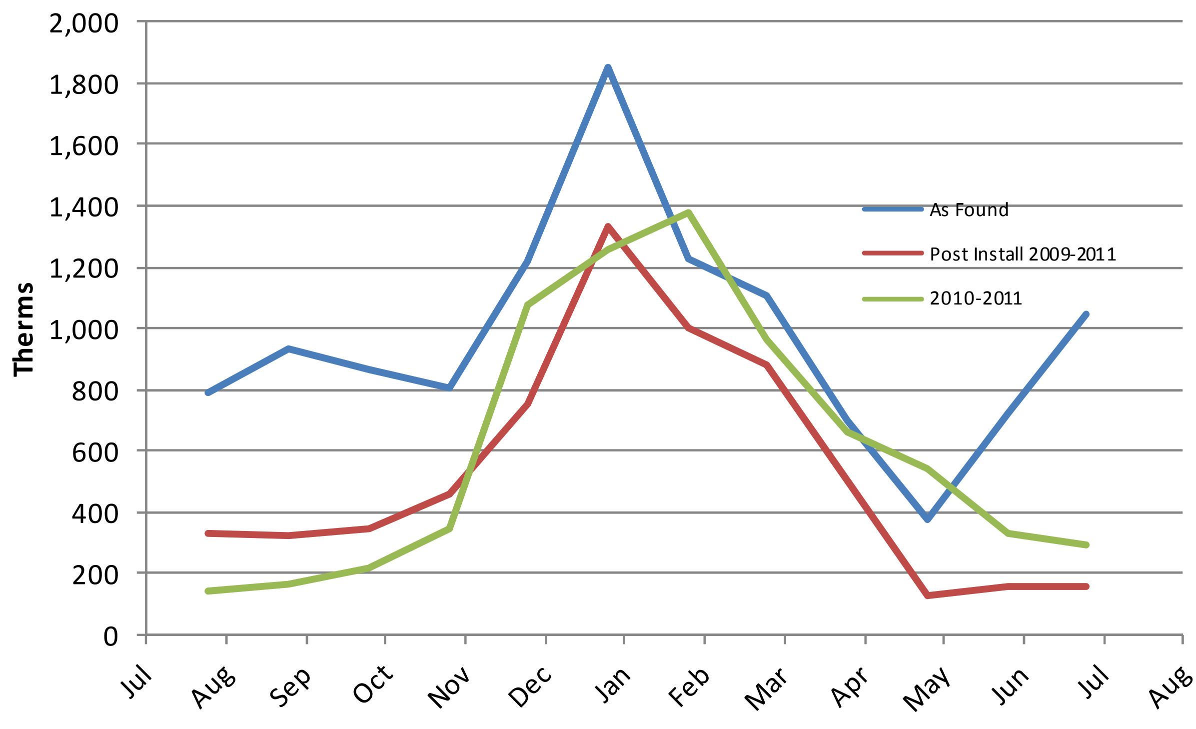


Figure 6: Persistence of Savings, Library in Iowa





The continued success at these facilities reflects research findings that shows that RCx programs have surprising persistence:

- Lawrence Berkeley National Laboratory, studying a set of 36 commissioned buildings, found “the tendency for the sample as a whole is for level or even slightly increasing savings over time.” (Mills 2009)

- In conjunction with Nexant, the investor-owned utility CenterPoint Energy studied six buildings they had retrocommissioned, finding that 37 out of 43 measures "exhibited strong persistence" two or more years later. (Krishnan 2008)
- In another LBNL study of eight Sacramento-area large commercial buildings, "approximately 80% of the peak retrocommissioning savings have persisted beyond three years," and "approximately 65% of the peak retrocommissioning savings persisted beyond four years." (Bourassa 2004)
- Looking at "over 100 measures from three California third-party RCx programs," SBX Consulting found failure rates of only "3%, 13%, and 20% for the first three years, respectively." (Roberts 2010)
- Ten university buildings in Texas showed "average chilled water and hot water savings [of] 90% and 100% of the first-year savings respectively" after four years and, for eight of the buildings, "81% and 74%" after eight years. (Ahmad 2011)

"Comprehensive commissioning includes training, and, in some cases, installation of permanent metering and feedback systems," one study said. "These improvements live on after the commissioning engineers leave the site." (Mills 2009) Echoing what we've learned onsite, experts overwhelmingly cite those same three conjoint factors as the mechanism that creates persistence: building operators with adequate management support who are educated by training-oriented RCx providers on the changes that were made and how to regularly monitor system performance so they can act should savings start to deteriorate.

Paying for and Ensuring Savings Maintenance

Consistent staffing and internal champions are always vital in making sure RCx savings persist. Having invested in saving energy, end users are prone to monitor their energy consumption to ensure savings are being maintained. In one case, Michaels provided energy analysis and engineering for a private college's campus-wide energy management system with the primary driver being operating cost reduction. This resulted in roughly 20 percent savings for both natural gas and electricity, but the project was not commissioned, and functional testing was not performed. Energy use has crept up in the intervening eight years, prompting concern of rising cost by the finance department. The solution and next step is to perform RCx on 17 facilities. In this case, the end user made a significant investment with the energy management system to successfully reduce operating cost but they intend to hold energy costs flat despite rising energy costs over time. Due to their initial investment and commitment to saving energy, they monitor and intend to aggressively maintain stable net energy bills.

In the one case however, for unknown reasons, maintenance staff clearly unwound the control sequences that were implemented as part of the RCx project. The contractor reinstated the control sequences and maintenance staff again unwound the measures. The reporting mechanism forces the issue with management so this can be resolved. This is in process as of the publishing time for this paper.

Do No Harm

Another element of RCx that supports persistence of savings is that most measures cannot be noticed by building occupants. Michaels employs a "do no harm" approach to RCx, meaning at minimum maintain comfort conditions and indoor environment, and improve them when possible. Most savings from Michaels' RCx projects are derived from reducing or eliminating simultaneous heating and cooling, which is not perceptible when done correctly, and providing or optimizing fan and pump speed control. These measures are imperceptible by occupants, and this invisibility is one reason savings persist over time, but staff training is a necessary element as well.

Follow-Up Reporting

As demonstrated above, impacts from Michaels' RCx projects are substantial and in most cases should clearly be evident with billing analysis before and after RCx. Michaels' program includes functional testing and real-time measurement and verification, while resolving deficiencies before the contractor leaves the site. Energy bills are monitored for consumption approximately three months after implementation, and after a full 12 months of post-implementation operation a report is completed comparing predicted performance against actual performance. In most cases, as indicated above, actual energy savings meet and exceed predicted savings. However, the 12-month report serves as a follow-up to indicate whether savings are not being achieved.

"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," one study said. (Tso 2010) Another noted, "[A one-building study] found that more than 83 percent of the originally estimated savings had persisted, a high level of long-term persistence. However … close to 100 percent of the energy savings would have been maintained if ongoing support had been provided to the building staff as part of the RCx work." (Ahmad 2011)

Training

Customer staff understanding of how their systems use energy is critical to maintaining savings. Michaels provides staff training teaching how customer-specific systems use energy, how the as-found system operation was wasting energy, and what was done to reduce energy consumption as part of the RCx project. This understanding is key because many savings opportunities are due to misdiagnosis and mistreatment of symptoms, which can include letting systems run around the clock, such as at warmer and less efficient performance for boilers, or the opposite for chillers. It is critical that staff understand the actual cause of these problems.

For example, in one facility in which Michaels provided RCx, the end user was operating HVAC systems 24/7 because they had frozen pipes in the below-grade space between the suspended ceiling and the floor above. That was a wasteful solution to the problem, which was created by shutting down supply fans and associated fresh air while letting exhaust fans run nonstop. This results in negative building pressure drawing in outdoor air—in this case, very cold winter air—wherever flow paths provided the least net resistance to flow. In this case, relatively leaky construction around the sill and joists was the path and the suspended tile created a barrier to flow, trapping the cold air where it could freeze the pipes. This is also a typical cause for freezing coils in air handlers, although they should have freeze protection control to avoid this.

Understanding sources of problems alone can save a lot of energy. Building staff *have* to understand the causes of these problems or measures will be undone. In some cases, if they are not convinced of the solution, monitoring can be performed to ensure success. In the case of freezing pipes, temperature loggers can be deployed in the ceiling space to track temperature as winter heating season approaches.

The experience of Michaels and other RCx providers is that building operators often welcome the opportunity to improve both their building's performance and their professional performance. According to one study, "The most frequently reported downside [of retrocommissioning] was the large time demands on the building engineering staff. However, all respondents thought it was worth the price. [Operators at every site in the study] said that RCx is beneficial to their operations, due to on-going training and continuous improvement of system specifications." (Bourassa 2004)

"The training associated with RCx projects is viewed by the utility as a discrete activity," one study said. "But training can and should be the 'thread' that ties together the entire process and all levels of management, user and facilities." (Salas 2010)

This primacy of training emerges repeatedly in RCx literature as the distinguishing factor between standard and high-achieving programs. "Four sites listed training as the most important non-energy benefit from retrocommissioning," one study said. "Four sites [that cited] a high level of training value also have good energy savings and persistence. Conversely, [one site] reported virtually no training value and it has the least persistent energy savings of the group." (Bourassa 2004)

Simply offering training is not always sufficient; it has to be done well, and its lessons have to survive staff turnover. "Various utilities/agencies have tried to incorporate some form of persistence in their programs by providing a detailed systems manual and by training facility staff at the end of the project," one study said. (Ahmad 2011) "Although this is a good starting point, in many cases the manuals are not consulted and training is not converted to standard practice for reasons ranging from lack of resources to a shift in priorities to a change in personnel." Michaels is proud of its approach to training, but the RCs industry needs to develop best practices to make sure that lessons stick. Likewise, developing RCx models that provide post-inspection support is a challenge that RCx programs and providers must address.

Investing in Persistence

Another characteristic of Michaels' approach to RCx is to spend a little extra capital to help ensure persistence over time. Examples of this include:

- One project's primary savings measure was the elimination of a 100 hp circulating pump for a school heated and cooled by a ground source heat pump system. The system could have been modified to bypass the pump at lower implementation cost, leaving the pump installed, "just in case." Engineering analysis ensured that pump removal from the system entirely would cause no problem and not reduce redundancy. The pump, sitting in the school maintenance shop, will not pull 60 kW 24/7/365 again. Coincidentally, "just in case" design often contributes to wasted energy. This is not at all uncommon. The results of this project are shown in Figure 5.

- In another project, a temperature control zone that required substantial cooling load year round was driving the system serving the entire floor into cooling all year, resulting in wasted reheat energy in every other zone. The temperature sensor was removed from the system and the waste heat was used to heat the space in winter as intended.

- In a hospital, large variable air volume systems were serving zones that included equipment rooms, which require cooling year round. Similarly, these equipment room zones were removed from the central systems so they are not in full cooling mode all winter. Computer room air conditioners were installed to condition these spaces.

In Michaels' experience, measures can be implemented on the cheap, but if system design allows for energy waste, sooner or later it is likely to occur.

5.1.1 Monitoring

Understanding how the building actually performs, as opposed to how engineering equations say that a building is supposed to perform, is the cornerstone of RCx. That said, few if any RCx programs allow for truly "sufficient" monitoring—rarely is the pre-audit data extensive and granular enough to fully describe the building's energy use, and rarely is post-audit data collection complete or frequent enough to show the lifespan of measures. The root cause of this inadequacy is that building energy systems are not built to be monitored: major equipment is not separately metered, system design was not performed with monitoring in mind, and monitoring equipment must be either regularly collected or integrated into a building management system beyond what many building owners have ever conceived. Put simply, the "ideal" amount of RCx monitoring is asking for a lot.

As RCx becomes more mainstream, however, the benefits of such monitoring become clearer, and that "big ask" becomes reasonable to building owners and operators who understand what such integrated systems offer—real-time tracking of building performance and the ability to recognize energy waste as it happens.

"Monitoring-based commissioning programs provide the opportunity to develop tools to monitor and track savings, and notify operators when savings diminish. [The buildings in the study] added metering and analysis, remain cost-effective, and provide added benefits of rigorous savings verification, energy tracking, diagnostic capabilities, and long-term persistence tracking," one study said. (Jump 2007) This diagnostic capability cultivates persistence once the RCx provider has moved on, but RCx programs—and anyone interested in the proliferation of energy efficiency in buildings—need to be able to make the case that including such monitoring is cost-effective.

5.2 Recommendations for Persistence

Successful RCx requires an all-in commitment from program administrators, consultants, contractors, and multiple levels of end-user staff. Several layers of relatively inexpensive steps can be used by programs to realize deep energy savings with redundant insurances to achieve forecast savings.

- Customer facility staff and management must both be on board with RCx projects. Facility staff can make or break projects and management must be committed to taking action in "return" for free investigation and analyses.
- Include facility performance measures beyond energy efficiency to include reduced maintenance cost and headaches, and improving comfort. Sound engineering for measure identification and implementation is necessary to avoid backpedaling in these critical areas.
- Train staff to understand how their systems use energy, how the measures save energy and what was causing the as-found waste.
- When possible, engineer persistence into implementation by investing a bit extra to make reversion back to the status quo difficult, if not impossible.

6. Works Cited

Ahmad, Mushtaq. "Persistence of Energy Savings in Industrial Retrocommissioning Projects." *American Council for an Energy-Efficient Economy.* Washington, D.C., 2011.

Bourassa, N.K. "Evaluations of Retrocommissioning persistence in Large Commercial Buildings." *National Conference on Building Commissioning.* Atlanta, Ga., 2004.

Haves, Phil. *A Study on Energy Savings and Measure Cost Effectiveness of Existing Building Commissioning.* Portland, Ore.: Portland Energy Conservation, Inc, 2009.

Jump, David. "Tracking the Benefits of Retro-Commissioning: M&V Results from Two Buildings." *National Conference on Building Commissioning.* Atlanta, Ga., 2007.

Krishnan, Umamaheswar. "Retrocommissioning: A Persistence Study." *American Council for an Energy-Efficient Economy.* Washington, D.C, 2008.

Mills, Evan. *Building Commissioning: A Golden Opportunity for Reducing Energy Costs and Greenhouse Gas Emissions.* Berkeley, Calif.: Lawrence Berkeley National Laboratory, 2009.

Moore, Emily. "Making the Leap: Data and Lessons from Scaling Up Retrocommissioning Programs." *American Council for an Energy-Efficient Economy.* 2008.

Roberts, John. "Do Savings from Retrocommissioning Last? Results from an Effective Useful Life Study." *American Council for an Energy-Efficient Economy.* Washington, D.C., 2010.

Salas, Carl. "RCx Case Studies: The Good, The Bad, The GREAT, Plus A Path Forward Action Plan Based on Expanded Training!" *American Council for an Energy-Efficient Economy.* Washington, D.C., 2010.

Tso, Bing. "Results from a Comprehensive Impact Evaluation of the 2006-08 California Retro-Commissioning Portfolio." *American Council for an Energy-Efficieny Economy.* Washington, D.C., 2010.

Wall, Eric. "Not Quite Retrocommissioning—Using Lessons Learned from RCx Programs to Create a Cost Effective Option for DSM Programs." *Association of Energy Services Professionals.* Phoenix, Ariz., 2011.