# RETROCOMMISSIONING INVESTIGATION GUIDELINES

## Commercial & Institutional Buildings

### San Diego RCx Program

## Table of Contents

## Overview

During the retrocommissioning (RCx) investigation, the RCx Provider conducts a rigorous analysis of the building operations. Through observation, targeted functional testing, and analysis of trend and portable logger data, the RCx Provider identifies deficiencies in the operation of the mechanical equipment, lighting, and related controls, and determines opportunities for corrective action and other operational and maintenance improvements that reduce energy consumption and demand.

The RCx Provider should arrange a kick-off meeting with the Owner and appropriate facility staff to discuss any facility access and security issues, and to communicate their approach for the investigation process. A PECI Program Representative attends this meeting. The SDG&E® account representative is invited to attend this meeting. The PECI Program Representative also coordinates with the building Owner to invite any primary service contractors that may be key implementers later in the process, such as their controls contractor. This will ensure that the Owner and facility staff are clear about what to expect and the frequency with which the RCx Provider will be visiting the facility. As a reference, the Program provides a checklist of topics to cover with the Owner before the RCx Provider begins an intensive investigation of the building (see **Attachment A**).

It is especially important that the RCx Provider gather information on the Owner's operating requirements, so as to be sensitive to building schedules, functions, and processes during the investigation. The Program provides a form for the RCx Provider to reference for collecting this information (see **Attachment B**), which is requested as an attachment to the *RCx Investigation Report*.

The results of the RCx investigation are summarized in the *Master List of Findings* (included in the Findings Workbook, see section 2.0). The *Master List of Findings* provides a complete set of measures identified during the investigation and includes findings and measure descriptions, energy savings calculations, estimated costs, and simple payback calculations. When compiling the estimated implementation costs by measure, the RCx Provider will include estimated contractor costs as well as RCx Provider costs for additional (beyond what the Program provides) implementation assistance.

During the investigation, the RCx Provider should consult with the Owner on the level of additional assistance desired or warranted for each potential measure. Additional implementation assistance may include: preparing detailed scopes of work, writing detailed control sequences and schematics, working with in-house staff to implement and optimize measures, or providing full turn-key implementation services. As appropriate, total estimated costs should detail out Owner contractor costs and RCx Provider implementation assistance costs in the Findings Workbook.

Implementation assistance from the RCx Provider is an optional service for the Owner. Proposed costs for RCx Provider implementation assistance will be considered part of the implementation costs for the building Owner. If the Owner chooses not to contract with the RCx Provider during implementation, PECI will recalculate the estimated implementation costs (without RCx Provider assistance costs) to reexamine the paybacks and measure eligibility for the Program implementation incentive.

The RCx Provider is required to submit the *Master List of Findings* and all supporting information to the Program for review. Supporting information includes: all calculations and assumptions, trend and portable logger data, functional test results, building simulation parameters and results, site visit reports, or photographs that were used to identify the problem or opportunity.

Whenever appropriate or feasible, the RCx Provider should use the building automation system trending or portable data loggers to obtain baseline data that demonstrates the problem or opportunity.

Upon approval, the RCx Provider presents the results of the investigation in a meeting with the Owner, PECI Program Representative, key contractors and, if applicable, the SDG&E account representative. The RCx Provider and PECI Program Representative assist the Owner in selecting the best improvements for implementation.

The final package of improvements is presented to the Owner in the *RCx Investigation Report*. The *RCx Investigation Report* includes the measures selected for implementation from the *Master List of Findings*, the energy savings and payback calculations, and recommendations for implementation. The RCx Provider assists the Owner with determining more accurate costs for the implementation of each measure and includes these costs in the *RCx Investigation Report.*

## 1.0 Incentives

The Program funds RCx investigation costs using the following formula:

| | Incentive | Description |
|---|---|---|
| **Base incentive** | $8,000 | Incentive for all buildings. |
| **Square footage allowance** | $0.04/sq ft | Square footage of conditioned space to be retrocommissioned. |
| **Air handlers** | $1,000/AHU | Cooling or heating air handlers with supply fans over 5 hp. Dedicated outside air fans without cooling do not count towards total. |
| **Chillers** | $800/chiller | Chillers with significant hours of operation. Do not count emergency back-up chillers. |
| **Cooling towers** | $1,500/cooling tower | One cooling tower is defined as serving one chilled water plant. Cooling towers with multiple cells are counted as one tower. |
| **Chilled water distribution loop** | $1,000/loop | The number of chilled water distribution loops, each with its own pump(s). |
| **Total** | **For buildings with an EUI <=20 kWh/sq ft, the incentive is the minimum of the calculated value (above), $0.10/sq ft, or $100,000.**<br><br>**For buildings with an EUI >20 kWh/sq ft, the incentive is the minimum of the calculated value (above), $ (EUI-20)*.003/sq ft+ $0.10 /sq ft, or $100,000.**<br><br>**If exact electric usage is not known (e.g. if a building is part of a campus and not sub-metered), then the EUI shall be estimated by the Program using California Commercial End-Use Survey (CEUS) data.** | |

Systems that have similar, but atypical types of systems will be calculated in a similar manner.

The base cost relates to the fixed costs of retrocommissioning investigation activities, including preparing for and attending meetings, preparing reports for the Owner, and completing Program deliverables. The square footage and equipment cost allowances approximate the cost of investigating systems, determining appropriate findings and resolutions, and assisting the Owner in obtaining bids for implementation.

The investigation incentive is paid directly to the RCx Provider, 50% upon completion and approval of the *Master List of Findings* and the remaining portion upon submission and approval of the *RCx Investigation Report*.

While the RCx investigation focuses on low-cost improvements with short pay backs, major capital improvement opportunities may also be identified. Retrofit measures are beyond the scope of the Program; therefore, in these cases, the RCx Provider will direct the Owner to other SDG&E programs to complete the retrofits. Similarly, the RCx Provider may learn that the Owner is interested in SDG&E's demand response program. This information should be conveyed to the SDG&E Account Representative.

# 2.0 Eligible Measures

The San Diego RCx Program is striving to maximize the savings potential during the RCx work. Consequently all reasonable measure types within your scope of work should be examined. These measures typically cover the following types of systems:

1. HVAC
2. Lighting
3. Domestic Hot Water (DHW)
4. Misc. Pumps (Booster pumps, fountains, etc.)
5. Refrigeration

The goal of the Program is to implement the following types of measures:

1. Fix problems with existing controls
2. Enhance the control and operation of existing equipment
3. Make limited repairs/upgrades to the existing equipment to make it run more efficiently

Most commonly, measures will apply to the following HVAC system components and operational situations: chillers, cooling towers, economizers, air handlers, pumps, simultaneous heating and cooling, and controls.

The San Diego RCx Program will indicate some limited controls enhancements such as variable frequency drives installed on existing motors to replace vane axial controls, occupancy sensors to permit advanced control of existing systems, and additional capabilities added to existing energy management systems. These may be eligible under the San Diego RCx Program, if they meet the following qualifications:

- The measure must enhance or restore the operation of an existing piece of equipment or a system.
- The measure must have a simple payback of no more than four years.
- The cost of the measure must be no more than 10% of the cost of the existing system that it enhances, as estimated using the most recent version of the RS Means Building Construction Cost Data.

The following items are specifically excluded from the San Diego RCx Program:

- Lamp, ballast, and fixture replacements
- Replacement of existing motors with premium efficiency motors
- Major plant or distribution system conversions
- Short-term, routine maintenance items, such as filter changes, lubrication, and fan belt adjustments
- Fuel switching measures
- Measures that don't save energy; however recommendations uncovered during the investigation that improve other items (e.g. IAQ) should be indicated in the report

If the above items are identified as opportunities, then they may be recommended to the building owner, but should not be presented in the Findings Workbook.

Measures with a payback over 4 years are generally not eligible (although some that are close to 4 years payback may be considered). If measures are identified with greater than 4 years payback, measure scope and estimated costs should be reevaluated, to determine if there is potential to adapt the measure to bring it within 4 years. For example, installing VFDs on 8 air handlers may be too expensive, but possibly they could be cost-effective if installed on the 4 air handlers with the greatest load.

RCx Provider should check equipment warranties, in case there are any limitations on system modifications that may be carried out. This is referenced in the Kick off Meeting checklist (Attachment A).

If a previous system modification within the last 5 years was carried out using incentives (from utility or other publicly funded program), then similar measures are not eligible under this program. For example, if a VFD was installed using incentives from the Standard Performance Contracting Program, then optimizing those VFDs per the original incentivized scope of work is not eligible under this program. If there is doubt over the whether a measure is eligible with regard to this limitation, consult with the Program. This is referenced in the Kick off Meeting checklist (Attachment A).

For ongoing modifications to building systems (e.g. chiller replacement), the program may elect to delay the RCx process until after this work is completed to avoid lost opportunities and/or wasted effort. Consult the program in these cases.

RCx Provider should consider the impact of any applicable building and/or energy codes when recommending measures. All required codes shall be followed.

Note on eligibility of chilled or heating water loop conversions from constant to variable flow: These measures may be implemented under this Program so long as they do NOT involve cutting piping for inserting bypass piping near the pumps. Modifying / adding piping with flanged connections and/or replacement of existing three-way control valves with two-way valves are acceptable as long as all other requirements are met, e.g., the cost of the measure must be no more than 10% of the cost of the existing system that it enhances.

Note: Routine maintenance items should be done by the Owner prior to the RCx investigation. Major equipment maintenance items that result in energy savings and have a greater tendency to persist are considered eligible measures if they are performed due to, or in conjunction with, the retrocommissioning work. If major maintenance items that have long term persistence are found, such as fixing leaking or failed valves, actuator or damper operation, or leaks causing low refrigerant charge, is identified by the RCx Provider, these should be included in the *Master List of Findings*.

Thermal Energy Storage (TES) systems will be eligible for incentives if the RCx Provider can demonstrate kWh savings. If the system can only demonstrate peak demand reduction due to load shifting, it is not eligible for the Program (we cannot provide incentives for turning a non-functioning TES system on). A system that claims savings by disabling the TES system will be reviewed very closely, as this typically would not make economic sense for the Owner.

Also, while testing, adjusting, and balancing (TAB) is not considered part of the scope of the San Diego RCx Program, it may be part of a larger scope of work negotiated with the Owner. In these cases, the RCx Provider should record savings associated with the TAB work following these requirements:

- The TAB work is done because of the RCx Program and would not otherwise be done
- The TAB work corrects a deficiency and results in energy savings

For reference, **Attachment C** contains a list of common retrocommissioning measures.

# 3.0 Findings Workbook

To organize, communicate and track project progress and the selection and implementation of measures, PECI has developed a Microsoft Excel® "Findings Workbook" as a tool for the RCx Provider and program team to use. This tool is used during investigation and implementation, and produces the associated deliverables required by the Program. The Program requires the RCx Provider to use this workbook, as its intent is to facilitate and streamline reporting and project tracking. The Findings Workbook deliverables represent the minimum level of reporting that the RCx Provider must complete. RCx Providers are encouraged to expand upon these tables and provide additional information and narratives in the *RCx Investigation Report* and the *RCx Final Report* as they see fit to clarify entries for the benefit of the Owner and the Program's reviewers.

Using the 'General', 'Investigation Progress', and 'Data Input' worksheets, the RCx Provider can input all of the necessary data in these worksheets. Five other worksheets in the workbook are the basis for key program deliverables (see Scope of Work): *Investigation Progress Report*, *Master List of Findings*, *RCx Investigation Report*, *Implementation Progress Report*, and *Implementation Summary Table*. The worksheets related to these deliverables are linked to the 'Data Input' worksheet and are fully formatted. The RCx Provider should only have to make minor formatting adjustments to ensure that each deliverable prints cleanly. Details for each worksheet are provided in the following table. Worksheets requiring input are noted in bold; all of the other worksheets are output only.

**Findings Workbook Description of Individual Worksheets:**

| Worksheet | Phase | Purpose | Contents |
|---|---|---|---|
| Tips | ALL | Help for the Findings Workbook | Explanation for data entry, inserting and deleting rows, other edits, measures selected for implementation, and costs per kWh |
| **General** | RCx Investigation & Implementation | Project Summary | Summary of the project, including building characteristics, energy consumption, utility rates, and RCx project costs and savings |
| **Investigation Progress** | RCx Investigation | Bi-monthly progress checks during investigation | An itemized list of tasks and their corresponding completion date |

| Worksheet | Phase | Purpose | Contents |
|---|---|---|---|
| **Data Input** | RCx Investigation & Implementation | Data input into a central location | All data for each measure |
| Master List of Findings | RCx Investigation | Report investigation findings to the Program | Findings, descriptions of findings, supporting documentation file names, measures, energy and cost savings estimates, estimated costs, estimated program incentive, and simple payback |
| Master List Summary | RCx Investigation | Present investigation findings to the Owner | Findings, measures, benefits, energy and cost savings estimates, estimated costs, estimated program incentive, and simple payback |
| Investigation Summary | At the end of RCx Investigation | List of selected measures included in the *RCx Investigation Report* narrative | Selected measures, estimated energy and cost savings, hard costs, program incentive, and simple payback |
| Implementation Progress | Implementation | Monthly progress checks during implementation | Finding, measure, implementer, scheduled completion date, completion date, and actions taken-to-date towards implementation |
| Implementation Summary | At the end of Implementation | List of implemented measures, including updated cost and savings values | For each measure, updated energy and cost savings, actual costs, program incentive, and updated simple payback |

# 4.0Deliverables

The RCx Provider will prepare three key program deliverables during the RCx investigation: *Investigation Progress Report*, *Master List of Findings*, and *RCx Investigation Report*. Each of these is described below.

## 4.1 Investigation Progress Report

To keep a pulse on the progress of the RCx investigation, the Program recommends that the *Investigation Progress Report* be submitted bi-monthly during investigation. The RCx Provider should submit the Findings Workbook with the *Investigation Progress Report* worksheet updated to reflect current project status. The *Investigation Progress Report* worksheet in the Findings Workbook is set up to record completion dates for the tasks that are pivotal to investigation.

## 4.2 Master List of Findings

As indicated above, the observations and findings from the RCx investigation will be communicated to the Owner and Program via the *Master List of Findings*. In a meeting with the Owner and Program Representative, the RCx Provider uses the *Master List of Findings Summary* to present the RCx investigation results and assist the Owner with selecting measures for implementation. At the meeting, the Program Representative and Owner will discuss the available program incentives based upon the simple payback estimates from the investigation.

The RCx Provider is encouraged to communicate with the Owner throughout investigation about what measures are being identified. This is meant to avoid sinking a significant amount of time into a measure that the Owner will not implement for various reasons such as measure impact on critical items or project aesthetic related operations. For the *Master List of Findings*, cost estimates are sufficient. Also, measures that do not lead to energy savings, but result in non-energy benefits (IAQ, reduced maintenance, etc), should still be included in the *Master List of Findings*, but, for the Program, they do not need to have a cost-benefit analysis attached to them.

At a minimum, the *Master List of Findings* submitted to the Program must contain the following information for each finding:

- Finding name and assigned number
- Description of finding
- Recommended measure or improvement
- Supporting documentation file name(s)
- Baseline documentation method
- Evidence of implementation method
- Estimated annual electric savings (kWh and $)[1]
- Estimated annual gas savings (therms and $)
- Estimated total annual energy cost savings ($)[2]
- Estimated peak demand savings (kW)
- Total estimated implementation cost ($)
- Initial simple payback (years)
- Estimated Program implementation incentive ($)
- Estimated simple payback with incentive (years)

The *Master List of Findings Summary* for the Owner includes all of the above information, except for the 'Description of Finding' detail, and is printable on "at-a-glance" pages. The *Master List of Findings* template is located in the Findings Workbook, described in Section 3.0.

All calculations or modeling parameters and results must be submitted with the *Master List of Findings* for Program review, as well as the supporting trend or logged data and analysis. The Program will use this data as the baseline performance to prove implementation and verify savings for those measures that are implemented by the Owner.

## 4.3 RCx Investigation Report

The *RCx Investigation Report* is generated by the RCx Provider after measures are selected for implementation. At a minimum, the *RCx Investigation Report* includes all of the data presented in the *Master List of Findings*, as well as recommendations for implementation for each measure selected. To assist the RCx Provider, the Program provides a template for the *RCx Investigation Report*, including the cover page, table of contents, and text narrative to help guide the report (see **Attachment D** for more information). The required narrative for the *RCx Investigation Report* is limited to an introduction describing the investigation process and results and an implementation section to help the Owner take the next steps to implement.

[1] The estimated annual electric savings accounts for peak, semi-peak, and off peak for summer and winter seasons. Detail on how to calculate the annual electric savings for each measure is described in detail in Section 5.3.

[2] The estimated annual savings accounts for interactions between measures. Accounting for interactions is described in detail in Section 5.5.

To facilitate implementation, the RCx Provider assists the Owner with determining hard costs for the implementation of each measure and includes these costs in the *RCx Investigation Summary Table* (an attachment to the *RCx Investigation Report*). The RCx Provider may need to develop scopes of work and/or specs for each measure to obtain hard costs from contractors, guide in-house staff with implementation, and ensure measures are properly implemented.

In the *RCx Investigation Report*, the RCx Provider should also be clear about the format for submitting evidence that the measure has been properly implemented; i.e., trending, functional testing, site visit reports, and/or before/after photographs (see RCx Documentation Guidelines, a separate document in the toolkit, for guidelines on documenting RCx finding types). Evidence that the measures were implemented properly will be vital for the Owner to receive the program incentives.

# 5.0Required Documentation for Measures

Documentation for the individual findings (problems) and corresponding measures (fixes) must be detailed in the Findings Workbook. The RCx Documentation Guidelines section gives further detail on satisfying data requirements for the Program. Backup documentation external to the Findings Workbook is also required, including savings calculations, and RCx Providers should identify the file names for all supporting documentation in the 'Data Input' worksheet found in the Findings Workbook.

## 5.1 Guidelines for Documenting RCx Measures

Quality, consistent documentation of measures is an extremely important aspect of the San Diego RCx Program because, not only does it measure the overall success of the Program, but also adds to the industry's body of knowledge about the benefits and cost effectiveness of retrocommissioning. For this reason, the RCx Documentation Guidelines were developed to define field procedures and calculation methods for measuring and verifying the pre- and post- conditions for measures commonly implemented through the Program. RCx Providers are required to follow these guidelines and work with the Program to ensure that measures are properly documented and savings are verified.

A variety of measures may be implemented as a part of the Program and, with each type of measure, there may be different documentation requirements for:

- **How the issue was found** (a description of how the problem was detected must be input into the field "Finding Method" in the Findings Workbook);
- **How the savings are determined**; and
- **What evidence of implementation must be provided** (the method for providing evidence of implementation and the results of implementing this method are reported in the Findings Workbook)

The RCx Documentation Guidelines presents the requirements for each of these steps for potential RCx measures. In all, the RCx Providers must demonstrate to the Program that the measures they identify during RCx investigation are practicable and cost-effective, and collect **baseline data** in support of each measure. Before approving the *Master List of Findings*, the Program staff will review all **savings calculations** to verify assumptions, appropriateness of the calculation, and reasonableness of the result. This will include a review of the implementation cost estimates and the RCx Provider's Implementation Assistance cost estimates. Then, once measures are implemented, the RCx Provider is responsible for verifying that measures have been properly installed and must provide **evidence of implementation** in order to receive the Program incentive.

The Recommendations for Implementation (Findings Workbook) shall indicate a reasonable method to implement the measure that ensures the highest level of persistence that can reasonably be accepted by the Owner and operator. For instance, if a measure identifies that the chilled water reset strategy had the improper setting in the BAS user screen, the simple measure would be to recommend that the setting be fixed. However, it is quite likely that the improper values will be input again. Improved methods would be to recommend that these inputs are password protected or have some type of separate input screen along with the proper setpoints indicated so that these would not be accidentally overridden. A more extreme measure would be to hard code this, although this may not be acceptable to the building operator.

The following section provides further detail on each of these steps, as it is laid out in the RCx Documentation Guidelines.

## 5.2 RCx Documentation Guidelines

The RCx Documentation Guidelines (Excel spreadsheet) contains guidelines for problem identification, baseline documentation, calculation, and implementation verification, for 21 Finding Types.

**Row 1: Finding Type**

The first row of the RCx Documentation Guidelines table shows examples of the anticipated categories of findings to be corrected through the San Diego RCx Program. The typical RCx findings are organized into the following major categories. The number in parentheses is the number of finding types described within each category.

- Equipment Scheduling and Enabling (3)
- Economizer/Outside Air Loads (2)
- Controls Problems (3)
- Controls: Setpoint Changes (4)
- Controls: Reset Schedules (4)
- Equipment Efficiency Improvements / Load Reduction (3)
- Variable Frequency Drives (VFD) (2)

RCx Providers are encouraged to identify other problems or system operational enhancements that are not explicitly described in the Guidelines. Presumably, these findings will fit into one of the categories and the information within the category is sufficient to provide documentation guidance for the measure. If questions or issues arise concerning other findings, PECI will work with the RCx Provider and SDG&E® to define the documentation requirements.

**Row 2: Method for Finding the Problem**

The second section describes methods for finding problems. For some measures, trending or data logging may be used to both find the problem and collect the baseline data.

**Rows 3, 4 and 5: Baseline Data and Post-Implementation Verification Data Guidelines**

These sections describe acceptable methods for establishing a baseline, and for verifying implementation of the measures. Trending / logging of actual system performance is generally the most preferred method of establishing a baseline and verifying measure implementation, as it gives a true indication of system performance over a range of operating conditions (occupied / unoccupied, warm-up / shutdown, cool / warm OA temps, etc). However, other methods are also acceptable, as indicated in this section. If any of these other methods are used, contact the Program in advance of collecting the data, for approval. For

findings / measures in the 'Controls (Reset Schedules)' category, note that trend data is the only acceptable method for baseline and implementation verification.

For visually spot verifying that system performance matches that indicated by the EMS, provide brief documentation of observations. E.g., "On 5/14/09, toilet exhaust fan EF-1 was visually observed to be off when commanded to be off at the EMS. Same exhaust fan was visually observed to be on when commanded to be on at the EMS."

Note that other data beyond that indicated in the table may need to be trended / measured for the savings calculations. For example, besides trending equipment status (on/off), the kW power draw of the equipment would need to be spot measured (for constant load equipment) to calculate savings.

Trend data may be collected using data loggers or the trending capabilities of the building's EMS. See section 5.3 for general measurement guidelines.

See the Implementation Guidelines for additional implementation verification guidelines. The Program will not approve incentive payments unless the implementation is verified. If, during the verification process, it is found that some improvements have not been made correctly, the Owner and organization that implemented the improvement will be contacted to perform repairs or complete the process. The Program may derate savings if sufficient verification evidence is not provided.

**Rows 6 and 7: Calculating Energy, Demand, and Cost Savings**

The final section contains examples and guidelines related to savings calculations. See section 5.4 for general calculation guidelines. Savings for some of the measures are independent of weather and depend only on kW and hours of operation. For measures that depend on weather, calculations of savings most often involve bins of hourly temperature data or approved simulation models. If there is potential demand reduction, the Program requires an estimate of the measure's impact on peak demand.

For reference, **Attachment E** provides sample calculations for common retrocommissioning measures.

## 5.3 Measurement Guidelines

Baseline data for energy savings calculations can be gathered through trending, spot measurements, data logging, from manufacturer's data, or a combination of these methods. The following guidelines apply to collection of baseline data and, where applicable as indicated in the RCx Documentation Guidelines, data to be used for evidence of implementation. See section 2.2 of the Implementation Guidelines for additional general implementation verification guidelines.

### 5.3.1 Trending

For trending and data logging, collect a minimum of one week of data for non-temperature dependent data, and two weeks of data for temperature-dependent data. Whenever possible, data should be collected during operating conditions that are applicable to the measure.

If it is not possible to collect trend data for implementation evidence during applicable operating conditions, e.g., if the outside air temperature is too high to verify proper economizer operation, then another method should be used for verification of measure implementation. Refer to the Implementation Guidelines for acceptable alternate methods.

Trended or logged data used for implementation verification should be the same type as the baseline data.

To gather time-series data, RCx Providers may use the building automation system to trend data or may install portable data loggers. In all instances, the data collection method used must provide accurate values. This means that the accuracy of EMS and data logger sensors must be verified. On a limited

basis, portable data loggers will be available for loan from the Program on a first come-first served per project policy. The following table shows the preferred format for trend data collection:

| | |
|---|---|
| Data Format and Availability | ASCII; Importable to Microsoft Excel® Available as .txt, .csv or .xls files for the Program management team |
| Duration | Minimum of one week of data, two weeks preferable |
| Sampling rate | One to 15 minutes (Use a shorter interval when a data logger can sample and average separately. Some energy management systems may only be able to trend relatively few parameters simultaneously, and the shorter the sampling interval, the fewer points that can be trended.) |
| Averaging/Archiving Rate | Five to 30 minutes or less. For fast acting controls, or evaluation of control loop stability, short interval data may be required. |
| Typical points | Power, current, temperature, pressure, humidity, enable/disable command, status, VFD speed |

The Program recognizes that there may be instances where collecting time-series data for a measure may be inappropriate or unfeasible, and may accept alternate proof that a measure is appropriate. Other forms of proof include: trending using a lower sampling rate (when the BAS cannot support 5 minute or less intervals), functional test results, written observations or site reports, and photographs. To ensure baseline data will meet the Program's EM&V needs for implemented measures, the Program will expect close communication about the methodology used for collecting baseline data during the investigation.

### 5.3.2 Power Measurements

Energy savings estimates will be based on baseline data collected during the investigation. For collection of electricity data to be used in these calculations, power can be measured directly or estimated based on measurements of voltage, current, and power factor. Whether for a spot measurement or trending, the following guidelines apply, in order of preference:

1. Trend or log RMS power directly.
2. For constant load equipment, spot measure RMS power. For variable load equipment associated with savings initially estimated at less than 25,000 kWh/year, spot measure RMS power. Record location, time, and date of spot measurements.
3. Trend or log voltage and current and apply a power factor to calculate power (see Sec. 5.3.3 on power factor).
4. Trend or log current, spot measure voltage, and apply a power factor to calculate power. Voltage may be spot measured at the motor control center or electrical panel related to each piece of equipment being trended (see Sec. 5.3.3 on power factor).
5. For equipment with available part load efficiency curves, this data may be used as a surrogate for actual trending of power data if a trend data-based load profile is available. Verify and perform the following:
    a. Actual operation of the equipment is consistent with the assumptions in the data.

b. The load data covers the relevant range of operating conditions.
c. Supply the data as part of the analysis. A reference may be used if DOE-2 or a similar readily available data source is used.
d. Spot measure the power, along with relevant operating data, to establish the consistency of the curve fit with actual operating conditions. If a discrepancy is found, apply a correction factor to the curve fit.

6. Use nominal manufacturer's values for equipment with a constant nominal load (e.g., non-dimmed lighting, resistance heaters). Perform the following:

a. Spot measure random samples of the installed equipment, to ensure that the installed equipment meets the specifications. Measuring groups of identical equipment at an electrical panel is preferred over measuring individual pieces of equipment.
b. Determine, from inspection or spot power measurements, any variable adjustments that impact load, e.g., ballast factors.

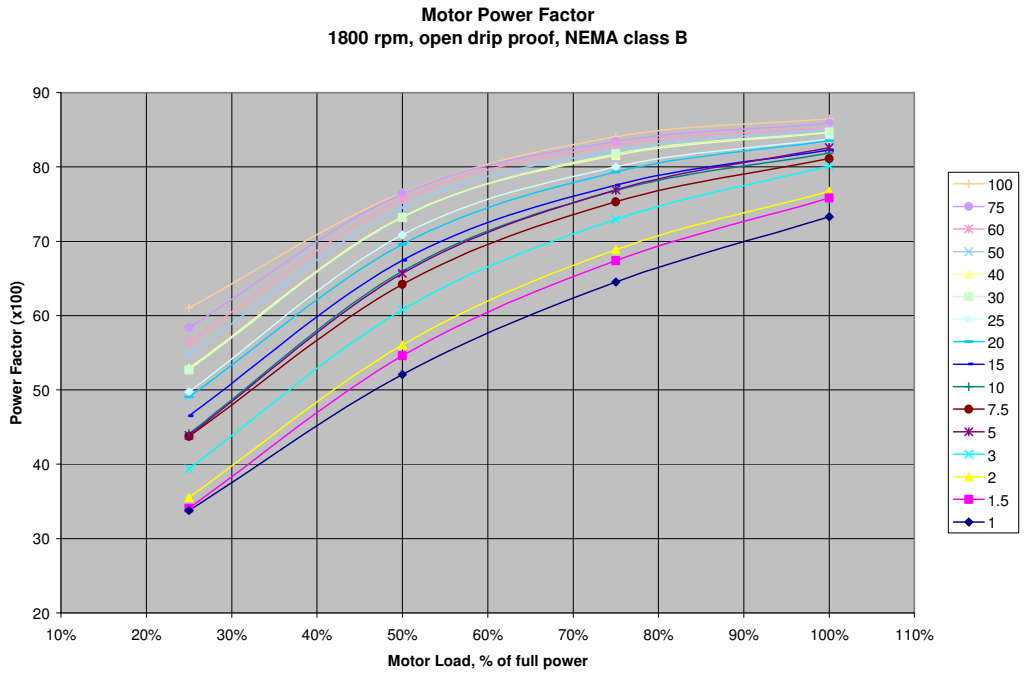
For spot measurements, record the location, time, and date of measurements. For spot measurements of voltage on three phase power, measure the voltage of all three legs and use the average in the energy use calculations.

Wherever trending or spot measurements of power are used as a means of implementation verification, perform the same method of power measurement for both the baseline data collection and implementation verification.

### 5.3.3 Power Factor

Provide justification for the power factor value used in the calculations, e.g., measured values, motor manufacturer's curves, lighting cut sheets. Constant power factors may be used for constant load equipment or for measures with estimated savings of less than 25,000 kWh/year.

The following chart shows power factor as a function of motor load and motor horsepower, for motors typically used in HVAC systems (1800 rpm, open drip proof, NEMA class B). These values may be used in power calculations when voltage and current are being measured / trended and the actual power factor cannot be readily measured. For other motor types, e.g., 1200 rpm, totally enclosed fan cooled, etc., power factor values may be obtained from the spreadsheet included in the on-line RCx Provider Resources (see www.sandiegorcx.com, username/password "rcxprovider").




Source: *MotorMaster+ version 4.00.06 motor database.* Developed for the U.S. Department of Energy by the Washington State University Energy Program, 2007.

The following table includes power factor correction values that may be used when the measured voltage deviates from the nameplate voltage.

| Power Factor Correction Values | | |
|---|---|---|
| **Motor Load** | **Voltage Difference from Nameplate Value** | |
| | **- 4%** | **+ 4%** |
| 100% | + 0.6% | - 1.0% |
| 75% | + 1.4% | - 2.0% |
| 50% | + 3.2% | - 3.6% |
| 25% | + 6.5% | - 6.9% |

Source: *Effects of Reduced Voltage on the Operation and Efficiency of Electric Loads, Volume 2.* Electric Power Research Institute (EPRI), 1981.

### 5.3.4 Sampling

For large numbers of similar equipment with similar operating characteristics, sampling may be used. This equipment should meet the following criteria:

- Components and control sequences for each piece of equipment are similar.
- Operating conditions for each piece of equipment are the same, e.g., outside air temperature, chilled and heating water supply temperatures, operating hours, occupancies served.
- For air handlers, supply fan motors do not exceed 15 HP.

Group equipment with similar operating parameters into use-groups. For each use-group, a sample size of at least 10% is acceptable. Samples should be representative to the rest of the population in the use-group. Provide supporting documentation, including a diagram of the various use-groups and a written description of the use-groups and their operational parameters. As an example, the air handlers listed in the following table can be grouped as indicated:

| Air Handlers | Quantity | Type | Occupancy Served | Operating Schedule | Use-Group Sample Size |
|---|---|---|---|---|---|
| AH-1 – AH-11 | 11 | VAV, CHW coil, HW coil, economizer section (serves perimeter zones) | Offices, conference rooms | 8-5 M-F | 2 |
| AH-12 – AH-13 | 2 | VAV, CHW coil, economizer section (serves interior zones) | Offices, conference rooms | 8-5 M-F | 1 |
| AH-14 – AH-15 | 2 | VAV, CHW coil, economizer section (serves interior zones) | Conference rooms | Intermittent from 8-5 M-F | 1 |
| AH-16 – AH-18 | 3 | VAV, CHW coil, HW coil, economizer section (serves perimeter zones) | Retail space | 7-10 M-Sat,12-7 Sun | 1 |
| AH-19 – AH-25 | 7 | CV, CHW coil, HW coil, economizer section (serves perimeter zones) | Retail space | 7-10 M-Sat,12-7 Sun | 1 |

### 5.3.5 Equipment Runtimes

For schedule-based equipment (e.g., lighting), trend run times for measures that are estimated to save more than 25,000 kWh/yr. For measures with less savings, nominal schedules may be used.

For equipment that operates based upon demand, trend run times if the trending can cover typical annual operational characteristics (e.g. air compressor). If the trending cannot cover typical annual operational characteristics (e.g. chiller operation), estimate run times with bin engineering calculations or a building simulation.

For runtimes obtained by trending of EMS data, there should be verification that the EMS data is correct. Status feedback data (AI/DI points) is preferable to Enable/Disable command data (AO/DO points).

### 5.3.6 Correlations

Include the development procedure for any correlations used in the calculations. Correlations are used to estimate system characteristics based on known values, e.g., chiller load as a function of outside air temperature (load profile). Correlations should be based on measured / trended data whenever possible.

Assumed load factors / nominal equipment efficiencies may be used for measures with a savings estimate of less than 25,000 kWh/year.

Short term trend data may or may not be adequate to collect loads that can be used to extrapolate energy savings. The following are recommended methods, in order of preference, to develop correlations:

a. Use trended data to create correlations between loads and relevant variables, e.g., fan speed as a function of outside air temperature. If these correlations are developed using inadequate data, i.e., if the data was not obtained during relevant operating conditions or over a sufficient range of the expected outside air temperatures, collect additional data later, prior to implementation, and update the savings calculations accordingly.
b. Perform load calculations / simulations using software to establish annual load profiles.

## 5.4 Determining Energy Cost Savings

Energy cost savings can be calculated in the Findings Workbook using either the customer's tariff (rate schedule) or an average rate.

### 5.4.1 Using the tariff to calculate energy cost savings:

The RCx Provider should model the energy cost savings using the tariff (rate schedule) to account for variances in energy and demand charges during different time of use periods. This results in more accurate cost savings when a measure's energy savings are not distributed across all time of use periods.

The Findings Workbook models three common tariffs (TOU-8, GS-2 TOU, and GS-2 non-TOU). If the customer is on a different tariff, enter the charges into the "custom" rate schedule cells. All energy rates ($/kWh) should include transmission and distribution costs, cost adjustments, and taxes.

### 5.4.2 Using an average rate to calculate energy cost savings:

The RCx Provider may also model the energy cost savings using an average rate by using $0.081/kWh (established by the Program) for each time of use period under the "custom" rate schedule. This cost does not include demand charges; the summer and winter demand charges need to be populated for demand savings.

Depending on the type of building and its energy use profile, calculating savings using the tariff will result in savings estimates that are not only more accurate, but up to 25% higher than savings estimated using the average rate of $0.081/kWh. Therefore, RCx Providers are encouraged to use the tariff when practical.

The energy cost going forward may be higher than the energy cost from the past year. If the cost of energy going forward is known, use the new cost for energy calculations rather than the historical cost.

For direct access customers, be sure to include both the generation and T&D cost components. These may need to be obtained from multiple sources.

Below is the SDG&E website link for tariff information:
http://www.sdge.com/regulatory/currentEffectiveTariffs.shtml

### 5.4.3 Savings Calculation Guidelines

**Method**

Energy savings may be estimated using either spreadsheet calculations or building simulations (energy modeling),. Use standard calculation methods (e.g., bin methods) and/or engineering software (e.g., DOE-2.2).

Spreadsheet calculations using bin data should include hours of operation, load, and temperature by location, in table format. Monthly average data may be used in appropriate calculations when the monthly calculation has been calibrated to the trended data.

The guidelines for determining energy, cost and demand savings are as follows:

1. For spreadsheet calculations, the annual energy savings is calculated by applying the operating profile (the times of day and year when the equipment is operating) to the energy savings profile (calculated savings as a function of the time of day and year) to generate the resulting energy savings in each time of use period.
2. For spreadsheet calculations, the annual energy dollar savings is calculated by multiplying the resulting energy savings in each time of use period (generated in #1 above) by the corresponding energy charge for that period. Using the Findings Workbook, this is most easily accomplished by determining or estimating the percentage of annual energy savings in each TOU bin, and entering those percentages in Columns X through AB of the 'Data Input' worksheet.
3. For reporting peak demand savings in the Findings Workbook, enter the average demand savings during the CPUC's peak kW reduction period (2 PM to 5 PM during the three consecutive weekday period containing the weekday with the hottest temperature of the year). Note that this may differ from the monthly peak demand savings used to calculate demand cost savings.
4. For spreadsheet calculations with peak demand savings, the annual dollar savings is the total of the annual energy (kWh) dollar savings plus the annual demand (kW) dollar savings. The annual demand dollar savings are calculated by multiplying the monthly peak demand savings by the corresponding monthly demand charge. Note that the Findings Workbook is not set up to have different demand savings each month. The Program focus is on kWh savings, so that is the emphasis in the workbook. If the demand kW savings are expected to vary significantly per month, the Provider should calculate the total (energy and demand) cost savings outside the workbook, and enter this total cost savings directly into the appropriate cell in the workbook (labeled "Estimated Annual Electric Savings ($)"). In all cases, the "Estimated Peak Demand Savings" in the Findings Workbook should indicate the demand kW savings during the CPUC period, **not** averaged over the entire year.
5. If a building simulation is used, the rate structure may be entered directly into the model. Also, the annual dollar savings from the model can be entered directly into the Findings Workbook. When this is done the energy savings profile does not need to be populated. For entering the estimated peak demand savings in the Findings Workbook, the proper DOE output needs to be used to match the CPUC demand period.

**Documentation**

Present savings calculations in a manner that is clear and easy to follow. In general all calculations shall be self documented, or reference another document that summarizes assumptions. Verbal documentation is **inadequate**, as is documentation included in emails/memos**.** Guidelines for savings calculations include:

- **Include trend data with calculations**. Trend data should be presented in a manner that is easy to follow, typically with Date / Time stamps in the first column. Include charts based on trend data, that graphically summarize the data.
- **Document and justify each input assumption used in the calculations**. Examples include: energy cost; boiler efficiency; annual operating hours; chiller staging changeover temperature. If an assumption deviates from a measured value that is used for the basis, clearly indicate the rationale.

- **Include binned assumptions for savings and occupancy**. For bin calculations, include the binned weather hours for the project's climate zone in a table; the total binned weather hours shall be 8,760 hours/year. Clearly indicate the equipment operating schedule, and account for this schedule in the binned weather hours for use in the calculations. The bases for the binning shall be clearly indicated. The load and savings calculations should be next to the binned weather data.

- **Provide justification for input values that vary as a function of another parameter**. Examples include: chart of VFD efficiency as a function of speed, obtained from previous research; chiller efficiency as a function of cooling load, obtained from chiller manufacturer.

- **Show each equation used, including any constants, and all intermediate calculations**. For spreadsheet calculations, and use additional columns where necessary for intermediate calculations.

- **Include units for each input and output value**, e.g., $ / kWh, Btu/h, % efficiency.

- **Include one-line system diagrams of relevant systems**, e.g., chilled water system piping schematic.

- **Provide the following documentation for relevant equipment**:
    - Nameplate information for major pieces of equipment
    - HP of all relevant motors (fans, pumps, etc.)
    - For pumps and fans over 20 HP, nameplate information that indicates the design head and flow

  The Program will grant exceptions where it may be impractical to obtain the data (e.g., the nameplate cannot be read, the motor is not readily accessible). These circumstances must be fully documented and, in these cases, conservative values should be used as a proxy for the nominal value.

Additional supporting documentation that could be provided as support for the savings calculations includes:

- Equipment cut sheets, for atypical equipment or to document data used in the calculations.
- Photos, clearly labeled with relevant information. Make sure that date/time on camera is correct.
- Copy of maintenance logs that document operating conditions, spot measurements, repeating problems, etc.
- Reference to tenant complaints relayed during the investigation work.
- Reference to historical equipment repair/replacement invoices
- Reference to original design intent and/or current owner's operating requirements
- Point to point checks
- Equipment calibration certification/documentation

**Review**

Savings calculations will be reviewed by the Program for reasonableness, accuracy and soundness. The Program may derate savings estimates for savings calculations that contain a high degree of uncertainty. Instances where a derating factor may be applied include:

- Sufficient backup documentation is not provided with the calculations

- Correlations are based on very limited trend data
- Interactive effects have not been accounted for
- System characteristics used in the calculations are based on assumed values, not trended / verified
- Non-preferred types of baseline data and post-implementation verification data are used

The amount of deration applied will correlate with the degree of uncertainty in the calculations. RCx Providers that consistently submit savings calculations that contain a high degree of uncertainty and, thus, often have their savings calculations derated will be re-reviewed for approval as qualified lead Providers for the Program.

## 5.5 Accounting for Interactions

The energy and demand savings from combinations of measures is usually different than the sum of savings from individually evaluated measures due to the fact that the savings of some measures may interact with each other. The savings from each measure should be calculated independently as the 'Estimated Annual Savings without Interactions'. To take into account the interaction between measures, the 'Estimated Annual Savings without Interactions' is multiplied by an 'Interaction Factor' to calculate the 'Estimated Annual Savings'. Any measure-related interactions or impacts with other building systems should be accounted for in the original savings calculations, e.g., reduced chiller energy use as a result of a lighting control measure that lowers lighting power usage (and, therefore, the cooling load) should be accounted for in the measure savings calculations.

The interaction factor should be estimated based on engineering judgment and the operational characteristics of the measures expected to be implemented. Interaction factors can be estimated specifically per measure, or a default of 0.85 may be used. Interaction factors may range from 0.7 to 1.0, depending on characteristics such as systems affected, climate zone, and ratio of internal to external load. Program engineers reviewing the calculations will evaluate the reasonableness of the factor, or how interactive effects are handled. If building simulations are utilized, interactive effects will be included implicitly in model outputs, and an interaction factor of 1.0 should be used. For all measures with interaction factors other than 0.85 for spreadsheet calculations and 1.0 for building simulations, provide justification for the interaction factors used.

An example of a measure that would have an interaction factor less than 1.0 is restoring operation of economizer dampers, if a separate measure related to increasing chiller efficiency through condenser water temperature reset. If the chiller efficiencies used in the economizer damper savings calculations were the baseline efficiencies used in the condenser water temperature reset measure, then the realized savings related to the economizer dampers would be less if both measures were implemented, since the chiller efficiency would be higher.

Even when the Owner has not chosen the package of measures to implement yet, accounting for interactions is important because this simple payback calculation must be sufficiently accurate to determine which measures will be implemented and allow the Program to correctly allocate incentive payments. After measures are implemented, calculate 'Updated Annual Savings' for the Implementation Summary Table, including interactions of the selected group of measures. If a group of "interactive" measures is not implemented as originally planned, then the interaction factors need to be adjusted accordingly.

## 5.6 Guidelines for Modeling Energy Savings

Energy modeling can provide a powerful and robust manner for estimating energy savings associated with proposed measures. Not only do energy models allow for interaction of building systems with loads and weather conditions, they also simulate the potential interactive affects between proposed measures, when packages of measures are run together. They also can properly apply the utility rate structure to calculate energy costs.

However, it can be challenging to simulate improper or sub-optimal operation using a simulation program. Therefore, the Program has established the following requirements for their use: Energy modeling can be used as a tool to estimate energy and cost savings for a project within the Program provided the following criteria are adhered to:

- Energy models must be developed using the DOE-2.2 or later building energy simulation program
- All input, building description language (BDL), and output files are submitted for review
- The following inputs (at a minimum) are included in the report (presented in the following tables, with examples). This information must be provided separately from the DOE2.2 input files to facilitate review by the Program.

### Description of Schedules and General Information

| Item | Sample Inputs |
|---|---|
| Floor Area | 16,800 $ft^2$ |
| Building Type | Office |
| Occupancy, Lighting, Plug Loads, HVAC – All Areas | 9 a.m. to 5 p.m. (M-F);<br>7 a.m. to 6 p.m. (M-F)<br>Reduced schedules weekends and holidays |

### Description of Lighting, Equipment, and Envelope Assumptions

| Item | Sample Inputs |
|---|---|
| **Lighting ($W/ft^2$)** | |
| Conference | 1.5 |
| Mechanical | 1.3 |
| Bath | 1 |
| Lobby | 1.8 |
| Break | 1.4 |
| Open Office | 1.3 |
| Office | 1.5 |
| Gift | 3.7 |
| Hall | 0.7 |

| Item | Sample Inputs |
|---|---|
| Active Storage | 0.3 |
| **Lighting Control** | |
| Occupancy Sensors | None |
| Daylight Dimming Control | None |
| **Equipment (W/ft$^2$)** | |
| Office/Admin EPD | 1.5 |
| Other EPD | Varies by space |
| **Envelope** | |
| Wall Insulation R-value | R-13 (0.089) |
| Roof Insulation R-Value | R-30 (0.034) |
| Floor U-Value | N/A |
| Glazing U-Value (E,W) | 0.57 |
| Glazing U-Value (N) | 0.57 |
| Glazing U-Value (S) | 0.57 |
| Glazing SHGC (E,W) | 0.39 |
| Glazing SHGC (N) | 0.49 |
| Glazing SHGC (S) | 0.39 |
| Window Shading | No Shading |
| Window to Wall Ratio | 10-20% |

## HVAC Systems

| Item | Sample Inputs |
|---|---|
| System Type | VAV |
| Fan Control | Inlet Guide Vanes |
| Supply Air Temperature Reset | Based on OA |
| Outdoor Air Minimum Flow | 0.3 |
| Demand Control Ventilation | None |
| Outdoor Air Economizing | Based on OA temp up to 75 F |
| Natural Ventilation | None |

Building models should be calibrated to within 10% of the monthly utility data using utility data covering a recent period of at least three years (36 months), whenever available. Spot and short-term

measurements of key building system components should also be used wherever possible to further calibrate the model.

Calibrate to demand first, then consumption. If demand is on and consumption is off, then operating/occupancy schedules may be off.

At a minimum, the trend data collected for identifying the finding and creating the baseline operating condition (e.g., heating and cooling loads and the HVAC system's responses to these loads) should be used in calibrating the model. Utilize hourly reports from model for calibrating model to trend data. Model can be calibrated by adjusting the following, for example:

- Lighting
- Plug loads
- Infiltration (0.1 cfm/ft2)

Typical spot and short-term measurements for use in model calibration may include: lighting and HVAC equipment operating schedules, lighting fixture power, space temperatures, supply duct static pressures and temperatures, fan and pump operation (preferably power) and motor power.

The model should be calibrated, whenever possible, using a weather file based on actual weather from a nearby weather site for the same time period, while analysis of the measures should be performed with TMY2 data.

Any variables adjusted in the model for the purposes of calibration need to be documented and submitted as part of the Findings Workbook. This information will include:

- The KEYWORD that was used for the calibration
- The baseline (un-calibrated model) input value used for the KEYWORD
- The calibrated model input value used for the KEYWORD
- The reasoning behind the adjustment of this KEYWORD value

Similarly, the KEYWORDS used in the measure analysis should also be similarly documented. This information will also be submitted along with the Findings Workbook, and will include:

- The measure number and name
- The KEYWORD(s) that was used to simulate the measure
- The baseline input value(s) used for the KEYWORD(s)
- The input value(s) used for the KEYWORD(s) to simulate the measure
- The source of the value used to simulate the measure

## 5.7 Implementation Cost Guidelines

Guidelines for implementation costs include:

- **Provide backup documentation.** Provide backup documentation for each measure's cost estimate(s), submitted with the Master List of Findings. At a minimum, this documentation should include material costs, labor hours and estimated hourly rates.
- **Base costs on Owner's expectations.** When estimating implementation costs, consideration should be given to the building owner's expectations for the quality of work carried out - whether they

require 'premium quality', 'standard', etc. Costs should include only those items that directly contribute to the energy savings, not the 'optional extras' (unless those optional extras are standard procedure and considered essential by the building owner).

- **Don't include in-house labor.** If a measure is intended to be implemented by in-house staff, then the labor cost should be recorded as $0.
- **Include implementation assistance as a separate cost.** Keep the costs for implementation assistance separate from other implementation costs, and enter the assistance cost for each measure in the appropriate cell in the *Findings Workbook*. If the assistance cost is greater than 15% of the measure cost, then provide a task breakdown. RCx Provider should check to ensure that tasks in the project Scope of Work are not duplicated in the implementation assistance.
- **Be accurate.** Since building Owners are obligated to implement measures with a payback of one year or less and can choose to implement measures with a payback greater than one year, it is important that the cost estimates provided with the Master List of Findings be as accurate as possible.

# Attachment A: Checklists

## Topics for RCx Investigation Kick-Off Meeting (sample)

- ☐ Introductions to appropriate building staff, including key contact for day-to-day work
- ☐ Overview of RCx Provider approach to investigation process
- ☐ Deliverables and expected schedule
- ☐ Owner's (current) operating requirements
- ☐ Information on BAS (type, interface, trendability, on staff expertise, controls firm, etc)
- ☐ Building entrance procedures
- ☐ Keys or access cards
- ☐ Identification requirements
- ☐ Parking permits
- ☐ Off-limits areas, or areas needing escort or prior notification to enter
- ☐ Permission to take photographs
- ☐ Document checkout/copying procedures

## Operations and Maintenance Topics and Tasks (sample)

- ☐ Analyze electricity utility usage / demand data (provided by the Program), at least two years of monthly data and one year of interval data. Obtain any additional utility data needed or desired for analysis from the utility or Owner.
- ☐ Review current maintenance protocols to establish the level of capability on site.
- ☐ Review historical equipment repairs / replacement costs to identify any recurring issues.
- ☐ Review history of tenant complaints.
- ☐ Review major equipment operating logs.
- ☐ Review equipment warranties, to determine if there are any limitations on modifications that may be carried out.
- ☐ Review any equipment that was installed or upgraded using utility program incentives

## Attachment B: Owner's Operating Requirements Data Collection Table (sample)

| Item | Area A<br>i.e., office | Area B<br>i.e., conference | Area C<br>i.e., computer | Area D<br>Other | Area E<br>Other |
|---|---|---|---|---|---|
| Temperature requirements and limitations | | | | | |
| Humidity requirements and limitations | | | | | |
| Pressure relationship requirements and limitations | | | | | |
| Filtration requirements and limitations | | | | | |
| Air change requirements and limitations | | | | | |
| Sound and noise level requirements and limitations | | | | | |
| Normal operating schedule for occupancy and/or protection | | | | | |
| Process and office equipment status during evening/night time hours | | | | | |
| Process and office equipment status during holiday hours | | | | | |
| Process and office equipment status during scheduled maintenance shutdowns | | | | | |
| Normal schedule for building cleaning crews | | | | | |

## Attachment C: Common RCx Findings and Measures

A wide range of measures may be implemented under the San Diego RCx Program, including most building systems such as HVAC, lighting, domestic hot water, and refrigeration.. Most commonly, HVAC measures will apply to the following system components and operational situations: chillers, cooling towers, economizers, air handlers, pumps, simultaneous heating and cooling, and controls. While measures are determined on a site-by-site basis, common RCx measures will correct the following Finding Types (examples included):

| Finding Type | Finding Examples |
|---|---|
| **Equipment Scheduling and Enabling** | |
| Time of Day enabling is excessive | HVAC running when building is unoccupied |
| | HVAC schedule of 4am start-up when the building isn't occupied until 8am |
| | time of day/holidays/weekends scheduling can be improved |
| | Optimum start-stop is not implemented |
| | Controls in hand |
| Equipment is enabled regardless of need, or such enabling is excessive | Exhaust fan controls (on/off and variable) are not integrated with AHU operation or equipment (labs, kitchens) |
| | Staging of equipment (e.g. multiple pumps) with drives to needs to be optimized |
| | Outdoor temperature lockouts need to be established |
| | CO control for underground garages is disabled |
| Lighting is on more hours than necessary | Lighting is on at night when the building is unoccupied |
| | Photocells should be used to control exterior lighting |
| | Lighting controls not calibrated/adjusted properly |

| | |
|---|---|
| **Economizer/Outside Air Loads** | |
| Economizer Operation – Inadequate Free Cooling | Economizer control optimization to utilize free cooling first (integrated economizer) |
| | Economizer linkage is broken |
| | Economizer setpoints should be optimized |
| | Plywood used as the outdoor air control |
| | Nighttime purge control is suboptimal or not implemented |
| Over-Ventilation. | Demand-based ventilation control has been disabled |
| | Outside air damper failed in an open position |
| | Minimum outside air fraction not set to design specifications or occupancy |
| **Controls Problems** | |
| Simultaneous Heating and Cooling is present and excessive | For a given zone, CHW and HW systems are on and running simultaneously |
| | Supply air temperature is too low, or needs to be reset, to minimize reheat |
| Sensor/Thermostat needs calibration, relocation/shielding, and/or replacement | OAT temperature is reading 5 degrees high, resulting in loss of useful economizer operation |
| | Zone sensors need to be relocated after tenant improvements |
| | OAT sensor reads high in sunlight |
| Controls "hunt" and/or need Loop Tuning or separation of heating/cooling setpoints | CHW valve cycles open and closed |
| | System needs loop tuning—it is cycling between heating and cooling |

| Controls (Setpoint Changes) | |
|---|---|
| Zone setpoint setup/setback are not implemented or are sub-optimal. | The cooling setpoint is 74 degrees 24 hours per day |
| Fan speed doesn't vary sufficiently | Fan runs at 2" static pressure. Lowering pressure to 1.8" does not create comfort problem and the flow is per design. |
| | Supply air temperature and pressure reset: cooling and heating |
| Pump speed doesn't vary sufficiently | Pump runs at 15 PSI on peak day. Lowering pressure to 12 does not create comfort problem and the flow is per design. |
| | The flow is not controlled to the minimum needed. Improve the method of flow control (proper modulation for flow control devices). |
| VAV Box Minimum Flow Setpoint is higher than necessary | Boxes universally set at 40%, regardless of occupancy. Most boxes can have setpoints lowered and still meet minimum airflow requirements. |
| | Demand controlled ventilation should be used for this zone |

| | |
|---|---|
| **Controls (Reset Schedules)** | |
| HW Supply Temperature Reset is not implemented or is sub-optimal | HW supply temperature is a constant 180 ºF. It should be reset based on demand, or decreased by a reset schedule as OAT increases. |
| | DHW Setpoints are constant 24 hours per day |
| CHW Supply Temperature Reset is not implemented or is sub-optimal | CHW supply temperature is a constant 42 ºF. It should be reset, based on demand or ambient temperature, to minimize the total energy use of the chiller and pumps, keeping it cold enough to maintain humidity control. |
| Supply Air Temperature Reset is not implemented or is sub-optimal | The SAT is constant at 55 ºF. It should be reset to minimize reheat and maximize economizer cooling. The reset should ideally be based on demand by looking at zone box damper positions, but could also be reset based on OAT. |
| Condenser Water Temperature Reset is not implemented or is sub-optimal | CW temperature is constant leaving the tower at 85 ºF. The temperature should be reduced to minimize the total energy use of the chiller and tower. It may be worthwhile to reset based on load and ambient conditions. |
| **Equipment Efficiency Improvements / Load Reduction** | |
| Spaces are over-lit. | The daylighting control needs adjustment. Some sensors need to be moved after tenant changes to space. |
| Pump Discharge Throttled | The discharge valve for the CHW pump is only 30% open. The valve should be opened and the impeller size reduced to provide the proper flow without throttling. |
| Over-Pumping | Only one CHW pumps runs when one chiller is running, as per design intent. However, due to the reduced pressure drop in the common piping, the pump is providing much greater flow than needed. |

| | |
|---|---|
| **Variable Frequency Drives (VFD)** | |
| VFD Retrofit – Fans | The variable pitch controls for the vane axial fan have been a maintenance problem. The vanes can be set to a fixed pitch to meet design flow, and a VFD added to meet off-design conditions, controlled by a supply air pressure sensor. |
| | VFD is in override mode, and was found to be not modulating. Optimization of drive settings is required. |
| VFD Retrofit – Pumps | Replace 3-way valves with 2-way valves and add VFD, to be controlled by differential ΔP. |
| | Only one CHW pumps runs when one chiller is running, as per design intent. However, due to the reduced pressure drop in the common piping, the pump is providing much greater flow than needed. Adding a VFD would allow the flow to be reduced back to the design value when only one chiller is running. |
| **Equipment Maintenance**[3] | |
| HX Surface needs cleaning/overhaul | Some of the AHU coils are dirty due to prior filtration issues. Cleaning the coils will reduce the CHW flow requirement. |
| Low refrigerant charge/Fixing leaks | RTU-3 has low charge, impacting capacity and efficiency. |
| | The seat of the HW valve for AHU-3 is worn and the valve is continually leaking HW, so the valve should be replaced. |
| Flow obstructions | The system cannot meet design flows, even with pressures above design. The low pressures are only in some parts of the distribution network, so an obstruction is suspected. |

[3] Routine maintenance items, such as filter changes, lubrication, and fan belt adjustments, should be done by the Owner prior to the RCx investigation. Other major maintenance items (such as the ones listed here), if performed due to or in conjunction with the RCx work, are considered eligible measures and should be recorded in the *Master List of Findings*.

# Attachment D: RCx Investigation Report Outline

The Program provides a template for the *RCx Investigation Report* and includes the following elements:

1. Program Cover (provided), customize for the facility
2. Table of Contents (provided, update as necessary)
3. Report Contents (see Outline below)

The RCx Provider should consider the following outline as the minimum content required and include any additional information gathered during the RCx investigation process that they feel may assist the Owner in selecting and implementing the operational improvements. Within the template, the highlighted [text in brackets] are meant to be replaced with the requested information and red *italics* are instructions that need to be deleted prior to delivery to the Program. All "XXXX" items within the report need to be replaced with the correct corresponding number.

### Introduction

Introduces the Report to the Owner with information about the RCx Provider and Company/Building involved in the project.

### 1.0 Project Overview

Copy and Paste from Findings Workbook, "General" worksheet. Include from the Project Information and Contact List sections (row 3-23).

### 2.0 Measures Selected for Implementation

An overview, recommendations for implementation, and evidence of proper implementation are outlined for each measure selected by the Owner. This section can include pictures, graphs and tables to support the data collected through investigation. Two examples of this section are provided in the following pages.

### 3.0 Next Steps

Description of the next steps in the Program for the Owner to anticipate, including the date they are expected to implement the selected measures.

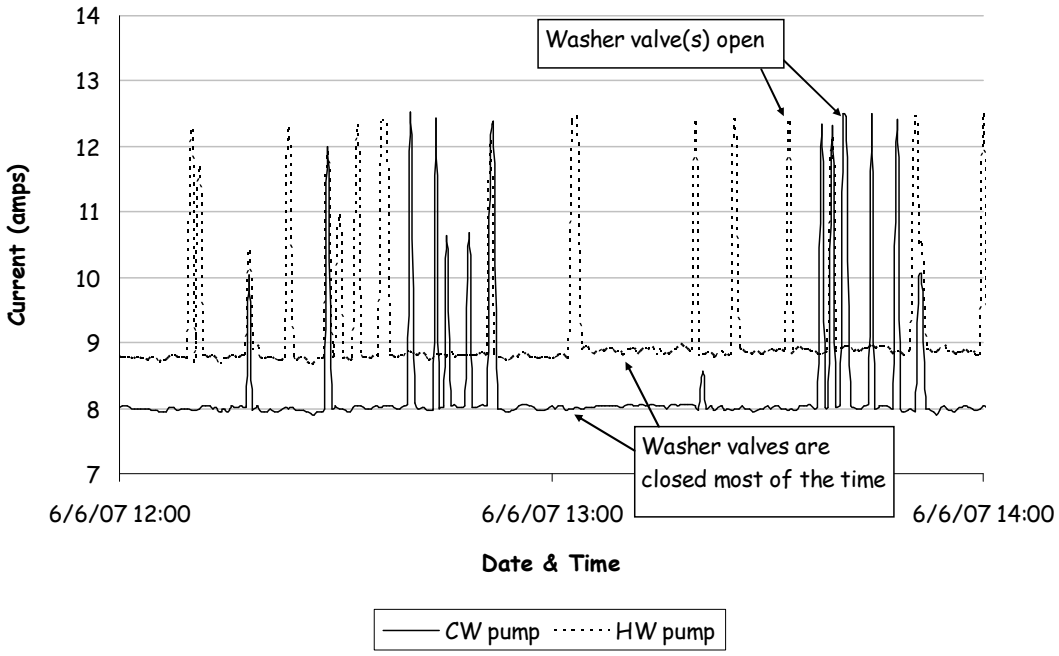
### Appendix A: Investigation Summary Table (printed from the Findings Workbook)

**An example of Section 2.0 in the RCx Investigation Report:**

## 2.1 *Measure 7: Add VFDs to Laundry Hot and Cold Water Pumps*

### Overview

Hot and cold water is provided to each of the three washing machines by two circulating pumps. As the hot and cold water valves on each washer open, water is supplied to the unit and each pump operates near full load. When water is not needed by the washers, pressure builds up in the piping (pushing each pump back up on its curve) until a pressure relief valve opens and allows water to circulate through the respective storage tank.




### Recommendations for Implementation

The recommendation is to control the laundry hot/cold water pumps using VFDs to maintain system pressure rather than allow each pump to ride its curve. In order to implement the proposed control strategy, a differential pressure sensor needs to be installed across the device with the highest pressure drop (i.e. load furthest from the pump), and a VFD must be installed on each pump to maintain the differential pressure needed to provide the design flow rate to this load. As each washer calls for hot or cold water and the control valves open and close, pressure within the circulating loop will vary. The VFD will modulate system flow as necessary to maintain the differential pressure setpoint.

### Evidence of Proper Implementation

The recommended method for verifying that this measure has been implemented properly is by spot measuring the motor current draw at the idle state (all washer valves are closed) and the full flow state (at least one washer valve is open) for both pumps and recording the VFD speeds at these conditions.

# Attachment E: Sample Calculations

The .xls files associated with three sample measure calculations, as well as a sample Findings Workbook including these three measures plus four others, can be found in the on-line RCx Provider Resources (see www.sandiegorcx.com, username/password "rcxprovider"). The three measures are:

- Optimize economizer damper operation
- Restore chilled water pump VFD to 'auto' operation
- Add VFDs to laundry hot and cold water pumps

Note that the on-line sample Findings Workbook is a 'generic' version, and may not match the current version used by the Program.