# Re-/Retro-commissioning: The Best Kept Secret You Can't Afford Not to Know

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ABSTRACT

Re- or retro-commissioning, the process of ensuring that an existing building's performance continues to meet or exceed its design over time, is increasingly the target of government policy and the beneficiary of market forces. New federal, state, and local mandates, in conjunction with voluntary, market-based standards, are poised to transform the marketplace. Having begun as an overlooked tool to ensure that commercial building owners get their money's worth from design and construction professionals, commissioning is now known to be the most cost effective measure available for reducing energy use, lowering costs, and mitigating greenhouse gas emissions in buildings. A recent meta-analysis by Lawrence Berkeley National Laboratory found that re-/retro-commissioning yields a median 16% energy savings with a payback time of 1.1 years for a cash-on-cash return of 91%. Economy-wide, the service has the potential to save building owners and operators more than $30 billion a year in energy costs by 2030 [1]. Voluntary, market-driven programs such as LEED®, Building EQ, and ENERGY STAR have emerged in recent years and encompass the process of existing building commissioning to varying degrees. Their rapidly growing popularity widens awareness and implementation of re-/retro-commissioning. Further, these standards are increasingly incorporated into state and local policy. Most recently, local governments in New York City and San Francisco have mandated re-/retro-commissioning in commercial building codes. These initiatives are the latest evidence of a trend towards making commissioning a business-as-usual activity in the maintenance and operation of buildings. As a result of recent market trends, as well as government policy aimed at capturing the benefits of commission-

ing, the secret is out. Continuing to overlook this cost effective quality assurance tool could not only be unlawful, but bad business.

## INTRODUCTION

Building managers today face a conundrum. Use of electricity, natural gas, and water in our buildings continues to increase, while operation and maintenance budgets shrink. Further, it is now cost prohibitive to invest large amounts of capital to renovate or rebuild the country's aging existing commercial buildings stock. What option is available to reduce utility costs while limiting the expense of construction in existing buildings? The answer is the re-/retro-commissioning process.

In this article, the retro-commissioning process will be defined. Reference sources will be listed, with emphasis on the five phases of retro-commissioning. The impact of federal, state, and local municipal laws on retro-commissioning will be presented. How voluntary, market driven programs, such as LEED® and Energy Star Portfolio Manager, promote retro-commissioning will be described. Finally, a case study of a federal building that used retro-commissioning will demonstrate the potential savings in energy usage that could be achieved using the retro-commissioning process.

## BRIEF HISTORY AND DEFINITIONS

The commissioning process was pioneered by Public Works Canada approximately 33 years ago as part of its project delivery process. In the 1980s, the American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE) developed the first commissioning guidelines, and The University of Wisconsin—Madison offered the first commissioning courses. The 90s saw other public and private associations develop commissioning guidelines. The United States Army Corps of Engineers and GSA made the commissioning process part of its new construction standards [2]. With the debut of LEED® in the late 90s, the United States Green Building Council made commissioning a requirement for new and existing buildings. The first decade of the 21$^{st}$ century saw the emergence of commissioning standards for existing buildings, which highlighted the concept of retro-commissioning.

During this period, there were many different educational, training, and credentialing opportunities offered by numerous agencies, such as the Association of Energy Engineers (AEE), AABC Commissioning Group (ACG), National Environmental Balancing Bureau (NEBB), ASHRAE, and numerous others.

There are now a variety of services grouped under the commissioning heading, including commissioning, re-commissioning and retro-commissioning, which should be distinguished:

*Commissioning* (Cx) is a quality-focused process for enhancing the delivery of a project. The process focuses upon verifying and documenting that the facility and all of its systems and assemblies are planned, designed, installed, tested, operated, and maintained to meet the owner's project requirements. The process is overseen by a commissioning authority, an entity identified by the owner, which leads, plans, schedules, and coordinates the commissioning team to implement the commissioning process.

*Re-commissioning* is a reapplication of the commissioning process to a project that has been previously delivered using the commissioning process. Re-commissioning may be deployed as part of an on-going commissioning process, or it may be used in response to facility changes, operations problems, or other needs.

*Retro-commissioning* (RCx), by distinction, is the commissioning process applied to an existing facility that was not previously commissioned [3]. RCx may be more specifically defined as a collaborative process for examining the operation and maintenance of a building and improving how its equipment and systems function together. RCx can resolve problems that result over time from building design or construction, or it may address problems that have developed as a result of the operations and maintenance of a building. [4] Because of its emphasis on facility operations and maintenance, RCx can improve overall building performance. Better performance equates to less energy and resource use, as well as lower operating costs. As a result, retro-commissioning is a very effective tool for improving resource efficiency.

## RETRO-COMMISSIONING PROCESS

The RCx process is a series of events that focuses on building operation in its present state. Though original design intent and con-

struction is important to understand, it plays a reduced role in existing buildings. For instance, practices considered energy efficient in an office building designed and constructed 25 years ago would not comply with the energy codes of today. The RCx process involves five phases: pre-planning, planning, investigation, implementation, and hand-off. These phases are illustrated in Figure 1.

**Pre-planning Phase**

The pre-planning phase identifies a candidate building or buildings and evaluates the suitability of retro-commissioning. This is typically determined through the analysis of utility cost data and quantifiable energy use. Tools such as Energy Star Portfolio Manager may be used to evaluate the candidate building's energy use index (EUI), measured in kBtu/sqft, and its utility cost index (UCI), measured in $/sqft, relative

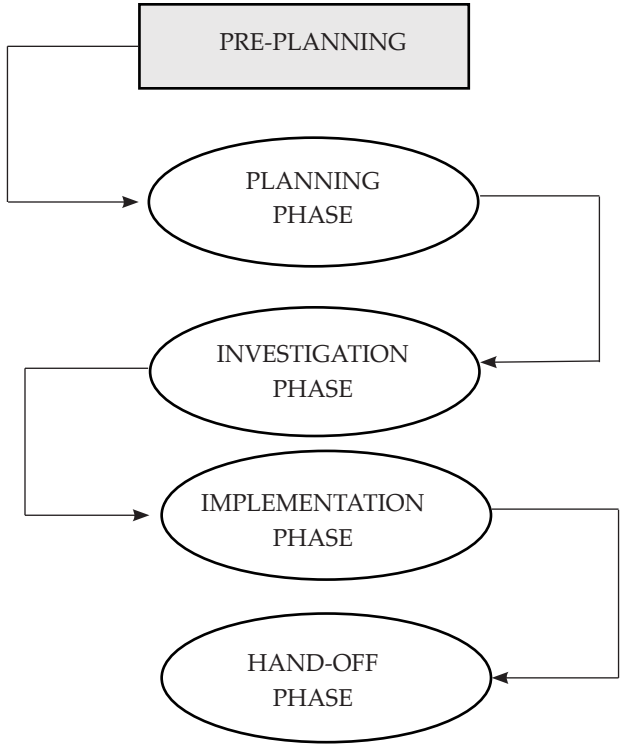


**Figure 1. Retro-commissioning Phases**

to similar buildings. If RCx is warranted by such an analysis, the commissioning authority should review and draft the goals, objectives, and functional requirements of the project. The planning phase commences once the owner's project requirements (OPR) are defined. The activities included in the pre-planning phase are illustrated in Figure 2.

**Planning Phase**

The planning phase involves confirming the building operations through interactions with operations and maintenance (O&M) staff and talking to building occupants. A major purpose of the planning phase is to finalize project goals and objectives, which the owner can prioritize and approve. Once facility staff interviews are complete and a thorough walk-through of the building is conducted, a plan must be developed. The retro-commissioning plan will identify and schedule all the activities that will be conducted in the investigation and implementation phases. This plan is a dynamic document that can respond to changes in the owner's needs and budget, as well as the condition of building systems. Once the retro-commissioning plan is approved by the owner, it is issued to the facility O&M staff, and the investigation phase begins. The steps involved in the planning phase are illustrated in Figure 3.

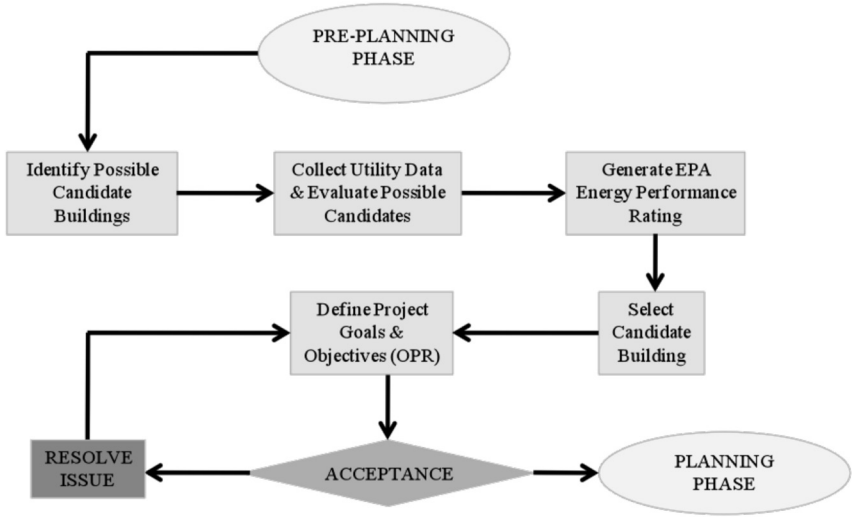


**Figure 2. Pre-planning Phase**

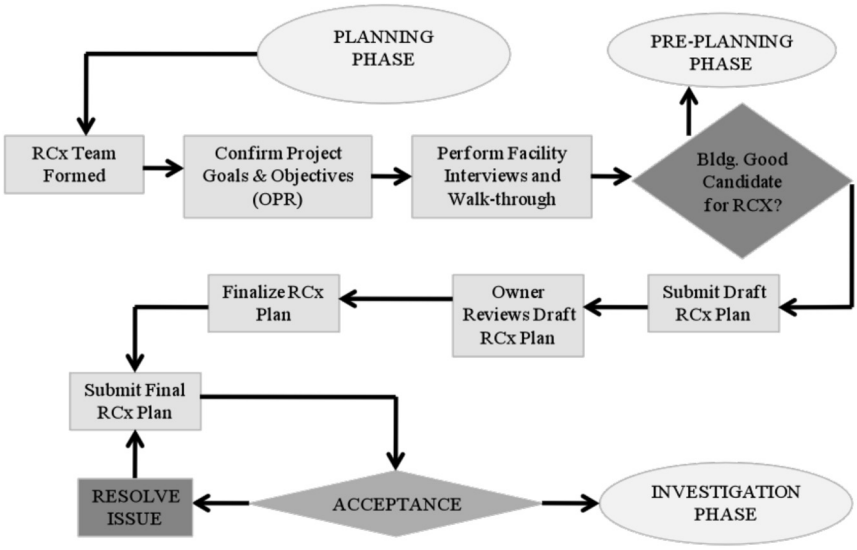


**Figure 3. Planning Phase**

## Investigation Phase

Once the final retro-commissioning plan is presented to key facility staff, the investigation phase begins. The phase includes an in-depth interview and building walk-through process that builds upon information gathered during the planning phase. All aspects of the building's systems and assemblies are examined in order to evaluate operation and condition. The systems usually include HVAC, lighting, domestic hot water, and envelope, including the roof. The investigations are usually conducted with the facility O&M staff on hand. Each finding resulting from the evaluation is catalogued. This catalog is the basis for developing energy conservation measures (ECMs), which include projected energy savings calculations and estimated construction budgets. An RCx case study, presented at the end of this article, includes an example of this process. Once potential ECMs are identified, they are presented to the owner for consideration. The owner may select all, any, or none of the indicated ECMs for implementation. If the owner elects not to implement any of the measures, the RCx process is ended. Regardless of the owner's decision, a final RCx investigation report with recommended implementation measures is submitted. After this report is reviewed by the owner, the implementation phase begins. Figure 4 illustrates the sequence of the investigation phase.

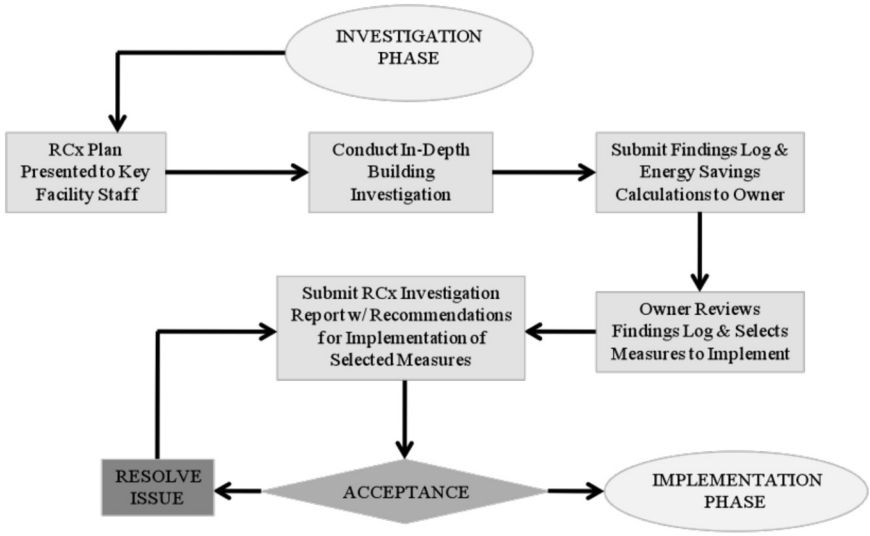


**Figure 4. Investigation Phase**

**Implementation Phase**

The implementation phase is the heart of the RCx process. Remediation of identified energy and resource waste is conducted here. An implementation plan is developed that lists all the ECMs to be employed. The implementation plan is very similar to the traditional commissioning plan in that it lays out all the activities and schedules that are required to complete the project. The plan includes pre-functional (start-up) and functional performance testing documents, which serve as a reference for the construction contractors and the RCx team. The contractors are primarily responsible for the execution and completion of the pre-functional tests, usually conducted at system start-up. Functional performance testing is also executed by the contractors but verified by the RCx team. Once all testing is completed to the satisfaction of the RCx team, a final report, or systems manual, is developed and submitted for owner review. Upon acceptance of the final report, the hand-off and persistence phase begins. Figure 5 illustrates the implementation phase.

**Hand-off Phase**

Retro-commissioning does not conclude when the implementation phase ends. Just as buildings are systems dynamic in function,

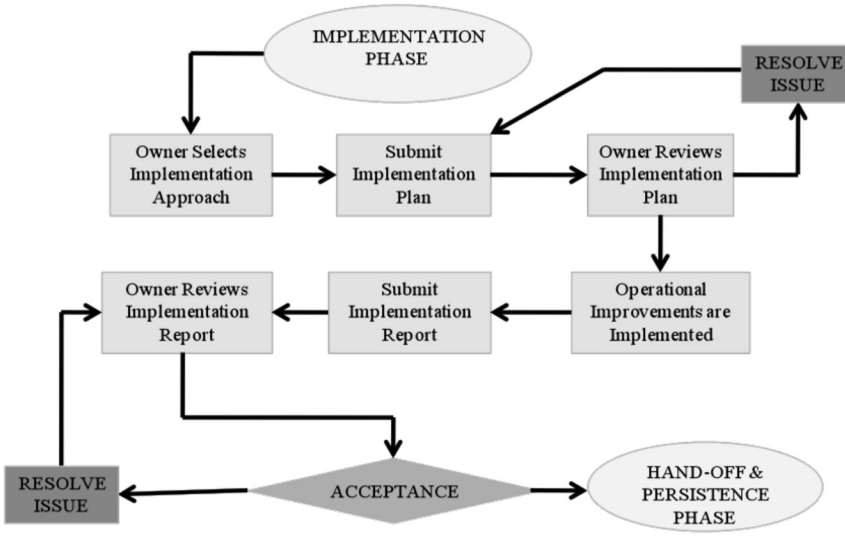


**Figure 5. Implementation Phase**

so is the RCx process. The hand-off phase involves verification of RCx activities while laying the groundwork for continual improvement. During this phase, O&M personnel are trained under the oversight of the RCx team. Seasonal tests of the building also occur. A "lessons learned" workshop is held to assist designers, contractors, and building end-users with identifying the failures and successes experienced during the RCx process. These lessons learned can be applied to the next project or re-commissioning of the building. The RCx team will conduct periodic performance evaluations of systems and assemblies to ensure that the building is still performing to expected criteria. They will also fine-tune systems in areas where the building is deficient. Depending on the contractual arrangements with the owner, a "persistence phase" of commissioning could be performed. In such a phase, the RCx team may return to the building on a periodic basis to monitor performance, make adjustments as necessary, and make further energy conservation recommendations as the building ages, assuring systematic, continual improvement of facility performance. The hand-off phase is illustrated by Figure 6.

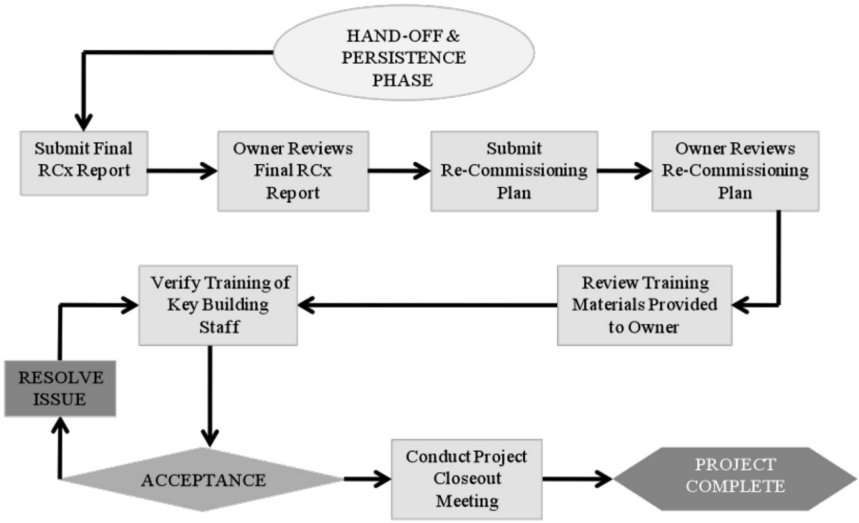


**Figure 6. Hand-off Phase**

## RETRO-COMMISSIONING AND THE LAW

A legal definition of due diligence typically refers to reasonable care or attention to a matter, which is sufficient to avoid a claim of negligence. In the realm of construction and facility management, a building owner depends on this concept. Unfortunately, with increasing frequency, this presents substantial risk to the owner. While it may once have been reasonable to expect professional architect/engineering firms and competent contractors to deliver a functional and efficient building that meets the owner's functional requirements, today's project delivery conditions have changed the situation. Whether it is roof leaks that bring moisture into the envelope, insufficient electrical service capacity, unreliable HVAC systems control, or a myriad of other maladies that may occur as a result of insufficient engineering or construction, the building owner is increasingly at risk of encountering a confrontational situation. Resolving such confrontations may require litigation or hiring other design/build parties to fix something that should have never been broken. The third-party commissioning and retro-commissioning

process was developed as a method to prevent such problems before they become difficult to correct. As a result, it is increasingly part of the legal landscape of building design, construction, and maintenance. A sample of current federal, state, and local mandates related to RCx are listed below. If past trends persist, it is reasonable to assume that more legislation along these lines will developed over time. The increasing interest in conserving scarce resources is a driving force behind the proliferation of commissioning-related regulations.

**Energy Policy Act of 2005 (EPACT 2005)**

- **Section 101** directs the Architect of the Capitol to develop a cost effective energy conservation plan for congressional facilities. The plan must include informational packets detailing ways to save energy at the workplace. The Architect of the Capitol is also directed to submit an annual report on congressional energy efficiency measures.

- **Section 102** sets goals of reducing the energy intensity (energy use per square foot) of the buildings of each federal agency by 2% per year from 2006-2015, compared to their 2003 energy use.

- **Section 109** requires federal buildings to meet the 2004 International Energy Conservation Code (IECC) for residential buildings and the ASHRAE Standard 90.1-2004 for commercial buildings. By August 8, 2006, DOE must establish building energy efficiency standards that direct new federal buildings to use at least 30% less energy than mandated by either the ASHRAE standard or the IECC.

**Guiding Principles for Federal Leadership in High Performance & Sustainable Buildings (2006)**

- These guiding principles require total building commissioning practices tailored to the size and complexity of the building and its system components in order to verify performance of building components and systems and help ensure that design requirements are met. This should include a designated commissioning authority, inclusion of commissioning requirements in construction documents, a commissioning plan, verification of the installation and performance of systems to be commissioned, and a commissioning report.

**Executive Order 13423 (2007)**

- This executive order requires federal agencies to reduce energy intensity by 3% each year, leading to 30% by the end of fiscal year (FY) 2015, compared to an FY 2003 baseline. This goal was given the weight of law when ratified by EISA 2007.

**Energy Independence and Security Act of 2007 (EISA 2007)**

- **Section 323—Public Building Energy Efficiency and Renewable Energy Systems**
  This section directs the GSA to set minimum energy efficiency and renewable energy performance requirements for leased space, to estimate energy performance in the prospectus submitted to Congress, and to make energy efficiency and renewable energy an evaluation factor for leases.

- **Section 431—Energy Reduction Goals for Federal Buildings**
  This section accelerates targets for energy use reductions in federal buildings to 3% per year for FY08-FY15, ending in a 30% reduction in energy intensity by 2015, consistent with Executive Order 13423.

- **Section 432—Management of Energy and Water Efficiency in Federal Buildings**
  This section requires that for large buildings (including at least 75% of agency building energy use), agencies must designate an energy manager. Energy and water evaluations, including retro-commissioning, must be conducted every 4 years for approximately 25% of the facilities of each agency.

- **Section 433—Federal Building Energy Efficiency Performance Standards**
  This section requires new federal buildings, if feasible, to reduce fossil fuel consumption by 55% in 2010, rising to 100% by 2030.

- **Section 434—Management of Federal Building Efficiency**
  This section requires large capital energy investments in federal facilities to be the most energy efficient that is cost-effective. It also requires federal agencies to meter natural gas, steam, chilled water, and water, as well as electricity.

- **Section 436—High-performance Green Federal Buildings** This section establishes an Office of Federal High-performance Green Buildings within the General Services Administration (GSA). The federal director is directed to conduct analysis, guidance, and training on life-cycle cost for green buildings and to identify green building incentives through recognition awards and retention of savings and other duties.

**Executive Order 13514 (2009)**

- This executive order charges federal agencies with ensuring that all new federal buildings entering the design phase in 2020 or later are designed to achieve zero net energy by 2030.
- All new construction, major renovations, or repair or alteration of federal buildings must comply with the *Guiding Principles of Federal Leadership in High-performance and Sustainable Buildings.*
- At least 15% of existing agency buildings and leases (above 5,000 gross square feet) must meet the *Guiding Principles* by fiscal year 2015. Agencies must make annual progress towards 100% compliance across its building inventory.
- Agencies must pursue cost effective, innovative strategies (e.g., highly-reflective and vegetated roofs) to minimize consumption of energy, water, and materials.
- Existing building systems must be managed to reduce the consumption of energy, water, and materials. Alternatives to renovation must be identified that reduce existing asset-deferred maintenance costs.
- When adding assets to agency building inventories, opportunities to consolidate and eliminate existing assets must be identified in order to optimize the performance of the property portfolio and reduce associated environmental impacts.
- Rehabilitation of federally-owned historic buildings must utilize best practices and technologies to promote the long-term viability of the building.

**State of California Executive Order S-20-04 (2004) [5]**

- This executive order requires that all buildings built or subsidized

with state funds be LEED® Silver certified.

**The New York City Council, Int.0967-2009 (2009) [6]**

- This ordinance requires American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE) Level II energy audits of the "base building" every 10 years, and recalibration or retro-commissioning of building systems for optimal performance.

**San Francisco Green Building Requirements [7]**

- The requirements stipulate that existing commercial buildings must undergo an energy performance study and make cost effective upgrades that would benefit San Francisco's emissions profile and building energy bills.
- Permit applicants must submit documentation prepared by a commissioning agent demonstrating compliance with LEED® EA Prerequisite 1.
- Effective January 1, 2011, a new building must achieve enhanced commissioning. (LEED® EA3.0)

## RETRO-COMMISSIONING RESOURCES

There are multiple resources for guidance on commissioning and retro-commissioning. The oldest and most recognized resources were developed by ASHRAE, Portland Energy Conservation Incorporated (PECI), AABC Commissioning Group (ACG), Building Commissioning Association (BCA), National Environmental Balancing Bureau (NEBB) and the University of Wisconsin—Madison. A short list of references is listed below. This list is not exhaustive but rather provides a basis for further study.

- ASHRAE Guideline: 0-2005 The Commissioning Process
- ASHRAE Guideline: 1.1-2007 HVAC&R Technical Requirements for The Commissioning Process
- ACG Commissioning Guideline
- PECI: A Retro-commissioning Guide for Building Owners
- FEMP: Operations and Maintenance Best Practices (Release 2.0)

## RETRO-COMMISSIONING CASE STUDY

### Introduction

Energy audits and retro-commissioning were conducted at seven GSA buildings in Region 4, located in the Southeast US. This is an account of the activities and results at one of those buildings, the Claude Pepper Federal Building in Miami, Florida. The process began in July 2009 and was completed in April 2010.

### Overview

Energy consumption data were obtained and analyzed for EUI, CUI, and inconsistencies. The initial site visit was performed during the weeks of November 2 and November 9, 2009. Equipment data were recorded, personnel interviews were performed, and a building survey was performed in order to gain an understanding of the challenges of building operation and energy management. A draft report was developed, along with a draft functional performance testing (FPT) plan, and issued to the GSA on December 4, 2009. The functional performance testing (FPT) site visit was performed during the week of February 1, 2010. Major building energy consuming equipment and control systems were tested for component operation, system functionality, operability, and control system integrity.

### Results

While the building was reportedly comfortable for the majority of the occupants, several significant shortcomings were uncovered:

- Dirty ductwork and equipment
- Non-functional equipment that was not repaired or replaced in a timely manner
- Equipment that operated 100% of the time rather than being scheduled off during unoccupied periods
- Apparent, disconnected ductwork above the ceiling
- Inadequate ventilation for extended periods
- Poorly located thermostats
- Obsolete pneumatic thermostats not connected to the building automation system (BAS)
- High humidity in the building, especially on the first floor
- Unknown water and air flow rates and capacities

**Recommendations**

The following recommendations were made as a result of the inspection phase of the RCx effort:

- Repair all noted deficiencies
  - — Non-functional chiller, VFDs, actuators
  - — Disconnected ductwork
  - — Out of calibration instruments and sensors
- Replace steam boiler with two packaged water boilers or electric reheat system
- Clean all ductwork and equipment
- Perform test and balance on the condenser water, chilled water, and HVAC systems
- Perform indoor air quality study with focus on mold, CO2, dust, etc.

**Case Findings/Conclusion**

The investigation phase garnered a series of energy conservation measures that were recommended to be implemented. (See Table 1.) When implemented, the ECMs are expected to result in an 18% reduction in electricity and natural gas usage and 19% reduction in utility costs. (See Figures 7 and 8.)

## SUMMARY AND CONCLUSIONS

Due to its potential for risk mitigation and resource conservation, retro-commissioning should be a regular part of Design / Build and O&M activities. Building owners in the public and private sector are facing increasing pressure to extend the life cycle of their facility while paying more and more for resources such as electricity, water, and natural gas. Retro-commissioning shows that cost savings and energy efficiency can be acquired without sacrificing large amounts of capital investment. For the public sector, legislative mandates will dictate that energy savings through retro-commissioning occur. Regardless of whether it is voluntary or bound-by-law, it makes sense to incorporate retro-commissioning in long-term operations plans from both a fiscal and a risk-management perspective. Existing buildings have to be maintained, because getting a new one is frequently not an option. Common sense, like retro-commissioning, should be no secret.

**Table 1 – Energy Conservation Measures**

| Energy Conservation Measures (ECM) | | | Annual Site Energy and Water Savings | | | | | | | Saving / Cost Ratios | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| C | D | G | H | | | | | I | J | K | L | M |
| No. | Title | Construction Cost | Estimated *Annual* Energy Savings (Million Btu) | Estimated *Annual* Water Savings (Thou. Gallons) | Estimated *Life-Cycle* Energy Savings (Million Btu) | Estimated *Life-Cycle* Water Savings (Thou. Gallons) | Estimated Present Value *Life-Cycle* Cost Savings[5] ($) | Estimated *Annual* Energy Savings (kBtu/GSF) | Estimated *Annual* Cost Savings ($) | MBtu / Constr $ | Energy $ / Constr $ (SIR) | Simple Payback |
| 1 | Low flow fixtures at sinks | $13,491 | 22 | 176 | 439 | 3,510 | $21,545 | 0.08 | $1,166 | 0.0016 | 1.60 | 11.57 |
| 2 | Replace DHW Heater | $3,202 | 29 | 0 | 371 | 0 | $9,651 | 0.10 | $435 | 0.0089 | 3.01 | 7.36 |
| 4 | Install high efficiency pump motors | $17,102 | 89 | 0 | 1,601 | 0 | $33,817 | 0.31 | $2,554 | 0.0052 | 1.98 | 6.70 |
| 5 | Install high efficiency fan motors | $28,679 | 137 | 0 | 2,468 | 0 | $52,141 | 0.47 | $3,938 | 0.0048 | 1.82 | 7.28 |
| 6 | Replace Variable Frequency Drives | $20,448 | 353 | 0 | 5,296 | 0 | $115,297 | 1.21 | $10,141 | 0.0173 | 5.64 | 2.02 |
| 12 | BAS - All DDC controls[1] | $517,681 | 1,833 | 0 | 27,490 | 0 | $598,473 | 6.30 | $52,639 | 0.0035 | 1.16 | 9.83 |
| 13 | Energy recovery at exhaust fans | $19,537 | 244 | 0 | 4,886 | 0 | $101,182 | 0.84 | $7,017 | 0.0125 | 5.18 | 2.78 |
| | | $620,140 | 2,707 | 176 | 42,551 | 3,510 | $932,106 | 9.30 | $77,890 | 0.0044 | 1.50 | 7.96 |

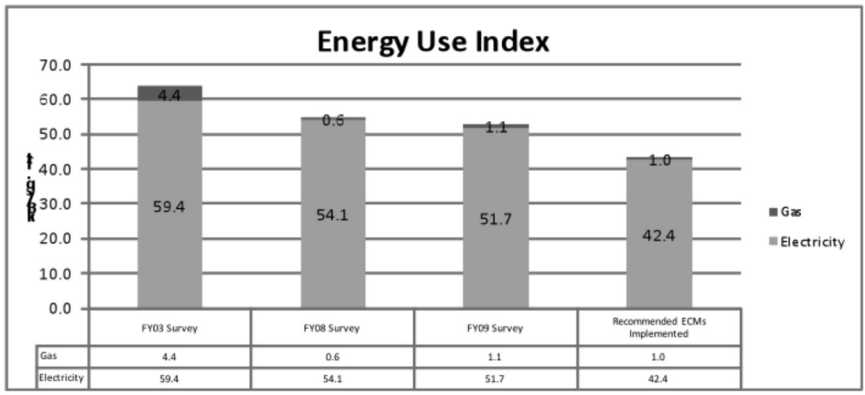


**Figure 7. Energy Use Index (Eui)**

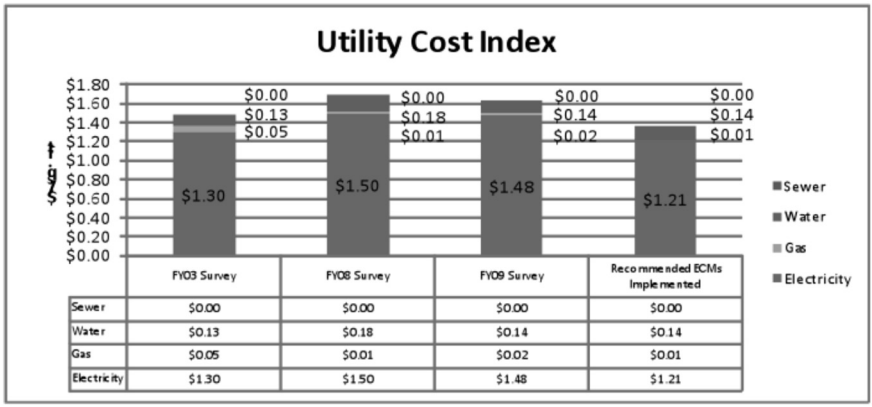


**Figure 8. Utility Cost Index (Uci)**

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# SUSTAINABILITY MANAGEMENT HANDBOOK

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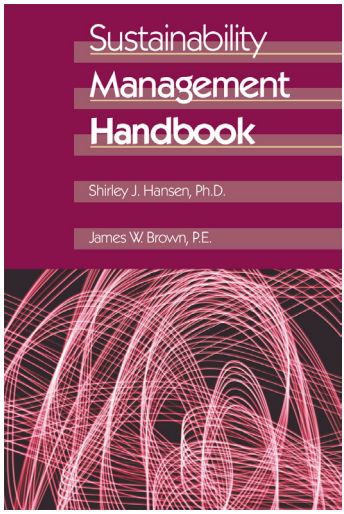


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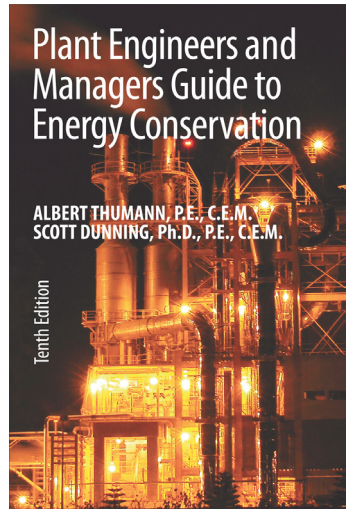


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