Ways To Save

Retrocommissioning

M&V Procedures and Requirements

February 2023

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Introduction

Retrocommissioning (RCx) has become a mainstream energy efficiency measure (or set of measures) implemented by building owners and managers to improve facility operations and efficiency. The PECO Ways to Save program offers an incentive for customers who implement RCx projects at their facility. This document provides a description of RCx projects, what RCx is and how it is defined, the standard International Performance Measurement and Verification Protocol (IPMVP) used to determine savings for RCx projects, and examples of RCx projects as they apply to the different analysis options of the IPMVP.

Custom Measures

A custom measure in the PECO ACT 129 Phase IV program is an energy efficiency measure that is not listed as a prescriptive measure in the PECO Retrofit and Custom application. Examples of custom measures include RCx, chiller plant optimization, Combined Heat and Power (CHP), Variable Frequency Drives (VFDs) on process motors, etc. Custom measures generally require site-specific energy data to both qualify and quantify kWh savings. A comparison of pre and post upgrade, site-specific trend data forms the basis of the savings. Trend data is typically obtained from a Building Automation System (BAS), PECO interval data, or equipment-level logging meters.

Retrocommissioning Process

The classic RCx process helps identify, implement, and maintain improvements to building systems and operations via the following five phases.

1. **Planning.** This phase involves screening buildings to determine whether they provide a good fit for RCx by assessing indicators such as equipment age and condition, building energy performance and size, and type of control system. Ideally, facilities should have an existing BAS in good working order, as well as HVAC equipment that is in relatively good condition.
2. **Investigation.** The investigation phase involves analyzing facility performance by reviewing building documentation, performing diagnostic monitoring and functional tests, interviewing staff, identifying a list of recommended improvements, and estimating savings and costs.
3. **Implementation.** The implementation phase involves prioritizing recommended measures and developing an implementation plan, implementing the measures, and testing to ensure proper operation.
4. **Turnover.** The turnover phase involves updating building documentation (e.g., system operation manuals), developing and presenting a final report, and training building operators on proper Operations and Maintenance (O&M).
5. **Persistence.** The persistence phase involves monitoring and tracking energy use over time, continually implementing persistence strategies (e.g., refining control measures or enhancing O&M procedures) to sustain savings, and documenting ongoing changes.

The RCx process is generally very data intensive. Observations are documented with data logging and trend data over several weeks or months to establish functionality or dysfunctionality over a range of conditions before and after measure implementation. Data collection begins with the investigation phase and continues beyond project completion in order to satisfactorily verify implementation and savings and facilitate independent evaluation without over-burdening operators.

Common Measures

The following are common examples of RCx measure opportunities of building systems that can benefit from RCx:

- Lighting that is on when it is not needed
- Air handlers that operate when not needed, either due to poor controls or changing occupant requirements
- Systems that simultaneously heat and cool
- Thermostats and sensors that are out of calibration
- Air balancing systems that are less than optimal
- Economizers that are not working optimally
- Controls sequences that are functioning incorrectly
- Variable frequency drives that operate at unnecessarily high speeds or that operate at a constant speed even though the load being served is variable

See Appendix A – RCx example measures, which details the appropriate IPMVP option, boundary, and measurement frequency for the examples above.

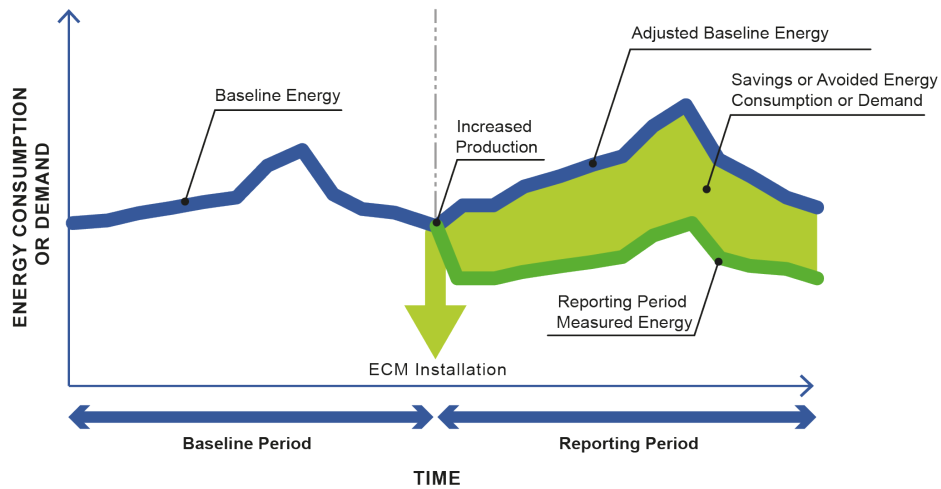
Determination of Savings

Determination of savings for RCx projects uses generally accepted Measurement and Verification (M&V) principles as described in the IPMVP. This protocol includes a framework (describing how the project parameters are defined) and analysis options for determining savings. The framework and analysis options are described below.

IPMVP Framework

Savings are determined by comparing measured consumption or demand before and after implementation of a project, making suitable adjustments for changes in conditions.

The IPMVP framework is composed of the measurement boundary, the measurement period, the measurement frequency, and adjustments (routine and non-routine). Figure 1 shows a graphical illustration of the framework.



Measurement Boundary

The measurement boundary encapsulates the equipment (or group of equipment) that is affected by the retrocommissioning project. The following are examples of RCx measurement boundaries:

- Air Handling Unit (AHU) scheduling change: The measurement boundary would include the air handler fans and dampers that introduce outdoor heating and cooling loads on the system and the parameters that describe those loads: temperatures, damper positions, and airflow.
- Chiller plant optimization: The measurement boundary would include the elements of the chiller plant undergoing operational changes, typically the chiller(s), pumps, and cooling tower fans.

Measurement Period

The measurement period is composed of a baseline period (pre upgrade) and a performance period (post upgrade or reporting period). The baseline period represents operating modes of the equipment during a normal cycle, obtained before any equipment modifications are implemented. The performance period represents operating modes of the equipment during a normal cycle, obtained after equipment modifications are implemented. Depending on the RCx measure(s) implemented, the baseline period can vary from two weeks (for a simple lighting hours of use (HOU) update) to one year (for a whole building analysis). Similarly, the performance period can vary from two weeks to several months, depending on the RCx measures implemented.

Measurement Frequency

The measurement frequency (how regularly to take measurements during the measurement period) is determined by assessing how the load varies during equipment operation. Examples of measurement frequency are listed below:

- Spot measurement: For constant loads, power is measured briefly, preferably over two or more intervals.
- Short-term measurement: For loads predictably influenced by independent variables (e.g., HVAC equipment influenced by Outdoor Air Temperature (OAT)), short-term consumption measurements are obtained over the fullest range of possible independent variable conditions. For systems expected to have nonlinear dependence (such as AHUs with outside air economizers), measurements should incorporate sufficient range to characterize the full breadth of conditions.
- Continuous measurement: For variable loads, power is measured continuously, or at appropriate discrete intervals, over the entire measurement period.

Adjustments

Adjustments refer to factors that affect the energy usage of equipment. These factors can be routine or non-routine. Examples of routine factors include changing outside air temperatures, occupancy hours, production volume, etc. Examples of non-routine factors include change in facility size, change in weekly operating shifts, change in number of occupants, etc.

Using this framework, the general equation used to estimate savings is:

Savings = (Adjusted Baseline Energy – Adjusted Performance Energy) ± Non-Routine Adjustments

IPMVP Options

Table 1 references the three IPMVP options used to determine savings for RCx projects in the PECO program. These include Option A (retrofit isolation key parameter measurement), Option B (retrofit isolation all parameter measurement), and Option C (whole facility consumption).

Table 1 IPMVP Options

IPMVP Option	Definition	How Savings Are Calculated	Typical Applications
A **Retrofit-Isolation Key Parameter Measurement**	• Savings are determined by field measurement of the key parameter(s) which define the energy consumption and demand of the Energy Conservation Measures (ECM) affected system(s). • Measurement frequency ranges from short term to continuous, depending on the expected variations in the measured parameter and the length of the reporting period. Parameters not selected for field measurements are estimated values. Estimates can be based on historical data, manufacturer specifications, or engineering judgment. • Documentation of the source of justification of the estimated value is required. The plausible saving error arising from estimation rather than measurement is evaluated.	• Engineering calculation of baseline period energy and reporting period energy from short-term or continuous measurement or key parameters(s) and estimated values. • Routine and non-routine adjustments as required. Key parameter(s) measured during both baseline and reporting period.	• A lighting retrofit where the power draw is the key parameter measured and secondly, lighting operating hours are estimated based on facility schedules and occupant behavior
B **Retrofit-Isolation All Parameter Measurement**	• Savings are determined by field measurement of the energy consumption and demand and/or related independent or proxy variables of the ECM affected system. • Measurement frequency ranges from short term to continuous, depending on the expected variations in savings and length of the reporting period.	• Engineering calculation of baseline period energy and reporting period energy from short-term or continuous measurement or key parameters(s) and estimated values. • Routine and non-routine adjustments as required. Key parameter(s) measured during both baseline and reporting period.	• Application of a variable speed drive and controls to a motor to adjust pump flow. Measure electric power with a kW meter installed on the electrical supply to the motor, which reads the power every minute. In the baseline period, this meter is in place for a week to verify constant loading. The meter is in place throughout the reporting period to measure power consumption and demand.
C **Whole Facility**	• Savings are determined by measuring energy consumption and demand at the whole facility utility meter level. • Continuous measurements of the entire facility's energy consumption and demand are taken throughout the reporting period.	• Analysis of the whole facility baseline and reporting period (i.e., utility) meter data. • Routine adjustments as required, using techniques such as simple comparison or regression analysis. • Non-routine adjustments as required.	• Multifaceted energy management programs affecting many systems in a facility. Measure energy consumption and demand with the electric utility meters for a twelve-month baseline period and throughout the reporting period.

Figure 2 presents a decision flowchart which can be used to determine the appropriate IPMVP option based on RCx project characteristics.

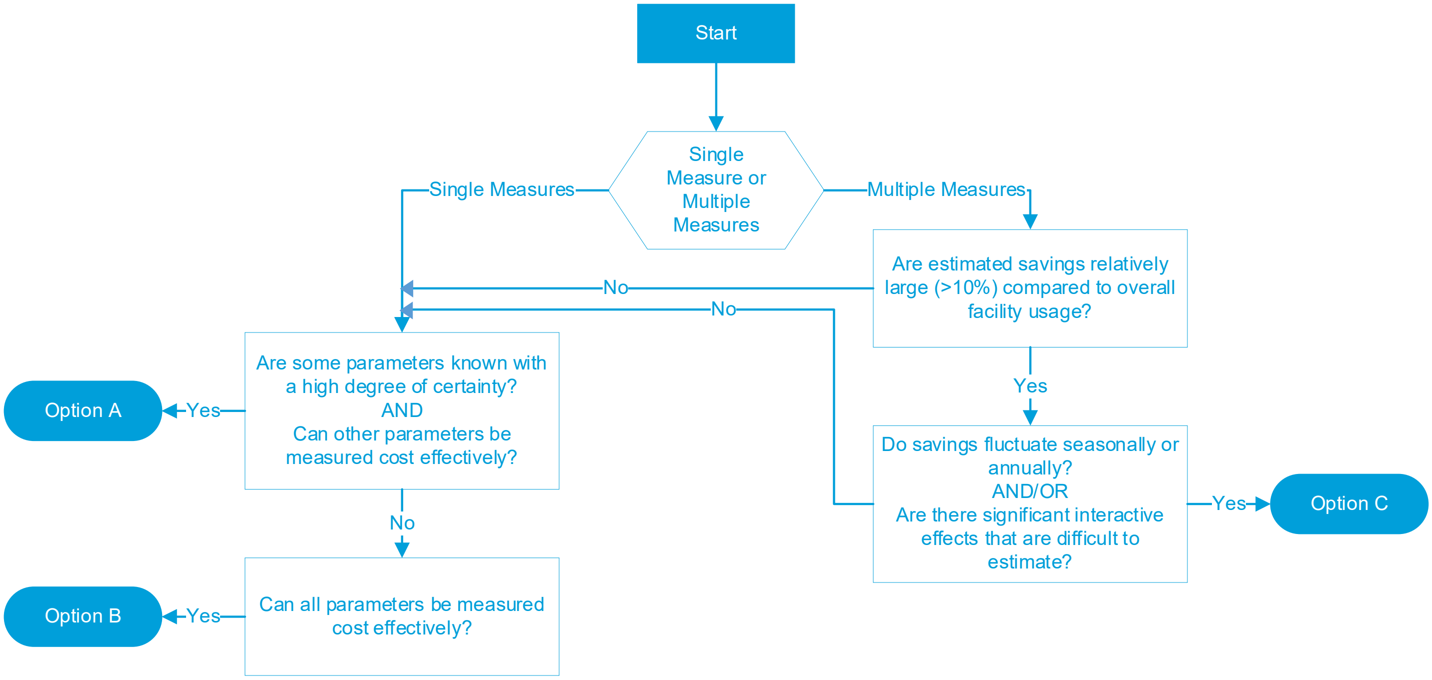


FIGURE 2 RCX FLOWCHART

Applying IPMVP to Retrocommissioning Projects

The type of analysis performed for an RCx project (Option A, B, or C) is generally determined by two factors: the nature of the project itself and the availability (or lack thereof) of pre and post equipment level data. Simple RCx lighting projects will typically utilize Option A, while complex chiller projects will typically utilize Option C. However, in the example of the chiller plant project, the availability of historical (pre-upgrade) equipment level data (e.g., interval kW and tonnage measurements for all chiller plant equipment) would allow an Option B approach instead of an Option C approach. From the perspective of deriving the best estimate of project savings, Options A and B are preferred because they generally offer a more accurate and direct estimate of savings as compared to Option C (which by its nature, includes electric usage for the overall facility and therefore has added “noise” in its composition). Because of this, Option C projects typically need to meet two requirements in order to be eligible for incentive. These requirements are:

- Meeting or exceeding an R^2 value of 0.75 and a p-value < 0.05
- Confirmation that the magnitude of the regression analysis energy savings is comparable with the sum of the estimated measure level savings derived from pre-implementation analysis.

See Appendix B – Option C Analysis Details for an example of a typical Option C analysis and how the two requirements above are incorporated.

Retrocommissioning Project Examples

Table 2 illustrates three examples of RCx projects, one each for Options A, B, and C.

Table 2 RCx Project Examples

IPMVP Option	Project Description	Boundary	Measurement Type	Frequency	Stipulations
A	**Lighting Schedule Upgrade**: This project involves a lighting scheduling upgrade in an office building where the interior lighting is controlled by a timeclock. The system operates lighting 18 hours per weekday and 10 hours per weekend day. The RCx measure will switch control from the timeclock to a BAS, which will optimize lighting operation based on an occupancy tuned schedule. Operations are expected to be repetitive week to week.	The lighting under scope	Trend data from the BAS (demonstrating the new hours of use) or the installation of light loggers to quantify the upgrade hours of use	Hourly over two weeks pre/post	Quantity and wattages of the interior lighting
B	**Domestic Water Pump VFD:** This project involves a VFD-controlled domestic water pump skid where the VFDs are currently operating the motors at full speed. To control flow, a legacy pressure reduction valve (PRV) modulates positioning based on demand. The RCx project involves removing the legacy PRV and allowing the VFD to modulate the flow based on demand (system pressure).	VFD and associated pumps	Logger or BAS data pre/post upgrade capturing kW measurements of the VFD/pump	Hourly over two weeks pre/post	No stipulated values
C	**Multi-measure:** This project involves multiple modifications to equipment operation using the existing BAS. Equipment undergoing modification includes scheduled air handler fan speed setbacks, cooling season temperature setbacks, and outside air damper repair/tuning.	Whole Building	PECO meter interval data	Hourly intervals for one year pre-implementation and six months post implementation	No stipulated values

Conclusion

In summary, RCx projects offer PECO Commercial and Industrial customers the twofold benefit of increasing facility energy efficiency and building performance with the opportunity to receive a PECO incentive based on those efforts. The IPMVP, Options A, B, or C, is generally used to quantify savings for this type of project. Retrocommissioning is a custom measure in the PECO program and is incentivized at $0.10/kWh saved over a one-year period. Incentives are capped at project cost. Project cost can include materials purchased for the project and 3rd party labor invoiced for the project. For any questions, please email the PECO Ways To Save Inbox or call the program hotline at 1-866-371-9343.

Appendix A – RCx Example Measures

RCx Measure	IPMVP Option	Measure Boundary	Measure Frequency	Stipulations
Lighting that is on when not needed	A	Lighting fixtures undergoing reduced run times	Hourly: two weeks pre/post	Quantity and wattage of affected fixtures
Air handling equipment that is on when not needed	A or B or A and B	Air handler	Hourly: two weeks to several months to establish functional boundaries	Capture enough post data to include seasonal variations
Simultaneous Heating and Cooling	C	Whole Building	Hourly: one year pre, six months post	Capture enough post data to include seasonal variations during simultaneous heating/cooling
Thermostats/Sensors Out of Calibration	C	Whole Building	Hourly: one-year pre, six months post	Capture enough post data to include annual seasonal variations
Non-optimal air balancing systems, such as failed dampers	B	Fan motors affected by imbalance	Hourly: two weeks pre/post	kW of affected motors
Improperly functioning economizers	B	Rooftop units affected	Hourly: summer evening and shoulder season pre/post	Capture enough post data to include shoulder season variations
Improperly configured control sequences	A, B, or C	Whole Building or specific equipment level	Hourly: one-year pre, shoulder, winter, summer post	Capture enough post data to include annual seasonal variations
VFD running full speed unnecessarily	B	Motor(s) with improperly functioning VFDs	Hourly: two weeks pre/post	kW of affected motors. Capture enough post data to characterize daily or seasonal variation

Appendix B – Option C Analysis Details

The following provides an illustration of a typical Option C analysis and how the two requirements outlined in the section ‘Applying IPMVP to Retrocommissioning Projects’ are incorporated.

When an Option C RCx project is submitted to PECO, the first step is to understand the scope and timing of the project. The customer/contractor must provide a list of the energy conservation measure(s) to be implemented and an engineering estimate of the kWh/kW savings associated with these measures. The engineering estimate should include appropriate measurements and trend data to characterize savings. The estimate should also include the dates each completed measure was identified, fully implemented (or a range of dates if implementation takes more than a week from start to finish) and completed. This savings estimate and raw data will be reviewed by PECO engineering and referred to during the Option C analysis to confirm if the magnitude of the resultant savings are justifiable.

When the project is submitted, PECO will download site interval meter data. Additionally, when the measures are implemented and verified, PECO will download and archive supplemental interval data. This data will be used to model the pre-implementation (baseline) period and the post-implementation (performance) period. The baseline period will include at least one full year of meter data AND independent variables for the corresponding period prior to measure implementation. For example, if the project began on 6/15/2021, the data set would include interval data and weather data (assuming weather correlation) from 6/15/2020 through 6/14/2021, plus any additional data prior to measure implementation.[1] The performance period should encompass enough time after measure implementation such that it captures meter and independent variable data of any seasonal effects of the implemented measures. For example, if the project is a chiller plant optimization, where the chiller plant operates during shoulder and summer periods, the post-implementation interval data should include enough shoulder and peak summer data to reflect the changes in energy usage that are incurred because of the project implementation.

Regression

Once these two data sets are obtained, PECO will analyze[2] energy use via regressions to model the variations in energy use introduced by independent variables, such as weather, occupancy, production, etc. The baseline and performance data sets are generally analyzed independently, thus

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[1] Due to Covid-19, certain facilities underwent significant reductions in occupancy and operations beginning March 2020. “Normal” operations are assumed to resume January 2022, unless otherwise discussed and documented with PECO. To reflect ‘typical’ operations for the baseline period of these facilities, the pre-implementation period should be 3/1/2019 through 2/29/2020.

[2] Various tools can be used to develop regression models. Each model should include an Analysis of Variance (ANOVA) table and full documentation of the input data used in their development. For example, Microsoft Excel generates an ANOVA table when using its embedded Data Analysis: Regression function. PECO and the evaluator should be able to replicate the *exact* model used to determine savings

PECO will develop two regressions for each project or measure. Both regressions must meet the following criteria to ensure they are adequate to model energy use.

- The coefficient of determination (R^2), or "goodness of fit" indicator, for each model should be ≥ 0.75
- Each independent variable should have a p-value of less than 0.05 to establish significance of the modeled variables.

Failure to meet either of these criteria may be an indication that Option C is not viable for verifying project savings.

Normalization

After models for the baseline and performance periods are confirmed to be adequate, Option C requires applying a standard set of input data (weather, occupancy, process, etc.) to the models to derive savings based on typical and forward-looking performance. This process is called normalization.

- Most Option C projects have weather-dependent variability and the analyst applies hourly TMY[3] (Typical Meteorological Year) data to both models. The TMY data are available online.[4] TMY data are location-specific, and the analysis should use data for the location closest to the project. Available TMY data includes Philadelphia International Airport and NE Philadelphia Airport. Seek guidance from PECO if there is uncertainty surrounding weather data sets.
- Some projects have additional independent variables for the regression model, such as production or occupancy. Normalization requires that both models use the same data inputs. Usually, performance period occupancy or production data are used in the normalized analysis for the baseline and performance because they are more forward-looking, but there may be situations that require other data.

Normalized results are obtained by applying the TMY data (and other variables, if appropriate) to both the baseline and performance regression models and estimating energy use for both models. Option C savings is the reduction of estimated energy use derived between the baseline and performance models.

This Option C savings estimate should then be compared to the initial engineering estimate of project savings provided by the customer/contractor when the project was submitted. If the magnitude of the regression savings is comparable to the magnitude of the modeled savings, this represents a justifiable savings claim, and the Option C savings estimate can then be used as the basis for the incentive. If the two savings values are not comparable in magnitude, further investigation is required to determine what the discrepancy is and how it might be reconciled.

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[3] Only TMYx data sets are acceptable for weather normalization, due to known provenance and recency of these data. Otherwise use TMY3 data sets.

[4] https://climate.onebuilding.org/WMO_Region_4_North_and_Central_America/USA_United_States_of_America/index.html

References and Additional Resources

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