

## Practical M&V for Recommissioning Projects

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### Synopsis

Recommissioning projects have become more commonplace and their value increasingly recognized by building owners, property managers, and utilities. However, concerns about actual achieved savings and persistence remain. Applying proven measurement and verification (M&V) methods into the recommissioning process can address these concerns.

A recommissioning case study was developed for an historic hospital after it had been partially renovated to include other uses, such as offices, research, clinics, and a data center. The installed HVAC recommissioning improvements are discussed, along with the corresponding M&V methods implemented for each. These methods varied in the amount of analysis, risk, metering, and cost required to verify the achieved energy savings.

The case study provides examples of practical M&V methods for some common recommissioning improvements. Project savings results are identified for each of the M&V methods presented, with noticeable changes to the annual cost savings based on level of M&V rigor. The paper finishes with observations and recommendations for measuring the performance of recommissioning projects.

### About the Authors

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## **Introduction**

Retrocommissioning (RCx) has become a popular Demand Side Management (DSM) measure in recent years. Despite its rise in popularity there continue to be questions regarding the actual savings and savings persistence attributable to these efforts.

RCx measures, by their nature are not hardware installations, but are rather operational changes that do not provide DSM program managers and building owners the comfort of more tangible energy conservation measures. Nevertheless, proper system operation is as important as proper design and equipment efficiency for efficient and effective building operation.

Adding to the challenges is the nature of RCx measures: RCx projects generate significant savings, but the measures themselves tend to be small, which makes the economics of doing detailed energy performance measurement and verification (M&V) challenging.

This paper considers the costs and benefits of M&V for RCx, and puts the discussion in context of a particular project. Through a case study, M&V methods for managing risks associated with RCx services are explored.

The findings in this paper can be used to help better direct M&V for RCx for both public benefit charge funded DSM programs and for projects financed through performance contracts between Energy Service Companies (ESCOs) and end users. Results from the case study may support development of general guidelines for selecting the most effective M&V options for commonly implemented RCx projects.

## Project Description

The project consisted of evaluating a facility that participated in the Xcel Energy Recommissioning program in their Colorado service territory. Investigations and metering were performed to compare findings and the likely effect on the savings of using various levels of M&V. The OEMC provided funding in addition to the Xcel Energy program to research methods, values and costs for M&V.

### ***Building Description***

The building that was retrocommissioned and evaluated for this study was the University of Colorado Health Sciences Center Building 500 in Aurora, Colorado. Originally constructed as a hospital in the 1940s, the seven-story, 450,000 square foot building on the old Fitzsimmons Air Force Base has since been remodeled to accommodate its current use as office, research, data center, storage, and clinic spaces.

Systems were installed to provide building cooling in the 1960s through 1980s. Facility staff estimate that the building's cooling load may reach 700 tons during the summer and trend data indicate that the secondary chilled water load varies from 160 to 610 tons.

The building is provided chilled water at 44 F and steam at 125 psi from the central utilities plant (CUP). Hot water is generated via converters in the building. The hot water provides heat to the AHUs and to convectors through the facility. Five secondary chilled water pumps stage to provide adequate chilled water to the air handling units.

A Siemens building automation system (BAS) controls and monitors the chiller plant, chilled water pumps, and several AHUs. Other local control systems handle the remaining AHUs.

Each floor is served by up to four AHUs; some of these are CAV and some are VAV. Most systems have air-side economizers. Individual system design supply airflow varies from 800 to 28,000 CFM for the approximately 30 AHUs, with a total of roughly 380,000 CFM. The installed total cooling capacity of the AHUs is about 900 tons at 2200 GPM chilled water flow. The total installed supply fan power is about 440 HP.

## RCx Activities and Measures

Measures for the Recommissioning Investigation Report were developed by interviewing the maintenance staff, reviewing equipment documentation, monitoring operating parameters for a 3-week period, and assessing equipment operation with respect to electrical demand and energy usage efficiency. As a result of these activities, 27 opportunities for demand or energy savings were identified.

For each of the measures anticipated to deliver significant savings, engineering estimates of the electrical demand, energy, and cost saving potential were performed. An estimated implementation cost and simple payback was also made for each recommended measure.

The installed measures are as follows:

- Reduce minimum outside air flow for selected AHUs
- Adjust economizers for selected AHUs
- Schedule selected AHUs off during unoccupied periods
- Reduce supply air flow for selected AHUs
- Eliminate secondary chilled water over-pumping
- Repair the heating water valve serving the Basement-E1 AHU

The total calculated savings potential of this set of measures is 143 kW peak period demand savings, 131 kW off- peak demand savings, and 947,000 kWh annual energy savings, resulting in \$56,000 annual electric cost savings. The estimated implementation cost for these measures is \$13,000, resulting in a simple payback of 3 months for the entire package of recommended measures.

Table 1 shows the costs, savings and economics of the measures as reported in the Xcel Energy RCx program Investigation Report.

**Table 1: Investigation Report – expected project results**

Measure	Annual Savings				Implem. Cost	SPB (yrs)
	kW Pk	kW Off Pk	kWh	Total Cost		
Adjust minimum OSA and Economizer totals	51.2	7.1	81,542	\$ 8,170	\$ 2,000	0.46
Schedule AHU totals	-	100.4	507,142	\$22,530	\$ 1,700	0.11
Reduce fan speeds totals	76.4	15.9	299,416	\$17,983	\$ 9,000	0.67
Eliminate SCHW over-pumping	7.8	-	34,113	\$ 1,829	\$ 150	0.08
Repair HW coil valve	7.2	7.2	24,612	\$ 5,672	\$ 150	0.03
<b>Grand totals</b>	<b>142.5</b>	<b>130.6</b>	<b>946,824</b>	<b>\$56,185</b>	<b>\$13,000</b>	<b>0.23</b>

In the balance of the paper, the values presented in Table 1 are compared against savings values found using more rigorous M&V methods.

## M&V Methods

For each measure, several M&V methods are investigated. These methods vary in rigor, metering, analysis, cost and ability to mitigate risk of non-performance. The available M&V methods include the following:

- Option 1 – Calculation and visual inspection
- Option 2 (IPMVP<sup>1</sup> Option A) - Partially measured retrofit isolation
- Option 3 (IPMVP Option B) - Retrofit isolation
- Option 4 (IPMVP Option C) - Whole facility
- Option 5 (IPMVP Option D) - Calibrated simulation

**Calculation and Inspection** – In this method, measure savings are calculated only during an investigation phase. Observation of the post-installation condition is limited to visual verification that the measure was completed. There is no IPMVP option that addresses this “M&V” option. While this method is not even M&V, it is widely used, and may be appropriate in certain situations.

This M&V method is common and is easy to implement, and costs for the M&V method are low. However, significant error in savings calculations could arise both because of initial study measurement and calculation errors, inaccurate assumptions and persistence issues.

**Partially Measured Retrofit Isolation** – This approach to M&V of RCx measures meets the requirements of Option A of the IPMVP. In this method, savings are determined by partial field measurement of the systems. Because RCx in a facility often results in many small measures that don’t individually have enough savings to support a lot of M&V activity, this method can be attractive for RCx projects.

In this method, the auditing engineer would measure some parameters, and make assumptions about others. The goal of upgrading M&V to this level is to increase accuracy and decrease risk at the lowest cost. Selection of points may depend on the goal of the M&V work.

**Retrofit Isolation** – This approach to M&V of RCx measures meets the requirements of Option B of the IPMVP. In this method, savings are verified by measuring equipment performance in the field and applying engineering calculations.

By measuring more values we can increase accuracy. In this method, all important parameters affecting energy use are selected. This method will provide the most accurate calculation of savings, but will also be the most costly.

**Whole Facility** – This approach corresponds to Option C of the IPMVP. Normally, this method entails the compilation and evaluation of utility bills, including baseline adjustments. Industry conventional wisdom (and experience) requires that the savings be at least 10 – 20% of the entire

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<sup>1</sup> International Performance Measurement & Verification Protocol Volume 1, DOE/GO-102002-1554, March 2002

utility bill usage and careful accounting of changes in energy use not attributable to the measures for this method to work well. Whole facility M&V is not considered in this paper. However, additional information is available in an NCBC paper from 2005 (Selch and Bradford).

**Calibrated Simulation** – Calibrated Simulation corresponds to Option D of the IPMVP. This method is not addressed in this paper.

## **Measure M&V**

Several measures are considered to illustrate the cost and benefits of various M&V methods for RCx. The measures are as follows:

- 1) Ensuring appropriate outdoor-air ventilation rates,
- 2) Operating economizers properly,
- 3) Resheaving constant volume fans, and
- 4) Scheduling air-handling units.

Naturally, successful project implementation requires that the identified measures are properly installed and functioning. Appropriate, but not overly expensive M&V is important to ensure this happens. The auditing engineer needs to plan the M&V method and collect any necessary data prior to changes affecting system characteristics and energy use.

For each of the considered measures, there are a number of different M&V strategies that could be employed. The purpose of our evaluation was to compare the accuracy, risks and costs of the various M&V methods to the energy and cost savings for the RCx measures.

## **M&V for Ensuring appropriate outdoor-air ventilation rates and operating economizers correctly**

**Minimum OSA:** Outdoor air ventilation rates are important to maintain indoor air quality within facilities and for maintaining a slightly positive pressure in a facility to reduce infiltration and increase comfort. However, bringing excess air into a facility has a significant energy and demand penalty.

**Air-side economizers:** Proper use of economizer control is an important AHU feature (and feasible in most parts of the country) to reduce energy use and resulting emissions and costs.

Table 2 presents the points necessary to perform each of the three different levels of M&V along with the cost to do a *single* M&V job at each of the three levels of M&V. Building 500 has ten (10) affected AHUs, so economies of scale were used to reduce the cost per air handler. The chiller plant efficiency could have been measured and incorporated into the Retrofit Isolation method, but was not for this project, due to the size of the chiller plant versus the building's cooling load.

**Table 2: M&V Points and Costs for the Economizer Control Projects**

<b>Measure 1 – Reduce excess outside ventilation air and ensure proper economizer control</b>					
Stipulated Values	Spot Metering	On-going Metering	Hours	Points	Cost
<b>Calculation and Inspection</b>					
CFM					
% OSA					
RAT					
SAT					
Schedule					
Weather (TMY)					
Chiller Efficiency					
7	0	0	1	0	\$ 100
<b>Partially Measured Retrofit Isolation</b>					
Chiller Efficiency	CFM pre	Tosa			
Schedule	CFM post	Tra			
		Tsa			
		Tma			
2	2	4	27	6	\$ 3,100
<b>Retrofit Isolation</b>					
Chiller Efficiency	CFM pre	Tosa			
	CFM post	Tra			
		Tsa			
		Tma			
		AHU S/S			
1	2	5	40	7	\$ 4,550

### M&V for resheaving constant volume fans

Resheaving of constant volume fans is a persistent measure that saves considerable fan energy while having a nearly zero impact on water pumping and chiller energy use. Because the sensible load does not change for a given condition, the only effect of lowering the supply air setpoint is that the latent load may increase a very small amount. Given today’s efficient chiller plants, supplying air at the lowest possible temperature and delivering the lowest possible air flow is an optimal state for space cooling with central chiller plants<sup>2</sup>.

An advantage that resheaving has over a VFD installation is that the measure is much more persistent, simple, and costs less than a typical VFD retrofit. The retrofit involves the reduction of supply air and, if necessary, reducing the supply air temperature so that space cooling loads are met with less required fan power.

The data needed for M&V of the fan resheaving measures, along with a cost estimate *per AHU* to conduct the M&V is provided in Table 3.

<sup>2</sup> Bradford, 1998

**Table 3: M&V Points and Costs for the Supply Fan Resheaving Projects**

<b>Measure 2 – Resheaving constant volume fans</b>					
Stipulated Values	Spot Metering	On-going Metering	Hours	Points	Cost
<b>Calculation and Inspection</b>					
kW SF pre					
kW SF post					
kW RF pre					
kW RF post					
Schedule					
SAT					
6	0	0	1	0	\$ 100
<b>Partially Measured Retrofit Isolation</b>					
Schedule	kW SF pre				
SAT	kW SF post				
	kW RF pre				
	kW RF post				
2	4	0	7	4	\$ 800
<b>Retrofit Isolation</b>					
	kW SF pre	AHU S/S			
	kW SF post	SAT			
	kW RF pre				
	kW RF post				
0	4	2	12	6	\$ 1,450

**M&V for AHU Scheduling**

There were several AHUs at Building 500 that were found to be running continuously, even though occupancy was only during typical weekday business hours. For AHUs not on the building automation system, timeclocks were installed at the control panels to shut off the fans during unoccupied hours.

The data needed for M&V of the scheduling measures, along with a cost estimate *per AHU* to conduct the M&V is provided in Table 4 below.

**Table 4: M&V Points and Costs for the AHU Scheduling Projects**

<b>Measure 3 – Schedule operation of AHUs</b>					
Stipulated Values	Spot Metering	On-going Metering	Hours	Points	Cost
<b>Calculation and Inspection</b>					
kW SF post					
kW RF post					
RAT					
SAT					
MAT					
Schedule					
Weather (TMY)					

Chiller Efficiency						
8	0	0	1	0	\$ 100	
<b>Partially Measured Retrofit Isolation</b>						
Chiller Efficiency	kW SF post	AHU S/S				
RAT	kW RF post					
SAT						
MAT						
Weather (TMY)						
5	2	1	14	3	\$ 1,700	
<b>Retrofit Isolation</b>						
Chiller Efficiency	kW SF post	Tosa				
	kW RF post	AHU S/S				
		Tra				
		Tsa				
		Tma				
1	2	5	44	7	\$ 5,050	

### M&V Results – Calculation and Inspection

The results from this M&V method were determined from follow-up inspections and discussions with maintenance personnel after the measures were installed, resulting in two changes from the Investigation Report:

- The Basement AHU needs to run 24 hours, due to a dedicated cooling load in one of the served spaces.
- AHU 7N is not a constant volume system. It is a VAV system with variable speed drives on the supply and return fans.

These changes to the initial assumptions led to a decrease of \$3,400 in energy cost savings, at an M&V cost of \$2,900, as shown below in Table 5.

**Table 5: Calculation and Inspection – project results**

Measure	Annual Savings				Implem. + M&V Cost	SPB w/ M&V (yrs)
	kW Pk	kW Off Pk	kWh	Cost		
Adjust minimum OSA and Economizer totals	51.2	7.1	81,542	\$ 8,170	\$ 3,000	0.37
Schedule AHU totals	-	86.9	439,148	\$19,510	\$ 2,300	0.12
Reduce fan speeds total	75.0	14.5	294,591	\$17,594	\$ 9,900	0.56
Eliminate SCHW over-pumping	7.8	-	34,113	\$ 1,829	\$ 350	0.19
Repair HW coil valve	7.2	7.2	24,612	\$ 5,672	\$ 350	0.06
<b>Grand total</b>	<b>141.1</b>	<b>115.7</b>	<b>874,006</b>	<b>\$52,776</b>	<b>\$15,900</b>	<b>0.30</b>

## M&V Results – Partially Measured Retrofit Isolation

This M&V method incorporated spot measurements on the supply and return fans before and after the retrofits, and trended points including SAT, MAT, RAT, and OSA to determine economizer positions and operating hours of the fans. Also, timeclocks were observed to be installed and set to the proper schedules. These measurements resulted in the following changes:

- The economizers were modulating, but not fully closing to 15% minimum outside air during high outside air temperatures. According to maintenance staff, this is due to old actuators and worn damper seals.
- The resheaved motor calculations were overly aggressive in using the “cubic law” to compare reduced CFM to reduced motor power. Actual post-retrofit motor power measurements were, on average, about 40% lower than pre-retrofit readings. CFM reductions were in the range of 15-20% for the retrofit.
- The AHU scheduling was working as expected, except for AHU 5SE which was running 24 hours during most of the monitoring period.
- The savings from the hot water valve leak were reduced due to a lower observed fan speed for the VAV system.

These changes to the initial assumptions led to a decrease of nearly \$17,000 in energy cost savings, at an additional M&V cost of \$20,700, as shown below in Table 6.

**Table 6: Partially Measured Retrofit Isolation – project results**

Measure	Annual Savings				Implem. + M&V Cost	SPB w/ M&V (yrs)
	kW Pk	kW Off Pk	kWh	Cost		
Adjust minimum OSA and Economizer totals	35.8	0.6	21,464	\$ 4,323	\$14,400	3.33
Schedule AHU totals	-	67.3	339,976	\$15,104	\$ 4,760	0.32
Reduce fan speeds total	55.8	13.2	224,482	\$13,423	\$11,880	0.89
Eliminate SCHW over- pumping	7.8	-	34,113	\$ 1,829	\$ 1,350	0.74
Repair HW coil valve	5.9	5.9	20,099	\$ 4,632	\$ 1,350	0.29
<b>Grand total</b>	<b>105.2</b>	<b>87.0</b>	<b>640,134</b>	<b>\$39,311</b>	<b>\$33,740</b>	<b>0.86</b>

## M&V Results –Retrofit Isolation

This M&V method incorporated the measurements above, plus additional in-depth analysis of the monitored results and follow-up conversations with maintenance staff on the persistence of the measures. The following changes were found:

- AHU 5SE was found to have a leaking hot water coil, based on measured temperature data at the air handler. This added a false cooling load to the AHU, as well as the additional steam heating use.

- The motor resheaving measures were originally intended to coincide with a reduction in supply air temperature, with a net zero change in cooling. After the resheaving retrofits, it was determined that sufficient cooling was being provided to the served spaces, and the supply air temperature was not lowered. This resulted in a significant peak kW savings to the chiller plant, since the airflows for each of these AHUs have been reduced.

These changes to the initial assumptions led to an increase of more than \$17,000 in energy cost savings from the original Investigation Report, at an additional M&V cost of \$37,000, as shown below in Table 7.

**Table 7: Retrofit Isolation – project results**

Measure	Annual Savings				Implem. + M&V Cost	SPB w/ M&V (yrs)
	kW Pk	kW Off Pk	kWh	Cost		
Adjust minimum OSA and Economizer totals	35.8	0.6	21,464	\$ 4,323	\$20,200	4.67
Schedule AHU totals	22.1	89.3	415,656	\$32,545	\$10,790	0.33
Reduce fan speeds total	123.4	123.4	306,367	\$30,500	\$14,220	0.47
Eliminate SCHW over-pumping	7.8	-	34,113	\$ 1,829	\$ 2,550	1.39
Repair HW coil valve	5.9	5.9	20,099	\$ 4,632	\$ 2,550	0.55
<b>Grand total</b>	<b>194.9</b>	<b>219.2</b>	<b>797,700</b>	<b>\$73,829</b>	<b>\$50,310</b>	<b>0.68</b>

### **M&V Results – Cost and Savings Summary**

Noting that there is an economy of scale for multiple instances of the same measure, the costs of various approaches are shown below in Table 8. A summary of the savings and costs for each M&V method are shown below in Table 9.

**Table 8: Summary of M&V costs**

Measure	M&V Cost		
	Calculation & Inspection	Partially measured	Retrofit isolation
Adjust minimum OSA and Economizer totals	\$ 1,000	\$ 12,400	\$ 18,200
Schedule AHU totals	\$ 600	\$ 4,080	\$ 12,120
Reduce fan speeds total	\$ 900	\$ 2,880	\$ 5,220
Eliminate SCHW over-pumping	\$ 200	\$ 1,200	\$ 2,400
Repair HW coil valve	\$ 200	\$ 1,200	\$ 2,400
<b>Grand totals</b>	<b>\$ 2,900</b>	<b>\$ 21,760</b>	<b>\$ 40,340</b>

**Table 9: Summary of M&V results - savings and paybacks**

Comparison of savings and payback for four (4) M&V approaches								
Measure	kW Pk	kW Off Pk	kWh	Cost Savings	Implem. Cost	M&V	Total	SPB (yrs)
No M&V	142.5	130.6	946,824	\$56,185	\$13,000	\$ -	\$ -	0.23
Calculation & Inspection	141.1	115.7	874,006	\$52,776	\$13,000	\$ 2,900	\$15,900	0.30
Partial Retrofit Isolation	105.2	87.0	640,134	\$39,311	\$13,000	\$20,740	\$33,740	0.86
Retrofit Isolation	194.9	219.2	797,700	\$73,829	\$13,000	\$37,310	\$50,310	0.68

## Conclusions

The following are primary findings and recommendations:

- Perform M&V, because results will not match calculations.
- When more measured data is gathered, the ability to spot other potential RCx opportunities increases.
- Utilizing the appropriate M&V method for each project type will reduce overall M&V costs while determining if energy cost savings goals are met.
- Paybacks are still good with M&V incorporated into RCx projects.

This paper demonstrates that detailed M&V does add cost, but more importantly aids in creating accurate and persistent measures and savings. Many potential pitfalls and rewards will not be found without delving into the measured data and extensive conversations with on-site staff who deal with these systems every day. Accuracy and validation of the success of RCx projects will not be successful without the use of appropriate M&V methods.

Another thought is that perhaps RCx programs should be retooled to encourage less work up front and more during implementation. Rougher estimates of savings could be used to estimate savings and help make go/no-go decision. If the project was a go, then the RCx agent could commence work focusing more on successful implementation where energy calcs could be done and the necessary data collected as a by-product of the implementation steps. Overall funding should be increased to provide higher quality measures and more persistent savings than may be currently realized.