California Commissioning Guide:
Existing Buildings

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Capitol Area East End Complex, State of California Department of General Services, Sacramento, CA

Acknowledgements

The information in this document is drawn from several existing guides to commissioning and retrocommissioning:

American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE). *Guideline 0-2005*, *The Commissioning Process (2005*).

Oregon Department of Energy. *Retrocommissioning Handbook for Facility Managers* (2001), prepared by Oak Ridge National Laboratory and Portland Energy Conservation, Inc. (PECI).

U.S. Department of Energy. *A Practical Guide for Commissioning Existing Buildings* (1999), prepared by Oak Ridge National Laboratory and Portland Energy Conservation, Inc. (PECI).

U.S. Environmental Protection Agency and U.S. Department of Energy. *Operations and Maintenance Assessments: A Best Practice for Energy-Efficient Building Operation* (1999), prepared by Oak Ridge National Laboratory and Portland Energy Conservation, Inc. (PECI).

U.S. Department of Energy, Rebuild America Program. *Building Commissioning: The Key to Quality Assurance* (1998), prepared by Portland Energy Conservation, Inc. (PECI).

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The California Commissioning Collaborative is a non-profit corporation with a mission to support and promote the practice of commissioning in California. Its Advisory Council and Board of Directors are made up of utilities, state and federal government, researchers, designers, building owners, and commissioning providers. The Board of Directors currently consists of:

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STATE OF CALIFORNIA – THE RESOURCES AGENCY ARNOLD SCHWARZENEGGER, *Governor*

CALIFORNIA ENERGY COMMISSION
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June 14, 2006

The Energy Efficiency Committee of the California Energy Commission (Commission) is pleased to endorse the **retro-commissioning** guideline developed by the California Commissioning Collaborative. This guideline provides an overview of the retro-commissioning process and discusses the benefits and costs of providing retro-commissioning services within commercial buildings. It is our hope that the guideline will provide valuable assistance to building owners and operators in understanding the retro-commissioning process and identifying the best applications in their buildings.

This guideline, along with its companion document on new building commissioning, fulfills the requirement in Executive Order S-20-04 for the California Energy Commission to develop commissioning and retro-commissioning guidelines for commercial buildings.

Governor Arnold Schwarzenegger signed Executive Order S-20-04 regarding Green Buildings on December 14, 2004. It established the State of California's priority for energy and resource-efficient high performance buildings. The Executive Order sets a goal of reducing energy use in state-owned buildings by 20 percent by 2015 and encourages the private commercial sector to set the same goal. The Commission is pleased to provide this guideline to help in meeting these goals.

JACKALYNE PFANNENSTIEL
Chairman
Presiding Member, Efficiency Committee

ARTHUR ROSENFELD
Commissioner
Associate Member, Efficiency Committee

About this Guide

The commissioning process for existing buildings, commonly referred to as *retrocommissioning*, is a systematic process for improving an existing building's performance by identifying and implementing relatively low-cost operational and maintenance improvements, helping to ensure that the building's performance meets owner expectations.

This Guide:

- Is written for building owners and managers, but others involved in the retrocommissioning process will also find it useful.
- Is not a how-to manual for retrocommissioning. Rather, it provides the necessary foundation for anyone considering a retrocommissioning project.
- Answers the following questions:
  - What is retrocommissioning and why should I do it?
  - What are the benefits and costs of retrocommissioning?
  - What happens during the retrocommissioning process?
  - Who should be a part of the retrocommissioning team?
  - How can I ensure that the benefits achieved from retrocommissioning are long-lasting and that operations at my facility are efficient over the long term?
  - How do I get started with a retrocommissioning project?

Helpful Hints

d Indicates a definition. Definitions can be found throughout the text and at the end of the guide in the **Glossary** (p. 73).

+ Indicates that additional information about the topic can be found elsewhere in the guide.

! Indicates an important topic.

Strategies for Ensuring Persistence of Benefits

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Getting Started 69

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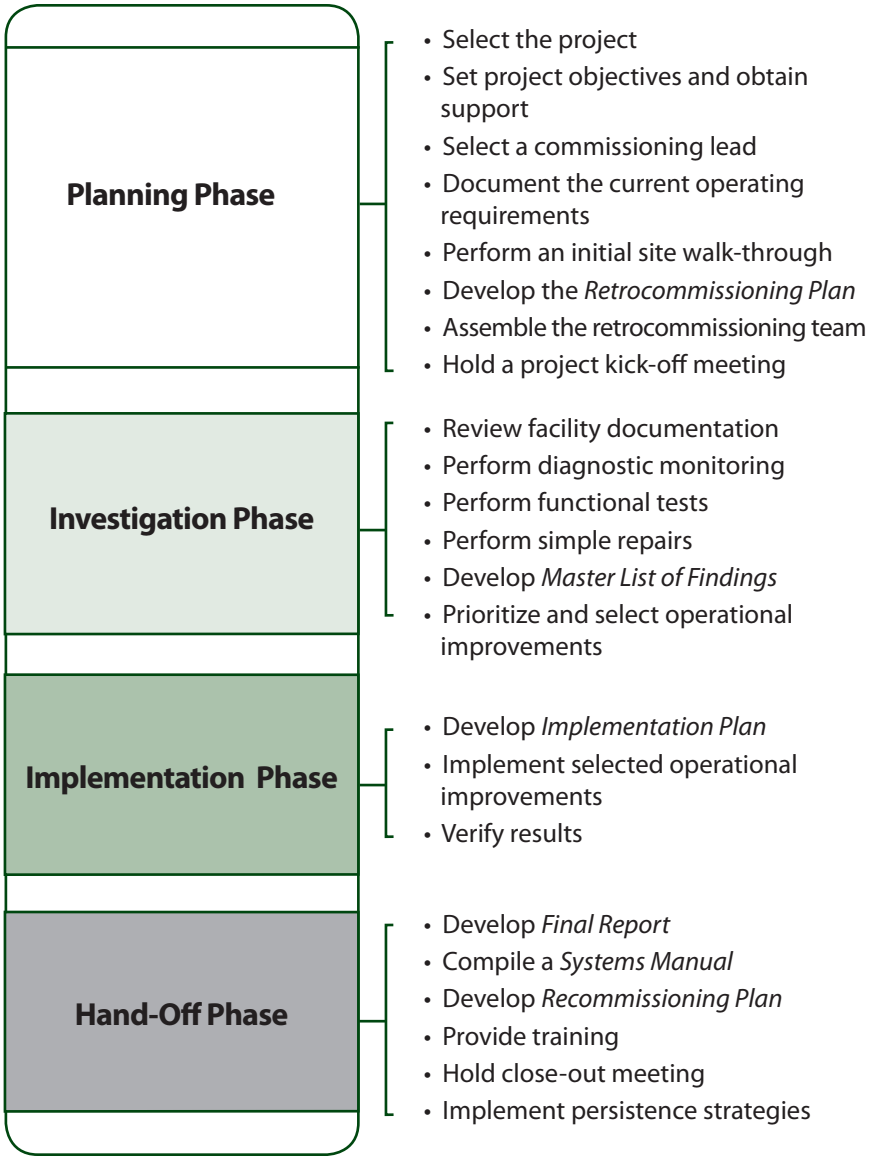
Appendix

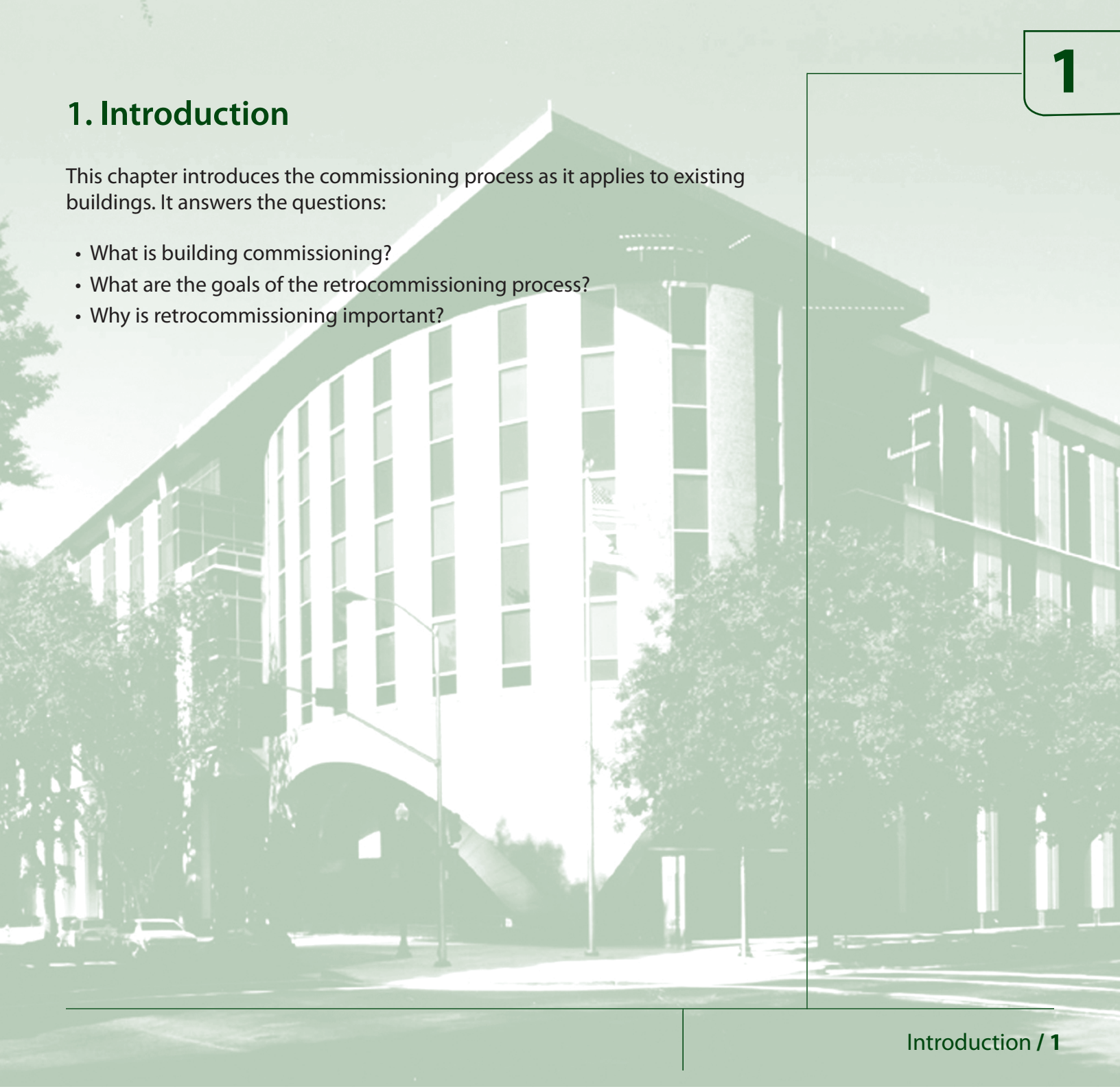
Retrocommissioning Process Overview



1. Introduction

This chapter introduces the commissioning process as it applies to existing buildings. It answers the questions:

- What is building commissioning?
- What are the goals of the retrocommissioning process?
- Why is retrocommissioning important?



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What is Building Commissioning?

The term commissioning comes from shipbuilding. A commissioned ship is one deemed ready for service. Before being awarded this title, however, a ship must pass several milestones. Equipment is installed and tested, problems are identified and corrected, and the prospective crew is extensively trained. A commissioned ship is one whose materials, systems, and staff have successfully completed a thorough quality assurance process.

Building commissioning takes the same approach to new buildings. When a building is initially commissioned it undergoes an intensive quality assurance process that begins during design and continues through construction, occupancy, and operations. Commissioning ensures that the new building operates initially as the owner intended and that building staff are prepared to operate and maintain its systems and equipment.

Retrocommissioning is the application of the commissioning process to existing buildings. Retrocommissioning is a process that seeks to improve how building equipment and systems function together. Depending on the age of the building, retrocommissioning can often resolve problems that occurred during design or construction, or address problems that have developed throughout the building's life. In all, retrocommissioning improves a building's operations and maintenance (O&M) procedures to enhance overall building performance.

Recommissioning is another type of commissioning that occurs when a building that has already been commissioned undergoes another commissioning process. The decision to recommission may be triggered by a change in building use or ownership, the onset of operational problems, or some other need. Ideally, a plan for recommissioning is established as part of a new building's original commissioning process or an existing building's retrocommissioning process.

As stated in the California Governor's Executive Order S-20-04, retrocommissioning, and then recommissioning every five years, is required of all State of California buildings more than 50,000 square feet in size. Recommissioning is one of

! Commissioning (Cx)

For more information on new construction commissioning, consult the *California Commissioning Guide: New Buildings,* a companion to this publication.

d Retrocommissioning (RCx)

Retrocommissioning is a systematic method for investigating how and why an existing building's systems are operated and maintained, and identifying ways to improve overall building performance.

+ More on Recommissioning

A more detailed discussion of recommissioning can be found in *Chapter 5: Strategies for Ensuring Persistence of Savings.*

the steps that can be taken to ensure that retrocommissioning, other efficiency measures, and their associated benefits last. The State of California also requires that all large state buildings receive a United States Green Building Council (USGBC) LEED®-EB rating. Retrocommissioning and LEED are discussed in more detail on page 7.

Goals of the Retrocommissioning Process

All forms of building commissioning share the same goals: to produce a building that meets the unique needs of its owner and occupants, operates as efficiently as possible, provides a safe, comfortable work environment, and is operated and maintained by a well-trained staff or service contractor.

Since each building project is unique, the person who manages the retrocommissioning process—the commissioning lead—will adapt the process to meet the project's specific goals. This guide outlines a comprehensive process for reaching those goals. The scope of the individual projects may differ, depending on size, complexity, and budget.

The retrocommissioning team is typically asked to perform the following activities:

Ensure that the building is performing efficiently and as expected. As part of the retrocommissioning process, the retrocommissioning team reviews the current building documents and operations and maintenance practices, analyzes energy use, and observes and tests building equipment and systems.

Recommend and implement measures that improve equipment performance. The commissioning team documents any deficiencies and potential improvements in the operation or condition of the facility's mechanical equipment, lighting, and related controls, then recommends corrective action. Some of these opportunities are pursued during the retrocommissioning process, with remedies that range from low-cost operational changes to extensive capital retrofits, while others may be deferred.

A more detailed discussion of the retrocommissioning team, typical roles in the project, and project management arrangements can be found in *Chapter 3: The Retrocommissioning Team*.

Commissioning Lead/ Provider/ Authority/ Agent

These titles are often used interchangeably, and have historically been used to refer to an individual hired to lead a retrocommissioning process. However, in this guide, "commissioning lead" can either be an individual from the owner's staff designated to lead the retrocommissioning process, or a third-party, hired to lead the process.

"Retrocommissioning freed up more staff time because it eliminated the need for personnel to operate the boilers and chillers."

- Julius de Leon
Assistant Building Manager
U.S. GSA

Verify that the building owner and staff receive adequate documentation and assistance to implement improvements, as well as training on monitoring and maintaining improvements. Key deliverables from the process, such as the *Master List of Findings* and *Final Report*, become new documents for the building record and important references for implementing and maintaining the measures. Ideally, training for building staff is ongoing throughout the retrocommissioning process and the commissioning team ensures that the operators understand the O&M requirements needed to keep the improvements working.

Why is Retrocommissioning Important?

Commercial buildings frequently undergo operational and occupancy changes that challenge the mechanical, electrical and controls systems, hindering optimal performance. Additionally, in today's complex buildings, systems are highly interactive. Increased need for system integration, due to the presence of sophisticated control systems, results in a trickle-down effect on building operations – small problems have big effects on performance.

Retrocommissioning helps to ensure that building equipment and systems are integrated so they perform together effectively and efficiently and meet the building owner's current operating requirements and expectations.

Unfortunately, most buildings have never gone through any type of commissioning process, and even well-constructed buildings experience performance degradation over time. No matter how well building operators and service contractors *maintain* equipment, if it *operates* inefficiently or more often than needed, energy waste and reliability problems can occur.

Even if building staff have been able to work out most of the operational "bugs" in the building systems, they are often forced to solve problems under severe time constraints and without the benefit of proper documentation. Having to address problems too fast and without adequate information can result in inadequate or partial solutions that can lead to other building problems.

d Building Owner
Often the word "owner" can refer to a number of different actors in a building. In this document, the term "owner" refers to whoever makes the decisions regarding the building's facilities.

The result of this situation? Poorly performing buildings, where:

- System and equipment problems result in higher than necessary utility bills.
- Unexpected or excessive equipment repairs and replacements cost the owner money and eat up staff time.
- Poor indoor environmental quality causes employee absenteeism, tenant complaints and turnover, and in the most severe cases, leads to lawsuits and expensive retrofits.

As a process, rather than a set of prescriptive measures, retrocommissioning adapts to meet the unique needs of each owner's O&M teams and occupants. When appropriately applied, the process avoids quick-fix solutions and addresses root causes to systematically improve building systems so they operate efficiently, effectively, reliably, and ensures that the improvements persist over time.

As this guide explains, retrocommissioning accomplishes the following:

- Brings the owner's needs and project requirements to the forefront to ensure that the resulting building operations will meet expectations.
- Improves the building's overall performance by optimizing energy-efficient design features, and directly addressing issues like equipment performance and system integration.
- Verifies that building staff members are well-trained and possess the documentation they need to operate and maintain the building.
- Identifies potential indoor environmental quality issues and eliminates occupant complaints.

Why Preventive Maintenance Isn't Enough

Preventive maintenance tends to focus on component-by-component care, rather than taking the holistic view that *operation* is of equal importance to *maintenance*. Preventive maintenance measures, such as cleaning coils, changing filters, tightening belts, and calibrating strategic sensors, are essential to the ongoing operations of a facility. Still, performing these tasks alone is not enough.

Good O&M practices also entail observing and monitoring building systems

Common Retrocommissioning Findings

Retrocommissioning involves a systematic, in-depth investigation of building operations, finding deficiencies that may not be immediately obvious or visible. Some examples of these deficiencies include:

- Variable speed drives no longer modulate appropriately
- Controls are circumvented or set up improperly
- Equipment runs more than necessary or runs inefficiently because of improper sequences of operation
- Controls were never tuned or require retuning to provide appropriate response time or to avoid hunting

! Monitoring and Routine Maintenance

Periodically monitoring systems and equipment to ensure proper operation should be as important as periodically performing maintenance tasks, such as cleaning coils, lubricating motors, or changing filters. Yet typically, little training is devoted to understanding building operation and system interactivity.

d Maintenance Tune-Up

A systematic process that includes conditions assessment and the implementation of maintenance measures that have not been completed during the regular maintenance schedule.

A more detailed discussion of enhancing preventive maintenance can be found in *Chapter 5: Strategies for Ensuring Persistence of Savings.*

to determine how and when they operate. In a typical building, staff are often taxed with nuisance problems and trouble calls and are too strained to proactively pursue operational tasks. Even if building staff are performing some monitoring and data collection, it is rarely in their skill set or job description to systematically analyze the information for deficiencies that are beyond the obvious.

Retrocommissioning goes beyond day-to-day building upkeep to provide a thorough assessment of the operation of mechanical equipment, lighting, and related controls. The intent is to improve how equipment operates as a system.

Why Maintenance Tune-Ups Aren't Enough

A maintenance tune-up is a systematic process performed either by in-house staff or an outside maintenance service provider, which includes a conditions assessment and the implementation of maintenance measures that have not been completed during the regular preventive maintenance schedule. This is often done prior to putting an ongoing preventive maintenance program in place or as the initial step in providing an ongoing maintenance service contract. Tune-ups tend to focus on maintenance of components and equipment, and address their physical condition.

Retrocommissioning includes tune-up procedures, but it also moves beyond tune-ups to look at operational issues, using a systems approach. It focuses more on operation than on maintenance, addressing *why* a piece of equipment is operating, not just *how* it is operating. Retrocommissioning looks at the operation of the entire system, in addition to the individual components. It looks at the root causes of operational problems, and thus its benefits are much more likely to persist. The focus on training and documentation also improves persistence.

Retrocommissioning and LEED®

What is the USGBC's LEED® rating system?

The LEED guidelines specify criteria that define environmentally superior buildings in each of six categories:

- Sustainable sites
- Water efficiency
- Energy and atmosphere
- Materials and resources
- Indoor environmental quality
- Innovation

In order to be LEED certified, a project must meet all the prerequisite requirements in each category. Projects then earn points by selecting more advanced criteria from various categories. The more points a project earns, the higher its LEED rating. This point system allows projects a great deal of flexibility in producing a LEED certified building. Upon completion, a certification package is created that documents the measures that were implemented, and the USGBC evaluates the certification package and grants a LEED rating along with a plaque and recognition on the USGBC website. There are distinct rating systems for new construction (LEED-NC), existing buildings (LEED-EB), and several other situations.

What are the LEED-EB commissioning requirements?

All buildings seeking LEED-EB certification must provide documentation that a commissioning process that meets the LEED-EB Rating System guidelines has been completed at the facility, or provide a five-year plan for completing the process. The LEED-EB guidelines also contain several related credits that may be incorporated to earn additional points, such as credits for monitoring energy performance and reducing overall energy use, and supporting operations and maintenance plans and providing staff education.

Projects undertaking LEED-EB certification should consult the most recent version of the LEED-EB Green Building Rating System for detailed information. More information about the LEED Rating Systems can be found on the U.S. Green Building Council's Web site at www.usgbc.org.

! What is LEED®?

LEED stands for Leadership in Energy and Environmental Design, a series of green building rating systems developed by the U.S. Green Building Council (USGBC).

LEED for new construction (LEED-NC) provides a standard for defining a "green building". It is used by owners, architects, engineers, and contractors to take a holistic approach in evaluating a building and its systems over the life of the facility.

LEED for existing buildings (LEED-EB) is applicable to building operations, processes, system upgrades, and minor space changes, and can be used by buildings new to LEED certification, or as a recertification vehicle for buildings that have previously achieved a LEED rating. As with other LEED systems, existing buildings can achieve one of four ratings; Certified, Silver, Gold, and Platinum.

1

2. Benefits and Costs of Commissioning Existing Buildings

There are numerous benefits of undertaking retrocommissioning. They include more effective and efficient building operation, energy savings, and improved indoor environmental quality. This chapter discusses the costs and benefits a building owner, manager, or operator should expect, and shares some strategies for reducing costs of retrocommissioning.

This chapter answers the questions:

- What are the benefits of retrocommissioning?
- What cost savings can an owner expect?
- How does retrocommissioning reduce a building's energy use?
- How much does retrocommissioning cost?

2

Retrocommissioning Benefits

Retrocommissioning benefits are far-reaching. Not only do they include cost savings, but also improvements to almost every aspect of operations and maintenance.

Everyone benefits from retrocommissioning. For owners, retrocommissioning reduces building operating costs that can lead to an increase in net operating income. Building managers notice fewer occupant complaints and increased ability to manage systems. Building staff receive training and improved documentation, and building occupants are more comfortable. The following section discusses these and other retrocommissioning benefits.

! Avoid the "Quick Fix"

Fixing the symptoms of a building or system problem without determining and addressing the root causes may provide dramatic and immediate savings, but these savings are not likely to persist, and the symptoms may reappear.

Improve System Operation: Beyond Preventive Maintenance

Good preventive maintenance practices are important, but sometimes they are not enough. Where preventive maintenance focuses on reliability and capacity of individual equipment and components, retrocommissioning takes a holistic view. The retrocommissioning process not only includes a conditions assessment that looks at maintenance issues and practices but also includes a thorough operations assessment. The operations assessment looks at control strategies, sequences of operation, and how well the mechanical equipment, lighting, building envelope and related controls perform together.

Savings from Retrocommissioning[1]

Retrocommissioning can produce significant cost savings in existing buildings. Savings vary depending on the building type, its location, and the scope of the retrocommissioning process. A comprehensive study found average cost savings in the following ranges:

Description	Range of Values
Value of Energy Savings	$0.11 - $0.72/sqft
Value of Non-Energy Savings	$0.10 - $0.45/sqft

[1]Mills, E., H. Friedman, T. Powell, N. Bourassa, D. Claridge, T. Haasl, and M.A. Piette. 2004. "*The Cost-Effectiveness of Commercial-Buildings Commissioning*," Lawrence Berkeley National Laboratory. http://eetd.lbl.gov/EMills/PUBS/Cx-Costs-Benefits.html

Improve Equipment Performance

During retrocommissioning, the retrocommissioning team assesses whether each piece of equipment is functioning properly. When it is not, they investigate the cause of the problem and recommend a solution. For example, if the commissioning team finds multiple chillers operating unnecessarily at low loads, they will collect and analyze chilled water system data and recommend changes that ensure chillers cycle on only when needed. The result? Equipment that lasts longer, works more reliably, needs fewer repairs, and uses less energy. Equipment that operates properly also demands less "crisis maintenance" from onsite staff and outside contractors, allowing staff to concentrate on their primary duties.

Increase O&M Staff Capabilities and Expertise

An essential aspect of the retrocommissioning process is providing training to building staff. Involving staff early allows them to take advantage of the training opportunities that occur throughout the retrocommissioning process. When staff members increase their understanding of building equipment and troubleshooting skills, they are better able to operate and maintain equipment and respond to occupant requests without circumventing energy-saving strategies. Training may include onsite walk-throughs with members of the commissioning team, developing and analyzing trend-logging strategies, and classroom-style presentations.

Increase Asset Value

Together, the benefits of retrocommissioning can translate into increased profitability for building owners by reducing operating expenses that lead to an increased net operating income and quicker returns on investment. Owners may also benefit from higher appraised building values if the property is properly appraised for its operating performance, since equipment that is well-maintained and operates efficiently increases the asset value of the property.

Energy Savings

Retrocommissioning provides a comprehensive analysis of a building's performance. This analysis includes specific recommendations on how to reduce the building's energy use and detailed guidance on how to implement the most cost-effective

"The University of California has undertaken a massive effort to retrocommission its existing buildings through monitoring actual operating data, diagnosing building problems and acting to remedy them. This program will save UC millions of badly needed operating dollars in the decades to come."

Maric Munn
Associate Director, Energy and Utility Services for University of California Office of the President

University of California
Office of the President
Oakland, CA
To read the case study, visit www.cacx.org

improvements. Depending on the project scope, these improvements can range from simple, low-cost fixes to complicated, highly integrated operational measures that are coupled with equipment retrofits. Retrocommissioning is considered successful when a building operates as efficiently as possible, meets the owner's operating requirements, and includes strategies to ensure benefits last over time.

The retrocommissioning team employs several strategies to improve a building's performance and reduce energy use. Early in the project, they perform a utility bill analysis to better understand how the building consumes energy. In the investigation phase, they look for typical operating issues like simultaneous heating and cooling, poorly operating economizers, and excessive air and water flows - all of which lead to energy waste. Throughout the entire project, the team takes a comprehensive view of the building operations and looks for ways to improve how equipment functions together as a system.

Energy savings from retrocommissioning can be significant. Whole building energy use can be reduced considerably, leading to cost savings in the thousands of dollars.

Improved Indoor Environmental Quality (IEQ)

The quality of a building's indoor environment affect the health, comfort and productivity of its occupants. The consequences of a poor indoor environment range from mildly inconvenient to very serious. Temperature and lighting can cause an uncomfortable work environment that hinders learning and lowers an organization's productivity. In more severe cases, poor air quality causes headaches, fatigue, or severe allergic reactions.

Poor indoor air quality can have many causes:

- Moisture and mold in the building envelope
- Inadequate outside air
- Poor air circulation
- Inappropriate control of ventilation air
- Poor craftsmanship in the air distribution system

! Energy Saving Goals

Building commissioning is an effective way to meet energy efficiency goals. In California, state-owned buildings are required to reduce their energy consumption by at least 20% by 2015.

See State of California Green Building Action Plan, March 2005—Detailed Direction that accompanies Governor's Executive Order S-20-04. Section 1.1.2.1.

! The IAQ Problem

Indoor air quality is a big problem in U.S. commercial buildings, some 20-30% of which suffer from indoor quality problems.

Poor IAQ is especially troubling in schools, where students spend close to 13,000 hours between kindergarten and 12th grade. The U.S. Environmental Protection Agency reports that half of U.S. schools – where more than 55 million students, teachers and school staff spend the majority of their time - have indoor air quality problems.

Conditions of America's Schools, February 1995. U.S. General Accounting Office, Health, Education, and Human Services Division, Document#: GAO/HEHS-95-61, Report#: B-259307.

Retrocommissioning reduces the risk of indoor environmental quality problems through its process of rigorous testing and staff training.

Incorrect building pressurization can also lead to poor indoor air quality. This is especially important in facilities with labs, morgues, indoor swimming pools, or any areas where pressurization is used to keep smells or toxins from migrating between spaces. Proper retrocommissioning ensures that pressure differentials between spaces are correct.

The Cost of Discomfort

Comfort problems affect every building owner – both those who occupy their facilities and those who lease them out.

Reduced Productivity

An uncomfortable building makes everyone less productive. Occupants spend more time complaining and often take more sick days. Building staff spend time responding to comfort complaints and have less time to attend to their regular operations and maintenance tasks.

Tenant Retention

A chronically unhealthy building can cause owners to lose tenants and money. When tenants leave, rent revenues and leasing commissions are lost. In addition, word of uncomfortable building conditions is likely to spread among business peers, increasing vacancy periods.

Increased Liability

Owners are increasingly on the receiving end of lawsuits over poor indoor air quality in their buildings. They result in high costs to the owner, inconvenience to tenants, and wasted time on everyone's part.

Improved Building Documentation

Up-to-date building documentation, including *O&M Manuals*, *Sequences of Operation*, and *System Diagrams,* is produced through the retrocommissioning process and is essential to maintaining and troubleshooting equipment. The *Preventive Maintenance Plan* and a *Recommissioning Plan* should describe in detail the human and financial resources that are necessary to maintain the benefits of the retrocommissioning process for many years.

For a complete discussion of building documentation, see *Chapter 5: Strategies for Ensuring Persistence of Benefits.*

Retrocommissioning Costs

The cost of retrocommissioning depends on the project's size, complexity, and the scope of the retrocommissioning process.

When compared to the substantial benefits made possible by retrocommissioning, the costs are often quite reasonable. However, the cost of a retrocommissioning process is often difficult to estimate. There are many published industry averages (see table below), and these almost always represent a wide range. When preparing for a retrocommissioning project, the owner should make sure to fully understand what costs to expect.

One reason for the wide range is that some projects have a broad scope, investigating the operation of all building systems, while others are affect a much more limited set of systems. The size of building also influences the cost per square foot: larger buildings cost less per square foot, since the costs of activities such as documentation, meetings, and monitoring are not sensitive to the size of the building. The cost of retrocommissioning for buildings with simple,

Retrocommissioning Costs[2]

Actual retrocommissioning costs, as reported in a study of 106 retrocommissioning projects

Description	Value or Ranges
Total RCx Cost	$0.13 to $0.45/sqft
Provider Fee as % of Total RCx Cost	35 - 71%
Average RCx Cost Allocation	
Planning and Investigation	69%
Implementation	27%
Verification, Tracking and Reporting	4%
Simple Payback Time	0.2 to 2.1 years

[2]Mills, E., H. Friedman, T. Powell, N. Bourassa, D. Claridge, T. Haasl, and M.A. Piette. 2004. *"The Cost-Effectiveness of Commercial-Buildings Commissioning,"* Lawrence Berkeley National Laboratory. http://eetd.lbl.gov/EMills/PUBS/Cx-Costs-Benefits.html

straightforward systems and equipment are obviously lower than for buildings with complex or antiquated systems (such as pneumatic controls). And, the degree of preparation that the facility does before the project is initiated and the availability and expertise of O&M staff can have a significant influence on costs.

Another issue to consider when examining the range of costs is that there is no standard convention for reporting the total cost of retrocommissioning. Quoted project costs may or may not include third-party commissioning provider labor, the labor of other team members who participate in the process, any instrumentation that must be procured for the project, and building documentation that may be developed. Depending on what kind of improvement opportunities are uncovered, the implementation of improvements may be an additional cost that is necessary to achieve benefits.

Building owners often look to in-house solutions to help offset the cost of retrocommissioning. The following sections highlight staff participation strategies that can reduce the overall cost of a retrocommissioning project.

Effectively Utilizing In-House Staff to Reduce Costs of Retrocommissioning

Building staff can take the lead in a commissioning project. And, even when a third-party leads the project, there are still opportunities to use facility staff to help reduce costs. When facility staff is actively involved in the retrocommissioning team, benefits can be numerous. The owner saves money, the team saves time, and the building staff gains valuable training and insight into the operation of the building.

There are many tasks that skilled staff can undertake to help streamline the process and increase the effectiveness of the commissioning lead's time. The staff may:

- Gather building documentation
- Perform appropriate preventive maintenance tasks prior to starting the retrocommissioning investigation
- Assist with diagnostic trending and testing
- Install and remove short-term diagnostic monitoring equipment

Chapter 4: The Retrocommissioning Team discusses the role of building owners, managers and staff in the retrocommissioning process and what owners should consider in determining the appropriate role for their staff, based on capacity and qualifications.

Utility and Government Resources

More and more frequently, utilities are offering programs to help reduce the costs of retrocommissioning. Utility representatives and government agencies can provide more information about the incentives they offer for retrocommissioning and other energy efficiency products and services.

- Perform simple repairs and improvements
- Track measures after implementation

Gather Building Documentation

Building staff can compile an up-to-date building documentation package prior to the retrocommissioning process. If this is not done ahead of time, the commissioning team will need to gather this information, which can be an expensive undertaking. The documentation packet should be available on-site and include as much of the following information as possible:

- Any previous commissioning reports
- Drawings relevant to the systems targeted for retrocommissioning (preferably "as-built" drawings)
- O&M manuals
- Testing, adjusting and balancing (TAB) reports
- Original design documentation
- An equipment list with nameplate information, dates of installation, and submittals including pump curves and fan curves
- List of outside service contractors regularly used
- Copies of current service contracts
- Current maintenance logs or schedules
- Control system documentation, such as *Sequences of Operation*, special control strategies, control diagrams, points list, control programming, etc.
- Energy-efficient operating strategies
- Energy bills (electric, gas, steam, chilled water, etc.) for at least the past 12 months (ideally for the past 24 months) along with a rate schedule, unit price, or supply contract information for each energy type
- Water and sewer usage bills for at least the past 12 months (ideally for the past 24 months)

Perform Appropriate Preventive Maintenance Tasks

Special care should be taken to make sure that in-house staff or an outside maintenance service contractor completes scheduled preventive maintenance

Sacramento County Coroner and Crime Lab
Sacramento, CA
To read the case study, visit
http://www.cacx.org/

work before retrocommissioning begins. For example, if retrocommissioning occurs during the cooling season, the annual maintenance tasks for the cooling plant and systems should be completed before commencing with the project. It is not cost-effective to hold up the retrocommissioning process because of dirty filters, loose belts, broken dampers, or loose electrical connections.

Assist with Diagnostic Trending and Testing

It is often appropriate and cost-effective to have the most motivated and interested building staff members assist with the short-term diagnostic monitoring, trend logging, and functional testing that occurs during the investigation phase of the project. This helps reduce project costs and provides the building staff with a learning experience that they can reapply later. If building staff are trained to initiate trend logs using the building's energy management control system (EMCS), a third-party commissioning provider or controls contractor will not have to perform this task.

Install and Remove Short-term Diagnostic Monitoring Equipment

Building staff may install and remove portable data loggers used for short-term diagnostics and assist with carrying out functional test plans. This is another method for reducing costs and gives the building staff exposure to different approaches to troubleshooting problems and verifying equipment performance.

Perform Simple Repairs and Improvements

Depending on the skill level of the building staff, they can perform a number of repairs and improvements. Using in-house staff to perform these tasks greatly reduces costs, as it precludes the need to hire outside contractors. The success of this cost-reducing strategy hinges on in-house staff training, knowledge, and willingness to carry out the work. Existing workloads of O&M staff should be analyzed to determine how tasks will be shifted to accommodate any additional work brought on by retrocommissioning.

Track Measures After Implementation

Immediately after the retrocommissioning measures are implemented, maximum savings are realized. Over time, however, the efficiency of the systems may decline unless explicit persistence strategies are put into place to maintain and monitor

Chapter 5: Strategies for Ensuring Persistence of Savings discusses how the facility staff can play a key role in ensuring that the savings from the RCx measures are long-lasting.

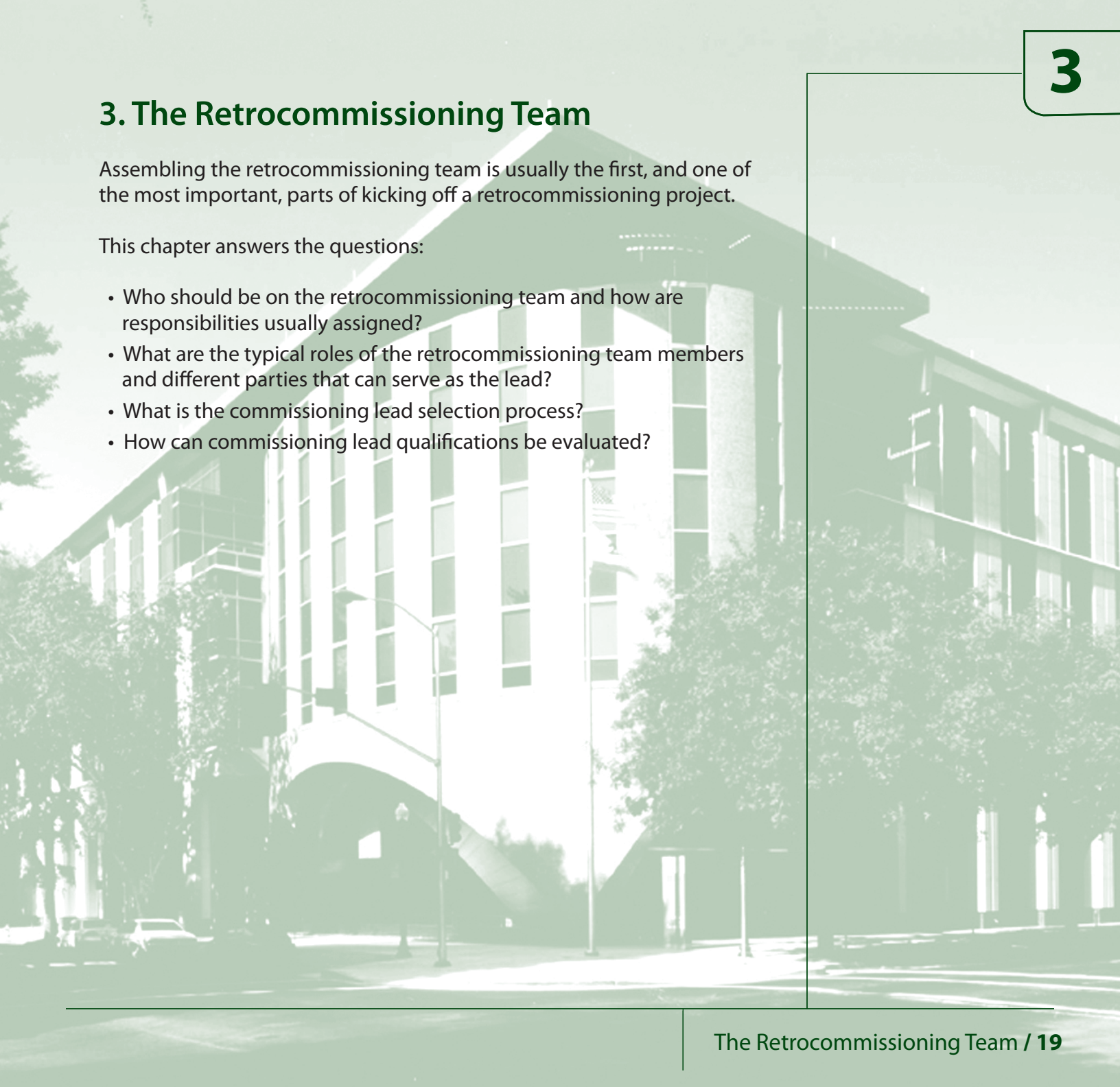
the improvements. Building staff can play a key role in tracking the measures after they are implemented to ensure they continue to work properly and that benefits last.

3. The Retrocommissioning Team

Assembling the retrocommissioning team is usually the first, and one of the most important, parts of kicking off a retrocommissioning project.

This chapter answers the questions:

- Who should be on the retrocommissioning team and how are responsibilities usually assigned?
- What are the typical roles of the retrocommissioning team members and different parties that can serve as the lead?
- What is the commissioning lead selection process?
- How can commissioning lead qualifications be evaluated?



Retrocommissioning Team Members and Their Responsibilities

Assembling a committed retrocommissioning team and clearly defining and documenting the responsibilities of each team member is vital to the success of the commissioning project.

Together, the commissioning lead and the owner assemble the retrocommissioning team and assign roles and responsibilities to each member. Budgets and special project characteristics can affect the team's structure. The team should match the size and complexity of the project.

Roles and responsibilities are outlined in the *Retrocommissioning Plan* and reviewed at a retrocommissioning kick-off meeting, along with all other plan elements. At this meeting, the owner and commissioning lead also describe the retrocommissioning scope, process, and schedule. All team members should be required to attend the kick-off meeting. Possible team members and the typical responsibilities of each are outlined below.

Commissioning Lead

The commissioning lead can be either an independent third-party contractor (commissioning provider), or a member of the owner's staff. Regardless, the individual should be able to look at the building with a fresh set of eyes, and without a vested interest in defending the status quo. The commissioning lead is responsible for heading up the retrocommissioning process and planning, scheduling and coordinating the retrocommissioning activities.

While any member of the retrocommissioning team may participate in any of the activities, the commissioning lead is ultimately responsible for their completion. They help the team identify systems or components in the building that are likely candidates for retrocommissioning. The commissioning lead helps put together the retrocommissioning team, holds the kick-off meeting to get the project started, and develops the *Retrocommissioning Plan*. The commissioning

Possible Retrocommissioning Team Members

- Commissioning Lead
- Building Owner or Owner's Representative
- Building Manager and Staff
- Design Professionals
- System Specialists

Contractors that may be part of the Retrocommissioning Team

- Installing contractors
- Manufacturers' representatives.
- Maintenance service contractors
- Controls contractors

When new equipment is integrated into a retrocommissioning project, the retrocommissioning team's responsibilities may expand to include the new equipment installation. *Integrating Building Retrofits with Retrocommissioning* (p. 50-52) discusses the advantages and cautions of including retrofits as part of the retrocommissioning scope.

lead oversees or performs the investigation, documents deficiencies and opportunities in an *Master List of Findings*, attends team meetings, and verifies that all necessary documentation and training are completed. They may also participate in implementing the system improvements if it is within their responsibilities, but in almost every case the commissioning lead verifies that the improvements were completed and are working correctly.

Commissioning Lead's Responsibilities

- Facilitate the project kick-off meeting
- Review existing building documentation, including the *Owner's Operating Requirements*
- Perform a detailed on-site assessment of the current O&M practices, documenting findings and potential improvements in the *Master List of Findings*
- Develop monitoring and testing plans
- Perform short-term diagnostic monitoring, using EMCS trend logging where appropriate
- Develop, perform, document, and oversee functional test procedures, as needed.
- Estimate energy savings and assist the owner with prioritizing the most cost-effective improvements for implementation
- Assist with, or oversee implementation of the selected improvements
- Perform post-installation monitoring and testing activities, as needed
- If needed, recalculate the energy savings based on the before and after short-term energy measurements
- Submit the *Final Report*
- Provide building operator training, as needed, on the implemented measures

Building Owner or Owner's Representative

The owner makes crucial contributions to the success of any retrocommissioning process. The owner's primary responsibilities are to support the retrocommissioning team and to clearly communicate expectations about how the building should operate. This means not only supporting the retrocommissioning team's responsibility to identify issues, but also having a commitment and a clear plan for resolving them. The owner's support enables the retrocommissioning process to

Additional Commissioning Team Tasks

Depending on the project scope, the team may be asked to fulfill additional tasks that help ensure the retrocommissioning benefits last, including:

- Review current service contracts and make recommendations for improvements
- Update or create building documentation, such as written sequences of operation for treated equipment and systems
- Develop a comprehensive training plan for O&M staff
- Develop methods for the owner and building staff to track the performance of the improvements
- Develop a *Recommissioning Plan* for the facility

See *Chapter 5: Strategies for Ensuring Persistence of Savings*

proceed more smoothly, correct more building problems, and thus produce greater benefits.

In addition to affirming the roles and responsibilities of the retrocommissioning team, the owner guides the process by clearly articulating expectations for how the building should operate. These expectations should be well-documented in the *Retrocommissioning Plan*. These become the *Owner's Operating Requirements (OOR)*, and along with the project objectives, serve as the foundation for the retrocommissioning project.

More information about the *Retrocommissioning Plan* and *Owner's Operating Requirements* can be found in *Chapter 4: The Retrocommissioning Process*.

Building Owner's Responsibilities

1. Develop and clearly articulate project objectives
2. Develop a scope of work
3. Hire or assign the commissioning lead
4. Build and support the retrocommissioning team
5. Clearly articulate the operating requirements for the building
6. Provide information and resources needed

Building Manager and Staff

The building manager O&M staff's commitment to the retrocommissioning effort is essential. Retrocommissioning is meant to enhance the overall O&M program and positively support the work of the building staff. It should not be presented as a fault-finding exercise. Staff support can be obtained by including O&M personnel when defining the goals of the project.

Chapter 2: Benefits and Costs of Commissioning Existing Buildings, discusses tasks that building staff can do to reduce overall retrocommissioning costs.

By participating in the retrocommissioning process, building staff can gain a better understanding of the building's systems and their interactions. Observing diagnostic trending and testing also improves the staff's understanding of equipment and control strategies.

Depending on availability, building operators should assist with, or at least observe, as much of the retrocommissioning process as possible in order to improve their understanding of the equipment and control strategies. This knowledge enables them to retest or recommission systems periodically as part of the ongoing O&M program.

Building Manager and Staff's Responsibilities

- Lead the retrocommissioning process, if time and expertise permits
- Gather building documentation
- Perform appropriate preventive maintenance tasks prior to starting the investigation
- Provide information on known building problems
- Calibrate critical sensors
- Initiate trending of key points
- Conduct or observe diagnostic monitoring and functional tests
- Perform simple repairs and improvements
- Track measures after implementation

Contractors and Manufacturers' Representatives

Installation contractors, maintenance service contractors, controls contractors, and manufacturers' representatives are important members of the retrocommissioning team when equipment is relatively new, still under warranty, or under contract for service. Their responsibilities may be limited, however, to what appears in their current contract, and any extra retrocommissioning responsibilities may need a separate contract. In some cases, one firm may have installed the system as a manufacturer's representative and also holds the service contract for the system. This is often true for control systems and large plant equipment such as chillers and boilers.

Installing contractors and manufacturer's representatives may be needed in a retrocommissioning project for equipment testing and/or implementation of measures that pertain to the equipment they installed. If equipment is still under warranty, it is especially important that the responsible company or individual be brought in *early* in the retrocommissioning process, as the warranty may become void if someone else manipulates the equipment. The TAB contractor can be brought back to rebalance the system prior to starting the retrocommissioning investigation.

Some owners do not have building operators, and some may employ only a few building operators with minimal skills or with limited time available. These owners

often use service contracts to cover the O&M of the HVAC, controls, and electrical systems. In these cases, the service contractor may take on retrocommissioning tasks that building operators would usually perform. The contractor may be requested to perform certain scheduled preventive maintenance tasks to coincide with the needs of the retrocommissioning project, as well as assist in data gathering, performing hands-on testing, and adjusting and calibrating equipment.

The controls contractor is an essential player on the retrocommissioning team when he or she is the person most familiar with the building's control sequences and programming, and is needed to perform trend logging and EMCS programming tasks. Having a control technician's expertise on hand can enhance the potential for improved control strategies for the building, although enlisting the time of a control technician may be expensive.

In any of these cases, there would be a natural tendency for these professionals to defend the quality of their earlier work. Significant tact must be exercised to ensure that there are no pointed fingers and that defensiveness does not interfere with objective assessment of the building.

Design Professionals

Whether design professionals are involved in the retrocommissioning process depends on the age of the equipment, the systems involved, and whether new installation is occurring during the retrocommissioning process. When retro-commissioning coincides with a new installation, the designer of the equipment should be part of the team.

Design professionals are also involved when the commissioning team needs additional expertise regarding design issues that are uncovered during investigation. In such cases, a design professional (ideally, the engineer who designed the original installation) may be brought on the team as a consultant to help resolve the issues.

System Specialists

When the commissioning lead or owner's staff lacks expertise in a particular technology, a specialist may be hired as part of the commissioning team. These

specialized systems could include clean rooms, fume hoods or scrubbers. These specialists may perform system inspection and diagnostic testing. Test results and recommendations should be submitted to the retrocommissioning team for review. Specialists may also be required to review documentation relating to the systems they test and to train operators on the proper use of this equipment.

Selecting a Commissioning Lead

One of the first and most important decisions a building owner will make is selecting the commissioning lead.

The commissioning lead's role can be filled by several different parties, either in-house or outside the company. In deciding who will serve as the commissioning lead, building owners and managers need to carefully consider the requirements of the job and the qualifications of potential candidates.

As discussed earlier in this chapter, the commissioning lead heads up the retrocommissioning team and facilitates the entire commissioning process. The commissioning lead must thoroughly understand the retrocommissioning process. It is not required that the lead be a technical expert, and can employ or partner with technology specialists. The lead should, however, have solid, hands-on experience with HVAC systems and controls.

Commissioning Lead Qualifications

The more complex the project, the more experience is required of the commissioning lead. On projects with special or mission-critical needs like hospitals or labs, it is particularly important to select a commissioning lead with directly relevant experience.

Individual projects may require a commissioning lead with more, less, or different qualifications than those described below. The following sections provide an overview of the most common qualifications required.

Technical Knowledge

In all retrocommissioning projects, the commissioning lead should have experience and up-to-date technical knowledge in the related fields of design, construction, and building operations. The commissioning lead should also have extensive and recent hands-on field experience in all aspects of the retrocommissioning process. The commissioning lead can employ or partner with technology specialists who have expertise in systems where the commissioning lead lacks experience. However, the HVAC and controls systems are so central to retrocommissioning that the commissioning lead should have a good technical knowledge of the fundamental, design, and operation of the HVAC system and the implementation of controls systems.

Relevant Experience

The commissioning lead must have experience troubleshooting and should have served in a similar capacity on at least two other projects with similar needs. On very complex projects, they should have experience on at least four similar projects.

Communication and Organizational Skills

The commissioning lead must have excellent written and verbal communication skills, diplomacy and an ability to resolve conflicts. Organizational skills and team leadership qualities are also important. If the lead will be asked to objectively assess systems for which they have had some responsibility, their ability to avoid defensiveness should be evaluated. In all retrocommissioning projects, the commissioning lead should be able to provide an objective and unbiased point of view.

Availability

Especially when utilizing in-house resources, one must evaluate carefully whether or not the commissioning lead candidate really has the time to conduct the project. If this is another task put upon an already overtasked building engineer or energy manager, the project may not receive enough attention, thus jeopardizing its success.

! In-House Commissioning Leads

Depending on the scope and complexity of the project, as well as the capacity and ability of in-house staff, the owner may wish to select a third-party commissioning consultant to be the commissioning lead. An alternative is to select a building or facility manager to manage the project, and bring in a commissioning expert to assist with certain tasks.

Involving a Third-Party Provider

The roles and responsibilities of third-party commissioning providers depend on the project's requirements of resources.

There are several advantages to hiring a third-party to lead or participate in the retrocommissioning process.

- The owner or manager may not have the time or staff resources to participate in the process, or the in-house analytical skills to perform the in-depth assessment and analysis that a robust retrocommissioning process requires.
- Consultants specializing in commissioning and O&M services have vast experience to draw upon, enabling them to quickly troubleshoot problems, uncover operational issues, and help pinpoint root causes. Also, a third party provider has no preconceived notions about how a building should perform, and has no vested interests in maintaining the status quo.
- Most commissioning providers are "tooled" for performing the work since they regularly use data loggers, power monitors, flow hoods, anemometers, combustion analyzers etc. They also have proven assessment and testing protocols and procedures that can be customized to fit almost any building.
- Engineering analysis is the specialty of a commissioning provider, who has the analytical skills and resources needed to diagnose hidden problems and determine the cost-effectiveness of selected improvements. Retrocommissioning requires a "forensic" personality and a curiosity about how things work. Most commissioning providers have these traits.

The following steps will help determine whether to select a third-party provider to assist in the process:

1. Evaluate the skills and depth of experience of the current O&M staff, and their availability for additional tasks.
2. Determine the scope of the project and what skills are needed.
3. Conduct a selection process.
4. Evaluate provider qualifications.

If a third-party is used, there are four distinct approaches that can be taken:

"At the Oakland Federal Building, retrocommissioning made the lives of the O&M staff a lot easier by allowing them to maintain the building instead of manually operating it."

Larry Lister
Commissioning Provider
Facility Dynamics Engineering

Ronald V. Dellums
Federal Building
Oakland, CA
To read the case study, visit
http://www.cacx.org/

Turn-Key

A commissioning provider is hired to oversee and implement the retrocommissioning process through all phases. This approach often works well for owners who have one or more buildings with no O&M staff, or minimal staff with little time or training. The provider leads the project, manages any necessary subcontracts, and is solely responsible for ensuring that the owner's goals and expectations are being met through each phase of the process.

Third-Party Team Lead

A commissioning provider is hired to lead the process, but the assessment work, to the extent possible, is shared with O&M staff. This arrangement works particularly well when members of the owner's staff have previous experience in commissioning, or have an expert level knowledge of building systems. Arrangements such as these should be considered an 'active partnership' between the facility staff and the commissioning provider, leveraging in-house expertise as much as possible through all phases of the process to reduce consulting costs.

Training

A commissioning provider is hired to work closely with in-house staff on initial projects, with the intention of having the in-house staff independently proceed with future projects. Owners with multiple buildings and well-trained and available O&M staff may want to hire a commissioning provider to work with the building staff for the first one or two buildings that undergo retrocommissioning. After the building staff is trained in the process, they can proceed with the rest of the buildings, acting as the commissioning lead.

Consulting

A commissioning provider is hired to work closely with in-house staff on initial projects, and the consultant is retained to perform advanced tasks on future projects. This is similar to the third approach in that an in-house staff member works to take on the role of the commissioning lead. However, in this approach the third-party commissioning consultant is retained for future projects to oversee critical parts of the assessment or tasks such as functional testing, data analysis, and savings estimates and calculations.

The Selection Process

As when evaluating lead qualifications, the selection process should be appropriate to the complexity and special needs of the project. If a design engineer, architect, contractor, or independent third-party commissioning lead is desired, there are two primary methods for selection: selection by proposal and selection by qualification.

Selection by Proposal

This selection process is one in which the owner issues a Request for Proposals (RFP). This process can be time-consuming and expensive because it requires the owner to specify the desired commissioning process and rigor, and then carefully evaluate each submission to ensure that leads are offering comparable scopes of work.

Selection by Qualification

With selection by qualification, the lead is selected based on qualifications and rate schedule, supplied as a response to a Request for Qualifications (RFQ). Although often simpler than the RFP process, using an RFQ does require the owner to carefully evaluate the leads' qualifications and interview past clients and references.

! Evaluating Provider Qualifications

When evaluating commissioning provider qualifications, owners should take the following steps:

1. Evaluate the provider's technical knowledge and experience with similar building systems and problems.
2. Evaluate the provider's non-technical skills such as communication and organization.
3. Establish whether commissioning is one of the individual or firm's core services.
4. Request and contact references.
5. Request and review sample work products.

Marriott Retrocommissioning (MRCx) Program

The Marriott International MRCx Program is a program developed by in-house facility staff that applies an approach that involves "minimum use of third parties for the maximum benefit." Under this model, the "facility staff is in the driver seat," and third-party assistance is engaged strategically through the process.

The in-house facility team's tasks typically include:

- Data gathering
- Utility bill analysis and benchmarking
- Assisting the commissioning provider lead with monitoring and testing
- Performing easy-to-fix O&M work
- Ongoing tracking of benefits

A third-party provider is hired as needed to assist with advanced tasks such as:

- Diagnostic trending and testing
- Identification of the root cause of problems
- Data analysis and energy calculations
- Development of systems drawings

Implementation of measures that are beyond the staff's expertise may be done by service or control contractors. Even when these third-party services are engaged, the facility staff remains closely involved in the process as part of their training and take on more of the retrocommissioning tasks over time.

Haasl, Tudi, Robert Bahl, E.J. Hilts, and David Sellers. *Appropriate Use of Third Parties in the Existing Building Commissioning Process – An In-house Approach to Retrocommissioning* (2004). World Energy Engineering Congress

4. The Retrocommissioning Process

A well-planned and executed retrocommissioning project typically occurs in four distinct phases: Planning, Investigation, Implementation, and Hand-Off.

This chapter answers the following questions:

- What are the phases of the retrocommissioning process?
- How are buildings selected to get the maximum benefit?
- What are the steps in preparing for a project?
- What kind of documentation is typically developed during a retrocommissioning process?
- What roles do trending, data logging, and functional testing play in retrocommissioning?
- Who should implement the improvement opportunities that are uncovered?
- What is the difference between retrocommissioning and retrofits?

4

The Retrocommissioning Process

There is no one-size-fits-all approach to retrocommissioning since every building is unique.

This chapter describes the typical retrocommissioning activities at each phase of the process: planning, investigation, implementation and hand-off. It is important to note that the retrocommissioning process must be adapted to meet the needs of each individual building project.

Planning

Initial planning activities are critical to the success of any retrocommissioning project as they set the objectives and lay the foundation for the project team to move forward.

Planning Phase Deliverables

- *Owner's Operating Requirements*
- *Retrocommissioning Plan*

To plan for a retrocommissioning project, the building owner or owner's representative must determine if their building is a good candidate for retrocommissioning, develop the internal goals, and obtain support for the project. (The commissioning lead can assist with this, or be selected after the project is defined internally.) With input from the owner, the commissioning lead develops the *Retrocommissioning Plan* and holds a kick-off meeting with other team members who are scheduled to play significant roles in the project.

The following sections discuss the major planning phase activities.

Select the Project

While most buildings can benefit in some way from retrocommissioning, some buildings are better candidates than others. Owners often want to make their worst performing buildings their first choice for a retrocommissioning project, but these facilities are not necessarily the most cost-effective candidates.

How do you choose from a portfolio of buildings? Learn more in *Chapter 5: Strategies for Ensuring Persistence of Savings*.

So, what makes a good candidate for retrocommissioning? A few of the top indicators include:

- Unjustified high energy use, or unexplained increases in energy consumption
- Persistent failure of building equipment or systems
- Excessive occupant complaints about temperature, air flow, and comfort

There are several other indicators that may predict a project's success and increase its cost-effectiveness. The characteristics to consider include: age, size, building controls, in-house staff, and building documentation.

Age

Equipment age can have a significant impact on the project. Newer buildings that were never commissioned often provide the most energy savings and non-energy benefits for the least cost. This is because the retrocommissioning project can focus on operational improvements using the new control system. Retrocommissioning done prior to substantial equipment replacement or retrofit is not always cost-effective for a building owner, since improvements coming out of a project may be voided. Timing is essential. A more detailed discussion can be found in *Integrating Building Retrofits with Retrocommissioning* (page 50).

Size

Buildings, large or small, with complex mechanical systems and direct digital controls tend to be good candidates for a retrocommissioning process. Smaller buildings with simple controls and a few roof top package units are often better candidates for maintenance tune-ups.

Building Controls

Buildings with computerized energy management control systems (EMCS) are better candidates than buildings that are fully pneumatic. Pneumatic controls easily drift and therefore need constant attention and calibration for benefits to last. Also, because of its trending capabilities, the EMCS can be used as a diagnostic tool during the retrocommissioning process to capture data. Hybrid systems, those that employ both computerized and pneumatic controls, can also benefit from retro-commissioning. However, without rigorous persistence strategies, the benefits may not last with zone level pneumatics due to calibration issues.

! Retrocommissioning Opportunity Indicators

- Presence of systems that simultaneously heat and cool, such as constant and variable air volume reheat
- Presence of economizers
- Pumps with throttled discharge valves
- Equipment or lighting that is on when the space is unoccupied
- Improper building pressurization (either negative or positive); i.e., doors that won't close or are difficult to open
- Equipment or piping that is hot or cold when it shouldn't be; unusual flow noises at valves or mechanical noises
- Short cycling of equipment
- Variable frequency drives appear to be operating at or close to 100% most of the time

How does a building's energy use compare to buildings of a similar size and type? *Chapter 5: Strategies for Ensuring Persistence of Savings* discusses various publicly-available benchmarking tools.

Project Champion

The most successful retrocommissioning projects have an internal "champion" to help push the project, convince others of its value, and advocate for the time and money necessary to complete the process. The best champion is the person with the most enthusiasm about the project, not necessarily the highest ranking person.

In-House Staff

Retrocommissioning performed on buildings with experienced, knowledgeable, interested, and available building staff is more likely to be cost-effective and have lasting results. Having at least one operator with expertise with the building's control system can increase the cost-effectiveness of the project and likelihood of the benefits persisting.

Building Documentation

Unless updating the building documentation is a primary objective of the retrocommissioning project, owners should choose buildings with available and up-to-date documents to increase overall cost-effectiveness.

Set Project Objectives and Obtain Support

Once a building is selected for retrocommissioning, the building owner or manager should define the project objectives. The primary objective of the project – such as to obtain cost savings by reducing energy use or to solve indoor air quality problems – will affect the overall vision, direction, and scope. Having the objectives well-articulated at the onset helps to guide the project and keep the team on track through completion of the process.

In order to complete a successful retrocommissioning project, the building or facility manager must secure the owner's and upper management's commitment as well as support from building staff.

No less important is soliciting occupant cooperation and support, and allocating adequate time and funds to the project.

Example Set of Objectives for a Retrocommissioning Project

- Obtain and verify cost-effective energy savings. Verification will require limited performance monitoring of selected building systems.
- Identify and recommend improvements to operational strategies, focusing on those measures that sustain optimal energy performance and reduce operating costs.
- Identify HVAC-related health and safety issues.
- Oversee and verify implementation of selected measures.
- Provide recommendations for energy-efficient retrofits for future investigation.

Select a Commissioning Lead

The owner can hire or assign a commissioning lead at the onset of the project, or after they have selected the building, defined the objectives, and garnered internal support for the project. Overall, the commissioning lead heads up the process, works closely with the building staff, and ensures that the owner's expectations are being met at each stage of the project.

The commissioning lead has many responsibilities and must be skilled in fostering communication and promoting a positive, team-based approach to problem solving. A well-qualified commissioning lead also has a depth of troubleshooting experience, and the diagnostic monitoring, testing and analysis expertise needed to uncover potential problems and select the most cost-effective solutions.

Document the Current Operating Requirements

An important objective of a retrocommissioning project is to ensure that the facility's operating requirements are being met, so one of the early retrocommissioning tasks is to define these requirements. These include any requirements or limitations for temperature, humidity and air filtration. If the *Owner's Operating Requirements* are not a part of the building record, the commissioning team should document this information for each area of the facility that has different uses.

Also, as the commissioning team proceeds, it is important to be aware of the *Owner's Operating Requirements*, so as to be sensitive to building schedules, functions, and processes during the diagnostic activities of the investigation. The *Owner's Operating Requirements* are also important to consider as they may affect the feasibility of some retrocommissioning measures. For example, scheduling of equipment or lighting may not be a possible energy-saving measure in an area of the facility that has extended or unusual operating hours.

Chapter 3: The Retrocommissioning Team provides guidance on qualifying and selecting a commissioning lead and team that best meets the project's needs.

Owners Operating Requirements

A document that details the facility's operating requirements including operating hours, process and equipment status during off-times, and requirements and limitations for temperature, humidity or air filtration.

LEED® Requirements

The retrocommissioning prerequisite of LEED-EB Version 2 requires development of a comprehensive building operation plan that meets the requirements of current building usage, and addresses the heating system, cooling system, humidity control system, lighting system, safety systems and the building automation controls.

Perform an Initial Site Walk-Through

To start the project, the commissioning lead should do a walk-through of the facility and get acquainted with building staff assigned to the project. This allows the commissioning lead to gain familiarity with the building and its main energy-consuming systems and equipment and identify areas of opportunity for further investigation. This is especially important when the project uses a third-party commissioning lead.

The commissioning lead can gain understanding about a building just by observing the overall condition of the equipment, the equipment in action, and the positions of valves and dampers. The commissioning lead should interview the building operators about operating conditions, current preventive maintenance actions, and any known performance problems. A few hours with a knowledgeable building operator can uncover numerous areas of energy waste, as they best know the day-to-day operations and the building's weak spots.

The commissioning lead should also obtain utility data from the previous 12 to 24 months as well as review preventive maintenance records and current service contracts. This information will allow the commissioning lead to conduct a utility bill analysis and further understand the current O&M practices at the facility.

Develop the *Retrocommissioning Plan*

After gaining a clear understanding of the project goals, the *Owner's Operating Requirements,* and current operating conditions at the facility, the owner and commissioning lead develop the *Retrocommissioning Plan.*

The *Retrocommissioning Plan* reiterates the scope of the retrocommissioning project. This deliverable ultimately serves as a guideline for team members to follow. It provides an outline of the processes and procedures that will be undertaken, a schedule of activities, roles and responsibilities of team members, the metering/monitoring plans, and forms and templates that will be used to document the retrocommissioning activities. The plan should be viewed as a flexible document that is revisited at certain milestones in the project.

LEED® Requirements

The retrocommissioning prerequisite of LEED-EB Version 2 requires a *Retrocommissioning Plan.*

Retrocommissioning Plan

A document that defines the project's objectives, scope, schedule, documentation requirements, and the roles and responsibilities of team members. The plan should include:

- General building information and contact information
- Goals and scope of the project
- Brief building and system descriptions, including a list of systems that will be investigated
- *Owner's Operating Requirements*
- List of team members, their roles, responsibilities, and expected deliverables
- Description of the communication, reporting, and management protocols
- Schedule (for primary tasks)
- Documentation request
- Investigation scope and methods
- Implementation phase requirements
- Project hand-off activities

Retrocommissioning Plan templates and samples are available on the CCC website: www.cacx.org.

Assemble the Retrocommissioning Team

Throughout these initial stages, the owner and commissioning lead begin to assemble the retrocommissioning team. This involves getting to know all the players in the building environment, the roles they play, and the experience they bring. Each participant should explicitly be invited to "join the team." This helps build committment to the entire process.

Hold a Project Kick-off Meeting

The project kick-off meeting brings the retrocommissioning team together to review the *Retrocommissioning Plan*. The commissioning lead organizes and leads the meeting. Participants may include the owner or owner's representative, building operators, and any contractors or other professionals that may be important to the process, such as controls contractors, maintenance service

contractors, or consulting engineers that are familiar with the building. At this meeting the owner and commissioning lead identify each team member's responsibilities and communicate the owner's expectations for the project.

Investigation

During investigation, the commissioning team conducts a systematic analysis of the building's performance through observation, review of building documents and O&M practices, and trending and testing of building systems.

Investigation Phase Deliverables

- *Diagnostic Monitoring Plan*
- *Master List of Findings*
- List of improvements selected for immediate implementation

Depending on the scope of the project, the investigation can take anywhere from several days to several months to complete. The results of this analysis are summarized for the owner in a *Master List of Findings*.

Review Facility Documentation

A thorough review of the building documentation allows the commissioning team to better understand the building's major energy uses and integration issues. Ideally, a building operator assigned to the project helps gather the appropriate documentation and answer questions for the team.

To the extent possible, the commissioning team should obtain and review the following documents:

- Original design documentation
- Equipment lists, with nameplate information
- Drawings for the building's main energy consuming systems and equipment, including controls, mechanical, and electrical
- Control system documentation, including sequences of operation, point lists, and control diagrams

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Having building documentation available and up-to-date will help to increase the cost- effectiveness of the retrocommissioning process, as it spares extra hours the team would otherwise have to expend searching for information or creating new documentation.

d ***Diagnostic Monitoring Plan***

A plan developed by the commissioning team for control system trend logging and portable data logging.

d ***Master List of Findings***

A summary list of findings generated during the investigation process. For each finding, the list contains the following fields: finding description, type of equipment, recommended improvement, estimated energy savings and costs, simple payback, recommendations and status of implementation. This is also known as the *Findings Log*.

- Operation and maintenance manuals
- Testing, adjusting and balancing (TAB) reports

Perform Diagnostic Monitoring

Once the commissioning team completes the facility site visits, the building staff interviews, and carefully reviews facility documentation. The next step is to gather exact data on when and how the systems operate through diagnostic monitoring. This helps to identify, characterize and confirm improvement opportunities as well as begin to detect the root causes of performance deficiencies.

Various methods of data gathering using meters, portable data loggers, and the building's Energy Management Control Systems (EMCS) allows for observation of the building's performance under various modes and operating conditions over time. Time-series data are collected and analyzed, allowing sampling and storing of various parameters at intervals ranging from 30 seconds to one hour. Some of the variables typically trended include whole-building energy consumption (such as electrical energy or demand, gas, steam, or chilled water), end-use energy consumption, operating parameters (such as temperatures, flow rates, and pressures), weather data, equipment status and runtimes, actuator positions, and setpoints.

Diagnostic Monitoring

Facility staff can reduce time spent on the diagnostic monitoring by assisting the commissioning team with tasks such as:

- Completing calibration
- Assisting with installation and removal of data loggers
- Assisting with trend logging, or developing, downloading or formatting computer files for analysis by the commissioning team

From this collected data, the commissioning team can calculate key metrics and perform statistical analysis as well as create data plots that show hourly, daily, weekly, or monthly trends, or how one parameter varies with changes in another. By analyzing this information, the commissioning team characterizes the performance and verifies whether or not the systems are operating correctly.

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A *Diagnostic Monitoring Plan* includes an outline of the process for monitoring, using EMCS trending and/or dataloggers: A *Diagnostic Monitoring Plan* typically includes:

- Points to be trended
- Value type to be trended
- Sampling rate
- Trend group each point will be analyzed with
- Visual method of analysis to be used

d Data Logger

A stand-alone electronic data-gathering device that utilizes sensors to collect equipment information over time. Data collected could include temperatures, pressure, current, humidity, or other operational information.

There are two methods of collecting trend data: EMCS trend logging and portable data logging.

Trend logging (trending) capabilities vary considerably among EMCS systems. The extent of these capabilities determine the extent to which the EMCS can be used for diagnostics. When using an EMCS with proprietary programming as a diagnostic tool, involving the controls contractor or vendor as part of the retrocommissioning team to assist with diagnostics is not unusual. They can assist in setting up trends and downloading or formatting computer files for analysis. To expedite trending and troubleshooting processes, it is best if the controls technician who originally set up the system is hired as part of the team.

Portable data loggers can be an extremely useful diagnostic tool, especially if the EMCS has any limitations in its ability to collect, store, or present data. Portable data loggers are battery-powered, small, light, and easily installed and removed without disrupting building occupants. Many come with sophisticated software package allowing data to be downloaded, easily graphed, and analyzed on a computer in a variety of ways. Because they are portable, these dataloggers can be applied where they are needed (a shortcoming of monitoring using an EMCS, whose sensors are already in place). Portable dataloggers can be an excellent way to supplement EMCS monitoring.

Perform Functional Tests

In most cases, the trend data only indicates a problem, but not the *root cause*. In these cases, or in cases where it is impossible to naturally observe every possible operating regime, the commissioning team conducts functional performance tests and takes the system through its paces, observing, measuring and recording its performance in all the key operating modes. The team develops a well-defined test protocol that describes how the test will be carried out. The commissioning team and owner schedule the testing and make any necessary preparations, such as checking and calibrating control points or temperature sensors. The functional tests typically involve forcing the system into a series of operating modes, and observing the system's response. The team will meticulously record all their activities and observations on a pre-defined data

! Measurement and Verification (M&V) for Utility Programs

If the project is receiving funding from a publicly or utility-funded program, demonstration of savings may be required in order to receive incentives. Therefore, caution should be taken and no changes should be made while a baseline of performance is being established.

! Resource

A library of functional test forms and guidance documents is available in the *Functional Testing Guide*, available from PECI at www.peci.org/ftguide/

PECI and LBNL, *Functional Testing Guide - From the Fundamentals to the Field*. Prepared for the US Dept. of Energy and the California Energy Commission's Public Interest Energy Research program.

sheet, and then ensure that all systems are returned to a "normal" state.

Involving the building operators as part of the commissioning team during testing enhances the retrocommissioning process and is a unique opportunity to deepen their understanding of the systems and controls.

Test Protocol

Facility staff can reduce time spent on functional testing by assisting the commissioning team with tasks such as:

- Defining tests
- Preparing for tests
- Manipulating the systems to conduct tests
- Putting the systems back to normal following testing

A test protocol is a form that describes exactly how a test will be carried out. It includes:

- Purpose of the test
- Instructions for carrying out and documenting test
- Equipment required for test
- Acceptance criteria
- Precautions
- Prerequisites for testing
- Detailed procedural steps for testing
- Procedure for returning to normal
- Analysis required
- Required sign-offs

Perform Simple Repairs as the Project Progresses

It is important to note that retrocommissioning is a changeable, iterative process. In some cases, investigation activities may be carried over into the implementation phase as more diagnostics are needed to identify and implement the appropriate fix. This is common when the control system is proprietary and the control contractor is needed for programming or trend analysis that may be essential for diagnostics and implementation.

Conversely, some implementation activities may occur during investigation. Often, completing simple repairs and adjustments discovered during the investigation

LEED® Requirements

The retrocommissioning prerequisite of LEED-EB Version 2 requires testing of all building systems to verify that they are working according to the specifications of the building operation plan.

is necessary to help get to the root cause of a problem, which increases the effectiveness of the diagnostic monitoring and testing. For example, it may be necessary to calibrate a mixed-air temperature sensor before diagnosing economizer problems.

Of course, the commissioning team should use caution when making even these small fixes. For example, if an overridden setpoint is causing inefficient operation, the commissioning team should consult with the building staff as to why this setpoint was changed. It may have been changed to respond to a comfort problem, which should be addressed before releasing the override.

d ***Master List of Findings***

A summary list of findings generated during the investigation process. For each finding, the list contains the following fields: finding description, type of equipment, recommended improvement, estimated energy savings and costs, simple payback, recommendations and status of implementation. This is also known as the *Findings Log*.

Develop the *Master List of Findings*

After diagnostic trending and testing is complete and the results are analyzed, the commissioning lead summarizes the findings in the *Master List of Findings*. The *Master List of Findings* is one of the most significant deliverables from the retrocommissioning process and ultimately becomes an important decision-making tool for the building owner. Every finding from the investigation phase, including the "field fixes" made during the course of the investigation, is summarized in the *Master List of Findings*. Ultimately, the *Master List of Findings* records, at a minimum, a description of the measure, estimated energy savings (if applicable), implementation cost estimates, simple payback (if applicable), and recommendations and status of implementation. When compiling the *Master List of Findings*, a unique ID number should be assigned to each finding. This number is used as a reference number throughout every retrocommissioning report and document to avoid confusion.

Uses of the *Master List of Findings*

The *Master List of Findings* serves multiple functions through the investigation and implementation. Common uses are listed below:

- Deliverable and decision-making tool for the owner
- Document for various contractors that may be implementing particular measures
- Ongoing record of the implementation status of the recommended measures (i.e., completed, under consideration, on-hold due to budgetary constraints)

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Many typical findings that result from retrocommissioning can provide less than one-year paybacks, especially if some of the implementation work can be accomplished by in-house staff. Any organization should be able to justify funding for such measures.

Depending on the owner's needs, the commissioning team should consider how

to sort and present the *Master List of Findings*, perhaps adding specific fields to the list. For example, the owner may have a certain simple payback or return on investment (ROI) criteria upon which their organization makes decisions. Other possible categories for the *Master List of Findings* include:

- System type affected (chilled water plant, air handling unit, lighting control)
- Type of problem (operations, maintenance, design, or installation)
- Non-energy benefits (improved indoor air quality, reduced maintenance, safety, etc.)

Prioritize and Select Operational Improvements

After the *Master List of Findings* is complete, the commissioning team presents the results to the owner and assists with selecting measures for implementation.

Depending on the owner's needs and scope of the project, the *Master List of Findings* may be a sufficient decision-making tool to proceed to implementation, as it provides a summary of the investigation findings, recommended solutions, and a cost-benefit analysis. Some owners may wish to have the *Master List of Findings* included in an *Interim* or *Investigation Summary Report* in which the commissioning team details their findings from the site assessment, building documentation review, and diagnostic trending and testing. In any case, the owner should require the team to supply all calculations and assumptions behind their energy savings and cost estimates.

To the extent needed, the commissioning team assists the owner with selecting measures for implementation. This process may take some time, as there are many factors to be taken into account before implementation begins, including the capability and availability of in-house staff to implement measures, budget constraints, and the availability of funds (program incentives) from outside sources such as utility programs. Simple, low-cost repairs and changes may be selected for immediate implementation.

d ***Implementation Plan***
A document prepared by the commissioning team to provide guidance or a scope of work for implementing measures identified during the investigation.

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The goal of retrocommissioning is to improve the performance of the building, not to develop a nice report that sits on a shelf. Even if the commissioning team is not tasked with conducting the implementation of prioritized improvement opportunities, the commissioning team should ensure that a plan is put into place to carry them out, and should reserve some of their time to verify the changes after they are made.

4

Implementation

The way implementation is carried out varies greatly among projects. Each building will require different types of measures, each owner is faced with unique budgetary and administrative situations, and each building staff will have different capabilities and contractor relationships.

Implementation Phase Deliverables

- *Implementation Plan*
- *Implementation Summary Report*

When using a third-party commissioning provider, the commissioning team should consider retaining them through the implementation phase, even if the implementation work is done in-house and especially if it is outsourced to another contractor. Even though the team has an intimate knowledge of the building systems and needed improvements, having the commissioning lead oversee the implementation may ultimately save time and reduce costs due to their experience specifying and developing implementation plans.

Develop an *Implementation Plan*

An *Implementation Plan* organizes and defines the work needed to obtain the required results. Primarily, the *Implementation Plan* includes a scope of work for addressing each issue or improvement that the owner has selected to implement along with requirements for verification. Depending on what post-implementation data the owner needs, either for internal purposes or for receiving incentives from an outside program, the plan also recommends methods for calculating energy savings and verifying the performance of the measures after implementation.

If the commissioning lead is a third-party provider and is providing turn-key implementation, the *Implementation Plan* should take the shape of a detailed scope of work for the sub-contractors to perform. This should also include any required verification activities or the plan can act as a guideline for the building staff who are assigned to making any repairs and improvements that can be done in-house. If the owner or managers prefer to hire the sub-contractors and oversee the work themselves, then it can be used to obtain bids from contractors.

LEED® Requirements

The retrocommissioning prerequisite of LEED-EB Version 2 requires repair or upgrade of all systems and components that are found to be not working according to the specifications of the building operation plan. If not implemented immediately, it requires a plan that includes a schedule that will complete all retrocommissioning actions within five years. All low-cost and no-cost measures must be implemented in the first two years of the implementation program.

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The scope of implemenation is difficult to predict at the beginning of a retrocommissioning project. When a third-party commissioning provider is used, it may be easier to include implementation activities in a second contract, drawn up when the scope is more well-defined.

Developing a solid *Implementation Plan* is key to getting the improvements done and verified correctly. Anecdotal evidence suggests that the most successful projects — where issues are resolved, improvements completed, and benefits are realized — are projects with a commissioning lead who oversees the project from start to finish. The following section discusses the various methods of implementation.

Implement Selected Operational Improvements

The owner must first choose an approach for implementing the recommended measures. Choosing an approach largely depends on the in-house building staff's expertise and availability, as well as the owner's willingness to manage the implementation activities. There are three common approaches to implementation as part of a retrocommissioning project:

- Turn-key implementation
- In-house staff implementation with commissioning provider guidance
- Owner-led implementation

Turn-Key Implementation

Turn-key implementation uses the third-party commissioning provider to perform most, if not all, implementation activities. The main advantage for the owner with this approach is that the owner holds only one contract (with the commissioning provider) for implementation. The commissioning provider is responsible for any subcontracts needed to accomplish the implementation goals. Also as the commissioning lead, the provider has the deepest insight into the building or system's operation at that point, and is best suited to addressing the issues. This is often the easiest option for the owner, as it reduces their time spent coordinating, contracting and managing implementation activities. This option is most appropriate when implementing improvements that require that most of the work be done by outside contractors.

In-House Staff Implementation with Commissioning Provider Guidance

Under this approach, the implementation is accomplished by in-house staff (whether or not they comprised the commissioning team), with the assistance

of the commissioning provider. This approach is ideal when in-house staff is highly skilled and can carry out much of the work, and need for implementation by contractors is minimal. The commissioning provider can either have a defined role in the implementation team, or can provide assistance and consulting on an as-needed basis.

Owner-led Implementation

The owner can also choose to take the results and recommendations from the investigation and proceed to implementation without further assistance from the commissioning provider or outside team members. This option may be attractive to owners who have strong, established relationships with a service contractor or a highly capable in-house engineer who can implement and verify the measures. Note that even in this case, the third-party commissioning consultant or provider may still conduct the tasks outlined in the hand-off phase section that follows.

Verify Results

Once an improvement is completed, it is important to retest the equipment or systems to ensure that the improvements are working as expected. Retesting can be done using EMCS trending, data logging, functional testing, simple observation, or a combination of these methods. For example, retesting might involve manually testing the repaired items such as dampers or valves to verify that they stroke properly, followed by trending or data logging to determine that they are modulating to maintain the desired setpoint at the appropriate times.

In order to confirm that each improvement as well as the combination of improvements are integrated and have the desired effect, the post-implementation data is compared to the original, baseline data. This final verification data can also be used to update the energy savings estimates if needed. The data gathered as a result of verification activities along with the updated energy cost savings information is compiled into the *Implementation Summary Report*. Also, future performance of each improvement can be periodically compared against the verification data to ensure benefits persist.

! *Implementation Summary Report*

Implementation Summary Report includes, by measure:

- Description of the measure implemented
- Updated energy savings calculations
- Final implementation cost
- Evidence of implementation

LEED® Requirements

The retrocommissioning prerequisite of LEED-EB Version 2 requires re-test of all building components that required repairs or upgrades to verify that they are working according to the specifications of the building operation plan.

Hand-Off

To ensure the building owner and operators have what they need to monitor and maintain implemented measures, an intentional and thorough project hand-off is essential.

Hand-Off Phase Deliverables

- *Final Report*
- *Systems Manual*
- *Retrocommissioning Plan*

Develop the *Final Report*

The *Final Report* is a record of the retrocommissioning activities and measures that were implemented. It is critical to long-term persistence of savings and benefits because it contains recommendations for O&M practices that help maintain the performance of the improved systems. It is a resource for current and future operators and should be made part of the permanent record of recommended O&M plan and practices for the building.

LEED® Requirements

The retrocommissioning prerequisite of LEED-EB Version 2 requires documentation of the results of the retrocommissioning activities.

Final Report

The *Final Report* is a summary of the project and provides a record of the retrocommissioning activities and recommendations for monitoring and maintaining the implemented measures.

The contents of the *Final Report* include:

- Executive summary
- Project background
- The *Master List of Findings*, with a description of the improvements implemented
- Updated estimates of savings and the actual improvement costs for each improvement implemented
- The EMCS trending plan and logger diagnostic / monitoring plan and annotated results
- All completed functional tests and results
- Recommended frequency for recommissioning by equipment type with reference to tests conducted during initial retrocommissioning
- Complete documentation of revised or new strategies implemented
- A list of capital improvements recommended for further investigation

Compile a *Systems Manual*

Sometimes, the *Retrocommissioning Plan* will call for a *Systems Manual*. This is a compilation of important building documentation such as the *Owner's Operating Requirements*, narrative descriptions of the *Sequences of Operation*, and the *Final Report*. It can also include either the *Operation and Maintenance Manual* itself, or a master list of all the building documents along with their locations. There are a variety of ways to put together a *Systems Manual*—the important thing is that the essential information about how to operate the building is included, as well as the lessons learned from the retrocommissioning process.

Systems Manual

A *Systems Manual* is a compilation of building documentation that greatly enhances the building staff's ability to operate the building effectively. It can include:

- Final Report
- Master list of building documentation with locations
- General building or plant description
- Systems diagram
- Building and equipment schedules
- Building control point list
- Equipment list with descriptions
- Sequences of Operation
- Control set points
- Alarm set points
- Available monitoring points and active trending capabilities
- Control graphics or diagrams
- O&M Plan
- Information on Ongoing diagnostics
- M&V Plan

Develop a *Recommissioning Plan*

Although the project is almost complete, it is helpful at this time to put a plan in place for future recommissioning projects. Even the best-commissioned building will require periodic focused attention to keep it running optimally. This can be done on a scheduled basis, or when performance begins to degrade. Since the building's performance will be well-understood and well-documented at the end of the retrocommissioning process, this is a good time to define the requirements for recommissioning. A recommissioning scope of work might even be drafted at this point to provide a good starting point for the future effort.

Chapter 5: Strategies for Ensuring Persistence of Savings covers the ways that savings can be ensured over time.

Provide Training

Ideally, training for building staff whether they are or are not part of the commissioning team should occur throughout the project. Early involvement provides staff with the best opportunity to learn about how issues are found and remedied. However, project hand-off is the ideal time to provide any additional training staff may need on the improvements and how to maintain them, as well as address other areas of building O&M that are of particular concern to the owner. This may be in the form of classroom training with hands-on demonstrations in the field. Videotaping the sessions for future use by current staff as a refresher or use in training new staff increases the persistence of the retrocommissioning benefits.

Hold a Close-Out Meeting

The project close-out meeting is generally held after the *Final Report* is completed. The *Final Report* is presented at the meeting and any outstanding issues and next steps are discussed. This meeting is valuable for discussing the lessons learned during the project, and provides an important opportunity to recognize individual successes and celebrate the overall success of the project.

Implement Persistence Strategies

Immediately after the retrocommissioning measures are implemented, the treated systems are operating at or near peak performance. Over time, however, the efficiency of the systems may decline, unless explicit strategies are put into place to maintain and monitor the improvements.

The owner should consider implementing one or more strategies that help to ensure that the energy savings – and other benefits – from the retrocommissioning project are long-lasting. Common strategies for ensuring persistence include:

- Developing policies and procedures for updating building documentation. For example, correcting the building's drawings to reflect any changes as they occur. Most importantly, immediately documenting any changes to sequences of operation or control strategies that affect the retrocommissioning improvements
- Providing ongoing training for building staff
- Enhancing the current preventive maintenance program to include upkeep of

sound operating practices and strategies

- Tracking whole-building energy performance
- Periodically recommissioning the building, paying close attention that the original retrocommissioning improvements are still producing benefits
- Instituting a plan of "ongoing" or "monitoring-based commissioning"

Integrating Building Retrofits with Retrocommissioning

Typically, retrocommissioning focuses on improving the overall performance of a building by investigating and improving how systems operate together. However, the retrocommissioning scope can also include other services such as prioritizing and scheduling deferred maintenance work and recommending and overseeing retrofits and equipment replacement. How much is included in the scope is a matter of timing, budget, in-house skills, age of equipment, and the owner's goals and objectives for the building. The following section discusses the advantages and cautions of including retrofits as part of the retrocommissioning scope.

First, commissioning should be part of any retrofit project, whether or not it is taking place under the retrocommissioning umbrella. The primary objective of commissioning during a retrofit project is much the same as commissioning during new construction – to confirm that the new equipment is working as designed and that it meets the owner's project requirements. When retrofits are installed as part of a retrocommissioning effort, there is the added advantage of ensuring that all existing building systems that interface with the new retrofits are performing at their best.

Deciding which to do first—retrocommissioning or retrofit—is not always a clear-cut decision, as it depends on the specific savings opportunities. Retrofits often are the first step in cases where buildings have major equipment and systems that are close to the end of their life or are in need of significant energy upgrades. Retrocommissioning is often the first step in buildings that are fairly well maintained

and have systems that are newer or have older systems that are very well maintained. Additionally, a retrofit often may be more effective when applied to well-functioning systems. For example, before replacing a chiller with a more efficient model, retrocommissioning - as a first step - can often reduce cooling loads by eliminating simultaneous heating and cooling, allowing the existing chiller to be replaced by a smaller model.

In general, caution should be taken to implement only retrocommissioning improvements that will remain intact if recommended retrofits are implemented soon after the retrocommissioning project is completed. The retrocommissioning lead is well-positioned to advise and help create the best plan for integrating building retrofits with retrocommissioning.

When retrofits are part of a retrocommissioning project, the commissioning team should still follow the typical process of a retrocommissioning project as discussed earlier in this chapter. However, the commissioning team's responsibilities may expand to include the following tasks related to commissioning the retrofit project:

- Developing commissioning specification for the new equipment
- Including retrofits in the *Retrocommissioning Plan*, specifically addressing the new equipment and how it interfaces with existing systems
- Overseeing the commissioning of the retrofit project:
  - Developing and overseeing prefunctional checklists and functional test procedures as needed on the new equipment
  - Performing short-term diagnostic monitoring of existing systems and the new equipment to ensure they are properly integrated
  - Developing a separate *Master List of Findings* for the retrofit and ensuring that the identified deficiencies are resolved to the owner's satisfaction
- Overseeing the delivery of specified staff training and system documentation for the new equipment

The commissioning of retrofits has much in common with the application of the commissioning process to new buildings. In new buildings, the commissioning process includes a definition of the owner's project requirements, review of the design drawings and specifications, review of submittals, inspection of installed

equipment, functional testing of systems, training, and documentation. All of these steps are required in the construction of a retrofit.

Publicly-Funded Programs

Although it is ideal to have retrocommissioning include retrofits as an integrated part of the process, this may be difficult to do when an owner requires an incentive from a publicly funded program to move forward with energy-focused improvements.

When the activities are integrated it can be quite difficult to delineate which portion of the energy savings to attribute to the retrofit and which to the retro-commissioning project. Because of this, public entities often set up separate programs, one for retrofits and one for retrocommissioning, each with its own incentive structure. When both retrocommissioning and retrofits are anticipated, it is imperative that activities are well-planned so the savings are attributed correctly in order for customers to obtain their expected results and incentives. During the retrocommissioning process, if needed retrofits are discovered, they can be recommended for further investigation and possible funding once retrocommissioning is completed.

Energy Savings Agreements

Some level of retrocommissioning is usually appropriate when considering any type of energy savings agreement such as an energy savings performance contact (ESPC). There are two primary reasons for performing retrocommissioning before obtaining an energy-savings agreement. First, the energy savings gained from the operational improvements remain with the building (the owner gets all of the savings) and do not become part of the financial agreement. Second, retrocommissioning optimizes the existing equipment so the most appropriate capital measures are selected and financed through the agreement.

When retrocommissioning is performed before an energy savings agreement is finalized, it is important to inform the contractor about the retrocommissioning activities and give them a copy of the final report. If the performance contractor is not informed and energy bills from prior years are used to help determine the energy baseline, the baseline may be inaccurate. This may cause the cost savings upon which the financing is based to be significantly less than expected, leading to disagreements and even legal battles.

d ***Energy Saving Performance Contract***

A contract for energy efficiency products and services in which the payment is contingent upon energy savings actually resulting.

Summary of Recommended Deliverables by Retrocommissioning Phase

Planning Phase

- *Owner's Operating Requirements*
- *Retrocommissioning Plan*

Investigation Phase

- *Diagnostic Monitoring Plan*
- *Master List of Findings*
- List of improvements selected for immediate implementation

Implementation Phase

- *Implementation Plan*
- *Implementation Summary Report*

Hand-Off Phase

- *Final Report*
- *Systems Manual*
- *Recommissioning Plan*

4

5. Strategies for Ensuring Persistence of Benefits

At the end of the retrocommissioning process, the treated systems are well tuned and operating at their peak performance. However, buildings change over time and, unless explicit strategies are put into place to maintain and monitor the improvements, the performance of the systems may decline.

This chapter answers the following questions:

- What documents should be developed to assist the building operations staff in keeping the building's performance optimized?
- Why is training so important in keeping the building operating well?
- How does retrocommissioning form the basis for an effective preventive maintenance program?
- How is performance tracking done?
- How often will the building need to be recommissioned?

5

Strategies for Ensuring Persistence of Benefits

There are many things that can be done to ensure the benefits from retrocommissioning persist. These include creating or updating your building documentation, building staff training, preventive operations and maintenance, performance tracking and developing a *Recomissioning Plan*.

Building Documentation

Thorough, accessible documentation helps ensure that the benefits of retrocommissioning persist. Without a good record of the knowledge gained from the process, much of the long-term value may be lost.

At first glance, spending money on documentation may seem like an "extra." However, these documents supply building operators as well as HVAC, controls, or maintenance service contractors with the information they need to maintain systems and equipment, troubleshoot problems, and monitor the measures that were implemented.

For existing buildings that do not have complete or up-to-date documentation, the best time to update or create them is during the retrocommissioning project. Operational or equipment changes have been made and there is a motivated focus on improving O&M practices.

The *Final Report* from the retrocommissioning process becomes an important document for the building and an invaluable resource to current and future building operators. A *Systems Manual*, which can include a compilation, summary, or index of some of the other building documents, can also be a very helpful document. The *Final Report* and the *Systems Manual*, often associated with a retrocommissioning project, are described in Chapter 4. In addition to these standard retrocommissioning deliverables, building owners and managers should

consider including the task of creating or updating other essential building documentation such as *O&M Manuals*, as-built drawings, and written sequences of operation as part of the retrocommissioning scope.

In addition to the *Systems Manual* there are a few essential documents that should also be updated/created as part of the retrocommissioning project. These include:

- Equipment Lists
- *O&M Manuals*
- Control System Documents
- *Systems Diagrams*

Equipment Lists

It is important to have equipment lists for the building's main energy consuming systems, including controls, HVAC, terminal equipment, duct and piping fabrication, and electrical systems. Typically, the lists contain the following information for each piece of equipment:

- Unique equipment identification number and name such as AHU-2
- Nameplate information including model and serial numbers
- Manufacturer's name
- Vendor's name and contact information
- Equipment location
- Date installed

O&M Manuals

In general, *O&M Manuals* must be detailed enough to help building staff operate, maintain and troubleshoot equipment. In order for the staff to use them effectively, the information they contain must be well-organized. To increase usability, an index and table of contents should be included. It may also be helpful to organize the manuals by system rather than by

Recommended *O&M Manual* Contents

- Installing contractor contact information
- Product data
- Test data
- Performance curves (for pumps, fans, chillers, etc.)
- Installation instructions
- Start-up procedures
- Sequences of Operations
- Preventive maintenance requirements
- Parts lists
- Troubleshooting procedures specific to the equipment design and application
- Equipment submittals
- Design documents
- Control strategies
- Copies of commissioning tests, if applicable
- Copy of TAB report
- Warranty information

specification. At a minimum, *O&M Manuals* typically include:

- Performance curves (for pumps, chillers, fans, etc.)
- Operation requirements
- Preventive maintenance requirements
- Parts lists
- Start-up procedures
- Troubleshooting procedures

If a building already has good, up-to-date *O&M Manuals*, then they only need to be modified to include any changes to equipment or operations that are made as part of the retrocommissioning project. If the existing *O&M Manuals* are not complete enough to support effective O&M of the existing equipment, the owner should consider including a task in the retrocommissioning scope to improve them.

Control System Documents

Points Lists

Both for control and monitoring purposes, it is helpful to have a full and complete *Points List* that includes all the input and output points in the control system. This list should include information such as the point name (adhering to a consistent and clear naming convention), point type, sensor or actuator type, accuracy, name and type of the associated component, the panel in which it is attached, alarm limits, and trending frequency. A system diagram showing the actual location of the points is essential.

Documenting the trending procedures and capabilities helps to streamline trending and can avoid hours of frustration trying to match point names to their locations. Any changes made to the *Point Lists* as part of the retrocommissioning process should be recorded promptly. Calibration efforts should also be recorded.

Sequences of Operation

Sequences of Operation help building staff understand how the control system should operate. At a minimum, a detailed *Sequences of Operation* should be created for each

!

The *Control System Design Guide* is an excellent resource for point selection. It discusses the types of sensors that can be used, and considerations that must be made in their use. It also provides a sample point list for a range of common HVAC system types, including recommended accuracies and sampling rates. http://www.peci.org/ftguide/csdg/CSDG.htm

Another excellent reference is the *Specifications Guide for Performance Monitoring Systems*, developed for the California Energy Commission's Public Interest Energy Research Program. This document recommends points to be included for basic, intermediate, and advanced monitoring of buildings, using specification language that can be adapted and inserted into system specifications. http://cbs.lbl.gov/performance-monitoring/specifications/

HVAC and lighting system. In many cases, the original sequences were programmed into the EMCS but never put in writing, or if they do exist in writing, lack sufficient detail to help building staff understand how the controls are integrated within and among systems.

After a retrocommissioning project, any changes to the sequences should be carefully documented and the reasons for all changes should be described in detail. Improvements are more likely to persist when operators understand the rationale for the changes and agree with their implementation. Any control sequences that were not affected by the retrocommissioning project and are found to be incorrect or poorly documented should be corrected as a part of the retrocommissioning scope.

System Diagrams

A *System Diagram* enables the user to see the entire process of heating, cooling, and ventilation of spaces and visualize potential interactions. It depicts the entire system in schematic format, often called one-line diagrams.

These one-line diagrams are typically produced during the initial part of the investigation process to help the commissioning team better understand how the various systems are laid out and whether the current building documentation is correct. Also, a system diagram laid out in the simplest way possible goes a long way in clarifying the intended operation of the entire system and helps to identify possible errors that occurred during the construction of the system. Once completed, the system diagram can be incorporated into the control system operator workstation.

System Diagrams

As an example, a well-developed air handling system diagram includes the following features:

- The system's complete airflow path is shown, from point of entry into the building to point of exit
- All significant components are labeled, including dampers, coils, filters, fans and all final control elements and sensors
- Equipment operating parameters are stated, including flow ratings, horsepower ratings and other pertinent operating data

5

Building Staff Training

Training is perhaps the most essential factor in good O&M practices. Unless operators and managers have the right knowledge and skills, it will be impossible for the building to perform optimally over time.

When the building operating staff is part of the commissioning team, they should be involved in all phases of the retrocommissioning process, starting during planning. Assisting throughout the process provides invaluable on-the-job training. At the end, the entire building staff should understand the measures that were implemented and participate in any training session provided by consultants, vendors or contractors on the changes and improvements stemming from retrocommissioning

A well-designed training plan supported by comprehensive building documentation and videotapes of the training sessions will help ensure that the building is operated efficiently and that the benefits associated with the retrocommissioning process persist for the life of the building.

Perhaps the most common training opportunity lies in understanding and using the trending and alarming functions of the control system. The wide gap between the capabilities of these complex systems and the ability of building operators to fully utilize them leads to missed opportunities in both the early identification of building problems and significant energy savings. For example, trends and alarms can be set in the control system but unless the staff responsible for the EMCS are trained on how to retrieve and analyze the data and review alarm logs, the owner isn't getting the most out of their system.

Recommended Hand-off Training Topics

- Energy usage analysis
- Operating schedules & *Owner's Operating Requirements*
- Investigation process & methods used to identify problems and deficiencies
- *Master List of Findings*
- Measures that were implemented and by whom
- Describe improved performance that these measures will create (show before and after trends if applicable).
- O&M requirements needed to keep these improvements working
- Staff role in helping to maintain the persistence of savings

As part of hand-off, it is also useful to walk around the building to look at any physical changes or step through the new control sequences at the operator workstation.

Ongoing Training

A work environment that provides high-quality operator training and time to study how to optimize building operation is most likely to maintain a high level of building performance, year after year. Building operators should be encouraged to increase their knowledge and enhance their job skills by taking readily available training courses offered by utility energy centers, training organizations, and equipment manufacturers.

Ongoing Training Opportunities

Building Operator Certification (BOC)

The BOC trainings are designed specifically to help building operators improve their ability to operate and maintain comfortable, efficient facilities.

BOC courses are offered at two skill levels and cover several topics, including electrical, HVAC and lighting systems, indoor air quality, environmental health and safety, and energy conservation. Classes are usually a combination of lecture, discussion and small group activities. BOC classes are held continuously, at locations across California.

Course schedules and descriptions are available at the BOC Web site: www.theboc.info

Utility Customer Training Centers

California's investor-owned utilities and municipal utilities have customer training centers to educate their customers on matters related to smart energy use. Their workshops and seminars are constantly changing, and often include training related to building operations and commissioning.

Pacific Gas & Electric Company
Pacific Energy Center (PEC)
San Francisco, CA
www.pge.com

Sacramento Municipal Utility District
SMUD Customer Service Center
Sacramento, CA
www.smud.org

Southern California Edison
Customer Technology Application Center (CTAC)
Irwindale, CA
www.sce.com

San Diego Gas & Electric
Events and Training
San Diego, CA
http://www.sdge.com/training/

Southern California Gas Company
Energy Resource Center (ERC)
Downey, CA
http://www.socalgas.com/business/

A system should be in place to transfer information to new operators as they come on board. As part of their orientation, a new operator should go on an in-depth building walk-through with an experienced building operator, as well as review up-to-date building documentation.

Preventive Operations & Maintenance

Redefining preventive maintenance to include operational activities is a critical strategy for long-term energy-efficient performance.

Typically, the primary goal of a preventive maintenance (PM) program is to improve reliability and increase equipment life. In many buildings, staff implement rigorous maintenance-focused programs. However, even when equipment is meticulously maintained, operation that relies on inadequate control strategies or improper scheduling can result in significant energy waste, equipment failures, reduction in the useful life of equipment, and poor indoor air quality.

Owners can enhance PM goals by incorporating procedures that promote efficient operation, empowering staff to take steps to maintain optimization, and supporting them with good documentation and training.

Incorporating Operations into Your Maintenance Plan

A typical PM plan consists of a checklist of maintenance tasks and a schedule for performing them. The checklists are kept for each piece of equipment and updated after maintenance tasks are performed. Incorporating operations into the current maintenance plan entails similar rigor for recording setpoints, settings, and parameters for the control strategies. It also means that operators regularly review and update the *Owner's Operating Requirements* as occupancy or operational changes are made and continuously ask questions such as:

- Have occupancy patterns or space layouts changed?
- Have temporary occupancy schedules been returned to original settings?

! Putting the "O" back in O&M

Consider how poor maintenance adversely affects operational performance. Likewise, poor operation practices can increase the amount of maintenance required to keep equipment running.

Putting the "O" Back in O&M, 1999. O&M Best Practices Series, US Environmental Protection Agency and US Dept. of Energy.

! Resources

More information on service contracts can be found in *Operation and Maintenance Service Contracts: Guidelines for Obtaining Best-Practice Contracts for Commercial Buildings*, one of seven volumes in the US Environmental Protection Agency and US Dept. of Energy funded O&M Best Practices Series. All seven are available in the CCC library: www.resources.cacx.org/library/.

- Have altered equipment schedules or lockouts been returned to original settings?
- Is equipment short-cycling?
- Are time-clocks checked monthly to ensure proper operation?
- Have any changes in room furniture or equipment adversely affected thermostat functions?
- Are new tenants educated in the proper use and function of thermostats and lighting controls?

In all, a preventive O&M plan differs from a typical PM plan in that it calls for periodically checking operational and control issues and investigating issues that affect efficiency. To facilitate this, a reference list of operational parameters and the building's adjustable settings can be developed to help monitor and maintain the proper settings for the facility. The commissioning team can be tasked with developing this list, or as part of the retrocommissioning scope of work.

The *Preventive Operations and Maintenance Plan*

A *Preventive Operations and Maintenance Plan* contains the following information for each piece of equipment on the equipment list:

Operations information

- Parameters for normal operation
- Settings and setpoints for the control strategies
- Alarm limits for different operating modes

Maintenance information

- Expected equipment life
- Expected efficiency
- Maintenance schedule
- Maintenance task descriptions
- Forms for collecting and documenting required information

! Outsourced Preventive Maintenance

When building staff is not available or trained to perform maintenance tasks, owners may have a maintenance service contract in place with an equipment vendor, installing contractor, or a maintenance service contractor. Most companies providing service contracts focus on maintenance of equipment, and building owners and managers need to specifically request requirements that address operating issues in service contracts.

If included in the *Retro-commissioning Plan*, the commissioning team can review any existing service contracts and make recommendations on how to enhance the current level of service to address efficient operation.

Performance Tracking

Tracking building performance helps building operators detect and diagnose problems early, before they lead to tenant comfort complaints, high energy costs or unexpected equipment failure. In fact, problems in today's buildings may be impossible to detect without performance tracking.

There are three important strategies for performance tracking: benchmarking, utility tracking, and performance monitoring. Each of these strategies is a common task in a retrocommissioning project and, therefore, is an opportunity for the building staff to learn and perform activities and then continue to implement them. These strategies are especially important in monitoring and maintaining the measures implemented as a result of the retrocommissioning process beyond the project's end.

Benchmarking

Benchmarking is a way for building owners and operators to track their building's energy use over time and compare it to other similar buildings. Owners of multiple buildings can use benchmarking to compare similar buildings in their portfolio and prioritize improvements.

Several online resources are available to help with building benchmarking. Two of the most comprehensive and widely applicable are ENERGY STAR® Portfolio Manager and the Cal-Arch Building Energy Reference Tool.

ENERGY STAR® Portfolio Manager

This web-based tool uses the energy bill data and building characteristics supplied by building staff to rank the building compared to other, similar buildings. When it compares buildings, Portfolio Manager takes into account factors that are outside the control of the building staff, like climate, occupancy level, hours of operation and space use. Buildings scoring 75 or higher can apply for the ENERGY STAR label.

Additionally, buildings seeking LEED-EB certification must be benchmarked using

! Choosing from a Portfolio of Buildings

Many buildings are owned or managed by government agencies, investment trusts or property management firms, all of which have diverse building portfolios. These organizations are prime candidates to undertake retrocommissioning because their broad holdings allow them to develop an organization-wide plan for retrocommissioning and then strategically screen and select projects. In these cases, an owner may choose to implement a screening plan for all of their facilities to support development of a multi-year plan. Any such screening would begin with benchmarking the different buildings' performance.

the ENERGY STAR Portfolio Manager tool and achieve a rating of at least 60%.

Portfolio Manager is a widely used building benchmarking tool. It was developed by the U.S. Environmental Protection Agency (EPA) and since 1999 approximately 12% of the total building market has been benchmarked using this tool.

Cal-Arch Building Energy Reference Tool

This web-based tool shows how a building's energy use per square foot compares to other California buildings. Unlike Portfolio Manager, Cal-Arch only requires the size of the building and the amount of energy it uses. As a result, Cal-Arch can be faster and easier to use than ENERGY STAR, but it does not take into account the effects of parameters like weather and occupancy on energy use.

Utility Tracking

Utility tracking and troubleshooting are key elements in ensuring long-term building performance. Where benchmarking compares utility consumption against other buildings, utility tracking measures the building's energy use over time and helps staff understand the building's energy consumption patterns. By tracking performance over time, facility managers and building operators can spot emerging problems before they cause occupant discomfort or premature equipment failure. There are a host of energy accounting software tools available. Utility tracking can also be automated using an Energy Information System (EIS).

Benchmarking Tools

ENERGY STAR® Portfolio Manager
www.energystar.gov/benchmark

Lawrence Berkeley National Laboratory Cleanroom Benchmarking
http://ateam.lbl.gov/cleanroom/benchmarking/

Oak Ridge National Laboratory Benchmarking
http://eber.ed.ornl.gov/commercialproducts/cbenchmk.htm

Cal-Arch Building Energy Reference Tool
http://poet.lbl.gov/cal-arch/

! Resources

Energy Information Systems (EIS) can be used to harvest the data from a control system, and perform powerful analysis and reporting. For more information, go to the California Commissioning Collaborative's on-line library (www.resources.cacx.org/library/):

Motegi, Piette, Kinney, and Dewey, 2003. *Case Studies of Energy Information Systems and Related Technology: Operational Practices, Costs, and Benefits.* Public Interest Energy Research (PIER).

"A well-run building should be re-commissioned every three to five years. After completing 41 energy and related conservation projects at Adobe's headquarters buildings and realizing savings of just under $1 million per year, we recommissioned three buildings and discovered another $273,000 in savings!"

- George Denise
General Manager for Facilities,
Cushman & Wakefield at Adobe Systems Incorporated

Adobe Towers
San Jose, CA
To read the case study, visit
http://www.fyp.org/

Performance Monitoring

The data handling capabilities of control systems allow building staff to "listen" to the building by supplying data on building operations over time. In order to be useful, a control system must have enough memory to trend and archive data. It is also important to understand how the system stores data. Are they automatically downloaded to a hard drive, or does this process need to be scheduled?

Without analysis capabilities, however, the data will be useless. When building staff are not familiar with the trending capabilities of the control system, or unable to set up trends and retrieve collected data, it may be helpful to bring the control vendor or commissioning provider onsite to train at least one or two building operators on the topic.

Data collection is just the first step. Staff should also be trained on how to analyze and interpret the data. To assist the staff responsible for this, important metrics can be defined and evaluated and illustrative diagnostic charts can be "canned" to allow collected data to be reviewed in the most informative format to diagnose particular problems.

If it is part of the *Retrocommissioning Plan*, a skilled commissioning team member can set up "smart alarms" in the control system. Smart alarms can look at concurrent values of several variables or compare variables to limits that depend on the operating mode. Operators should be trained on what the alarm conditions signify, how to respond to these alarms when they are triggered, how to set up their own alarms, and how to refine alarms to avoid irritating and distracting false alarms.

Recommissioning Plan

Periodic recommissioning helps maintain the benefits of the original commissioning or retrocommissioning process.

Ideally, a plan for recommissioning is established as a part of the retrocommissioning process and is presented along with the *Final Report* during the hand-off phase of the project.

The need for recommissioning depends on several things: changes in the facility's use, quality and schedule of preventive maintenance activities, and the frequency of operational problems. In California, recommissioning is required of all state buildings of more than 50,000 square feet on a recurring five-year cycle, or whenever major energy consuming systems or controls are replaced.

Recommissioning is similar to retrocommissioning, although it is less expensive since some of the difficult data collection and documentation tasks were accomplished during the original project and need only to be revalidated. Recommissioning typically begins with a review of the *Owner's Operating Requirements* to determine if there have been any changes. When changes have occurred, systems are reviewed to determine if corresponding changes in equipment or operations are necessary. Next, systems are inspected and any issues are recorded in a *Recommissioning Master List of Findings*.

Functional performance tests and trend logs may be used to determine if the systems are still operating as intended. Minor system improvements may be implemented during recommissioning, while others may require more significant design, scheduling and budgeting. The building documentation is also reviewed to determine if updates or trainings are required. Finally, the *Owner's Operating Requirements* document is updated to reflect any changes in building systems and functions.

Although a third-party may have led the original retrocommissioning activity, building staff can lead the recommissioning effort, if they have the time, resources, and ability. One of the real advantages of involving building staff deeply in the original retrocommissioning effort is the experience they gain for performing subsequent recommissioning projects.

Time to Recommission?

Positive answers to two or more of the following questions indicates that it may be time to recommission:

- Is there an unjustified increase in energy use? Is energy use more than 10% higher than previous years?
- Have comfort complaints increased compared to previous months or years?
- Has nighttime energy use increased?
- Is building staff aware of problems but without the time or in-house expertise to fix them?
- Has control programming been modified or overridden to provide a quick fix to a problem?
- Are there frequent equipment or component failures?
- Have there been significant tenant improvement projects (build-outs)?
- For State of California buildings over 50,000 square feet: Has it been five years or more since the previous recommissioning process? Have any major energy consuming systems or controls been replaced recently?

5

"The notion of Monitoring-Based Commissioning (MBCx), or continuously commissioning buildings in operation, should be the cornerstone of every corporation's energy policy, program, and plan."

Len Pettis
Chief of Plant Energy and Utilities
California State University

Continuous Commissioning® and Monitoring-Based Commissioning (MBCx)

Continuous Commissioning® and Monitoring-Based Commissioning are two processes that use retrocomissioning techniques. They are distinct from retrocommissioning in that they install extensive metering that is left in place to provide ongoing commissioning and help ensure persistence of benefits.

In Continuous Commissioning® (practiced by the Energy Systems Laboratory of Texas A&M University), third-party commissioning providers work closely with building staff to commission major pieces of equipment and involve the building staff in selecting and implementing improvements. The providers then commission the entire building, optimizing it to current operating requirements. Monitoring equipment is left in place, and a dedicated third-party analysis staff reviews data to ensure persistence of savings.

Monitoring-Based Commissioning (in a program provided by the University of California and California State University systems, along with California utilities) is similar in that it has an emphasis on involving the building staff and leaving monitoring equipment for ongoing diagnostics. It has an increased emphasis on training of the building staff, and empowering them to use the monitoring through analysis training, automation of diagnostics, and "smart" alarms.

In both programs, ongoing monitoring is used to establish a baseline of appropriate operation. Deviations from that baseline indicate opportunities for ongoing operational improvements and immediate equipment repairs. Recommissioning may still be needed, but it should be required at less-frequent intervals, and should be much more tightly focused due to the availability of trained staff and monitored data.

6. Getting Started

So how does an owner or building manager get started with retrocommissioning? There are a few key steps that will help get a new retrocommissioning project off to a strong start:

Become informed about retrocommissioning

Explore the resources listed in this guide, explore online resources, and begin talking to others about their experiences with retrocommissioning.

Determine if your building is a good candidate for retrocommissioning

While most buildings can benefit in some way from retrocommissioning, some buildings are better candidates than others. There are several indicators, discussed in Chapter 4 of this guide, that may predict a project's success and increase its cost-effectiveness. If you have a portfolio of buildings, consider starting with one or two buildings to demonstrate the benefits.

Determine what local, utility, and government resources are available

More and more frequently, utilities are offering programs for existing buildings that target O&M measures. Contact utility representatives and government agencies to learn about the incentives they offer for existing building commissioning and other energy efficiency products and services.

Determine what budget is available

Understanding how your organization allocates funds for maintenance expenditures and capital improvements may reveal sources of funding for retrocommissioning that would have gone unused or been spent on other projects.

Develop a plan for commissioning your portfolio of buildings

For owners or managers of multiple properties, a multi-year, organization-wide strategy may be useful when implementing retrocommissioning. Developing a strategy helps to prioritize projects and develop a plan that will address as many

"Incorporating green building practices saves energy and money. We achieved a ten percent energy usage reduction at our San Ramon Valley Conference Center after installing a control system that efficiently uses energy only where it is needed."

Robert Harris
Vice President of
Environmental Services
Pacific Gas and Electric
Company

buildings as possible. An owner may choose to select the most cost-effective projects first, providing funding and justification for implementing the additional projects in subsequent funding-cycles. Or, owners may "bundle" multiple buildings into one project—including both highly cost-effective and less cost-effective buildings into one reasonably cost-effective package. This will ensure that retrocommissioning can occur in as many buildings as possible while meeting the organization's overall cost-effectiveness requirements.

Obtain buy-in from members of the organization

Consider giving a presentation on retrocommissioning or inviting a commissioning expert to come explain its benefits to staff and decision makers. Identify any decision-makers in your organization who may need convincing and be sure they are present.

Build a team

It is important to hire or assign one individual who is responsible for leading the retrocommissioning effort. First, review the qualifications and availability of the in-house staff to fill the leadership role and to understand what role, if any, a third-party commissioning expert should fill. The size and complexity of the project and the availability and skill set of the in-house staff will help determine the extent of services that are needed from an outside commissioning provider. Will the consultant need to lead the project or just be available to perform the more complex data analysis, energy calculations, and provide troubleshooting guidance for complex control issues? Does your ability to obtain funding such as utility incentives require a third-party expert to be involved at some level in the project? The team should at minimum include an in-house "champion" who is enthusiastic about the potential benefits of the process, as well as a high-level stakeholder who can communicate the organization's strong commitment to the retrocommissioning process. Refer to Chapter 3 for more information on the roles and responsibilities of the retrocommissioning team and when and how to hire a third-party commissioning lead.

Become an advocate for retrocommissioning in your organization

If you are in a position of authority, others in your organization will take the lead from you. If you are fully committed to the retrocommissioning process, communicate your expectations and become an active participant. You will achieve maximum benefits and others will recognize the value of retrocommissioning as well.

7. Appendix

Acronyms

ASHRAE	American Society of Heating, Refrigerating and Air Conditioning Engineers
CC®	Continuous Commissioning®
Cx	Commissioning
CxP	Commissioning Provider
EMCS	Energy Management and Control System
GSA	General Services Administration
HVAC	Heating, Ventilation and Air-conditioning
IAQ	Indoor Air Quality
IEQ	Indoor Environmental Quality
LEED®	Leadership in Energy and Environmental Design
MBCx	Monitoring-Based Commissioning
M&V	Measurement and Verification
O&M	Operations and Maintenance
OOR	Owner's Operating Requirements
PM	Preventive Maintenance
RCx	Retrocommissioning
ReCx	Recommissioning
RFP	Request for Proposals
RFQ	Request for Qualifications
TAB	Testing, Adjusting, and Balancing

Glossary

Building Commissioning (Cx)
A systematic quality assurance process that spans the entire design and construction process. Building commissioning helps ensure that a new building's performance meets owner expectations by verifying and documenting that building systems and components are planned, designed, installed, tested, operated, and maintained to meet the owner's requirements.

Building Owner
Often the word "owner" can refer to a number of different actors in a building. In this document, the term "owner" refers to whoever makes the decisions regarding the building's facilities.

Commissioning
See Building Commissioning.

Commissioning Lead
The person who coordinates the retrocommissioning process. This can be either a third-party Commissioning Provider or an experienced in-house staff member.

Commissioning Provider (CxP)
A third-party individual or firm under contract to serve as the Commissioning Lead on a project.

Continuous Commissioning® (CC®)
A continuation of the commissioning process well into the occupancy and operations phase to verify that a project continues to meet current and evolving owner's requirements.

Data logger
A stand-alone electronic data gathering device that utilizes sensors to collect information over time. Data collected could include temperatures, pressure, current, humidity, or other operation information.

Diagnostic Monitoring Plan
A plan developed by the commissioning team for control system trend logging and portable data logging.

Findings Log
See *Master List of Findings*.

Functional Tests/Testing
Tests that evaluate the dynamic function and operation of equipment and systems using manual or automated monitoring methods and either passive observation or active testing of operation. Functional testing is the assessment of the system's ability to perform within the parameters described in the design.

Implementation Plan
A document prepared by the commissioning team to provide guidance or a scope of work for implementing measures identified during the investigation.

Indoor Air Quality (IAQ)
The characteristics of the air in the indoor environment, including gaseous composition, temperature, relative humidity, and airborne contaminant levels.

Indoor Environmental Quality (IEQ)
Encompasses all aspects of the indoor setting, including air quality, thermal comfort, lighting, and noise.

Maintenance Tune-Up
A systematic process that includes conditions assessment and the implementation of maintenance measures that have not been completed during the regular maintenance schedule.

Master List of Findings
A summary list of findings generated during the investi-gation process. For each finding, the list contains the following fields: finding description, type of equipment, recommended improvement, estimated energy savings and costs, simple payback, recommendations, and status of implementation. This is also known as the *Findings Log*.

Owner's Operating Requirements (OOR)
A document that details the facility's operating requirements including operating hours, process and equipment status during off-times, and requirements and limitations for temperature, humidity or air filtration.

O&M Manuals
Written documents that provide all the information necessary for operating and maintaining installed equipment.

Recommissioning (ReCx)
An application of the commissioning process to a building that has already been commissioned. Recommissioning may be scheduled or triggered by a change in building use, operational problems, a change in ownership, or other needs.

Recommissioning Plan
A document containing all the information required to recommission the facility. The plan may include specific tasks, their descriptions, and schedules. Other information that may be helpful includes operational requirements for key systems, functional tests, and documentation templates.

Request for Information (RFI)
A request made by contractors to designers to clarify details in the design.

Retrocommissioning (RCx)
Retrocommissioning is a systematic method for investigating how and why an existing building's systems are operated and maintained, and identifying ways to improve overall building performance.

Retrocommissioning Plan

A document that defines the project's objectives, scope, schedule, documentation requirements, and the roles and responsibilities of team members.

Retrocommissioning Team

The key members of each party involved with the project designated to provide insight and carry out tasks necessary for a successful commissioning project. Team members may include the commissioning lead, building owner or owner's representative, building staff, design professionals, contractors or manufacturer's representatives, testing specialists and the LEED coordinator.

Sequences of Operations

A narrative describing how the mechanical, electrical, energy management, and control systems are intended to operate during start-up, shut-down, unoccupied, manual, fire, power failure, security lock-downs, and other modes of operation.

Systems Manual

A system-focused composite document that includes the O&M Manuals and additional information of use to the owner and building staff in operating and maintaining the facility. This document is not typically part of a new construction project unless specified.

Test Protocol

A test form that describes exactly how a particular test will be carried out. It includes documentation of such things as required equipment, precautions, detailed procedural steps, and procedures for returning to normal.

Commissioning Resources

Look for quick reference icons in this section to indicate the following:

Training (T) Certification Program (C) Guidelines (G)

www.commissioning.org

(T) (C) (G)

AABC Commissioning Group (ACG)

A non-profit association of certified commissioning authorities, in conjunction with the Associated Air Balance Council (AABC), dedicated to the advancement of professional, independent commissioning services through education, training, and certification of qualified architects and engineers.

www.aceee.org

American Council for an Energy Efficient Economy (ACEEE)

The American Council for an Energy Efficient Economy website includes a section on commercial building performance with links to technical and programmatic resources.

www.ashrae.org

(T) (G)

American Society of Heating Refrigeration and Air Conditioning Engineers (ASHRAE)

The American Society of Heating, Refrigerating and Air-Conditioning Engineer's website offers commissioning guidelines, links, research, tools, and recommendations.

www.aeecenter.org

(T) (C) (G)

Association of Energy Engineers (AEE)

AEE is a source for information on energy efficiency, utility deregulation, facility management, plant engineering, and environmental compliance. AEE offers a range of information outreach programs including technical seminars, conferences, books, local chapters, and certification programs.

www.bcxa.org

T C G

Building Commissioning Association (BCA)

An organization of commissioning professionals, the BCA website offers publications, templates, training announcements, an e-newsletter, and an online discussion forum. The BCA also offers the Certified Commissioning Professional designation.

www.theboc.info/ca

T C

Building Operator Certification (BOC)

The BOC is a nationally recognized training and certification program for building operators, designed specifically to help them improve their ability to operate and maintain comfortable, efficient facilities.

www.cacx.org

T G

California Commissioning Collaborative (CCC)

The CCC is a non-profit organization dedicated to supporting building commissioning in California. Their website offers case studies, sample documents, a provider list, information on selecting a provider, a searchable library of Cx documents, a quarterly newsletter, and training and meeting announcements.

www.dsa.dgs.ca.gov

California Department of the State Architect

California's policy leader for building design and construction offers web resources such as commissioning and sustainability information and state codes and regulations.

www.energy.ca.gov/greenbuilding

California Green Building Initiative, State of California Executive Order S-20-04

The Executive Order sets a goal of reducing energy in state-owned buildings by 20% by 2015 and encourages the private commercial sector to set the same goal. The website provides the latest information and links to related websites.

www.chps.net

T G

Collaborative for High Performance Schools (CHPS)

As an organization whose goal is to facilitate the design of California schools that are healthy, comfortable and energy efficient, their website offers information on high performance schools, training and event announcements, and downloadable publications.

www.energydesignresources.com

G

Energy Design Resources (EDR)

The website is a palette of energy design tools and resources for energy-efficient design and construction. It features *Cx Assistant*, a web-based tool that provides project-specific building commissioning information to design teams, helps users evaluate probable costs and appropriate scope, and provides access to sample commissioning specifications.

www.energysmartschools.gov

T G

Energy Smart Schools

A program affiliated with the Department of Energy's Rebuild America, focused on high-performance schools. It has a strong emphasis on commissioning within the climate-specific Energy Design Guidelines for High Performance Schools.

www.energystar.gov

G

ENERGY STAR®

A US Environmental Protection Agency -sponsored program to help individuals and businesses achieve superior energy efficiency, whose website contains energy advice and building energy benchmarking tools.

www.eere.energy.gov/femp/operations_maintenance/

G

Federal Energy Management Program (FEMP)

The website offers information, tools, and recommendations on a wide variety of energy efficiency topics, including equipment procurement, new construction/retrofits, operations and maintenance, and utility management.

It is targeted towards federal facilities but useful for any building owner.

www.fypower.org

Flex Your Power

The website for California's state-wide energy efficiency marketing and outreach campaign contains comprehensive information on available rebates, grants, and loans, product guides, educational opportunities, and resources for new and existing buildings.

http://eetd.lbl.gov/

Lawrence Berkeley National Laboratory (LBNL)

The Building Technologies department, within LBNL's Environmental Energy Technologies Division, performs research and development leading to better energy technologies and reduction of adverse energy-related environmental impacts. Their High Performance Commercial Building Systems program has an emphasis on integrated commissioning and diagnostics, and has many publications related to commissioning.

www.nemionline.org

T C

National Energy Management Institute (NEMI)

Affiliated with the Sheet Metal and Air Conditioning National Association, NEMI provides training for commissioning and related technical matters, and certification of HVAC professionals.

www.nebb.org

T C G

National Environmental Balancing Bureau (NEBB)

NEBB exists to help architects, engineers, building owners, and contractors. They establish and maintain industry standards, procedures, and specifications for work in its various related disciplines.

www.pge.com/pec

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Pacific Gas & Electric (PG&E) Pacific Energy Center (PEC)

Pacific Gas & Electric Company's educational center in San Francisco features educational programs, tool lending library, and services. Their website includes energy information and class schedules.

www.peci.org

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Portland Energy Conservation, Inc. (PECI)

PECI helps transform markets through education and incentive programs that build demand for more efficient products and services. PECI's Resource Library contains several well used commissioning resources, including the Model Plan and Guide Specifications, Functional Testing Guide, Control Systems Design Guide, O&M Best Practices Series, and the Proceedings of the National Conference on Building Commissioning.

www.energy.ca.gov/pier

Public Interest Energy Research (PIER)

PIER offers a portfolio of research, development, and demonstration projects that is administered by the California Energy Commission.

www.rebuildamerica.gov

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Rebuild America

A program of the U.S. Department of Energy, focused on community-based solutions to reducing energy use in existing buildings.

www.smud.org/education/

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Sacramento Municipal Utilities District (SMUD)

The Sacramento Municipal Utility District offers a range of educational resources for energy efficiency education. The website lists workshops and seminars, references, and resources.

www.sdge.com/training

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San Diego Gas & Electric (SDG&E)

The website offers information on training opportunities and seminars for San Diego Gas & Electric customers, including Building Operator Certification courses.

www.sdenergy.org

San Diego Regional Energy Office (SDREO)

A non-profit corporation that provides information, research, and analysis on energy issues for the San Diego region. Their website offers information on programs and incentives, energy technologies, news, training opportunities, events, and policy updates.

www.sce.com/ctac

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Southern California Edison (SCE) Customer Technology Application Center (CTAC)

Southern California Edison's energy learning and demonstration center in Irwindale features six technology centers showcasing energy solutions, a conference center, meeting rooms, and classes. Their website lists class schedules.

http://www-esl.tamu.edu/

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Texas A&M University, Energy Systems Laboratory (ESL)

Texas A&M University's Energy Systems Laboratory is a division of the Texas Engineering Experiment Station. ESL has developed Continuous Commissioning® (CC®), a process that reduces energy consumption and costs in existing buildings while increasing comfort.

http://www.energy.ca.gov/title24/

G

Title 24

Title 24 contains California's Energy Efficiency Standards for Residential and Nonresidential Buildings. The Title 24 website provides links to information on the standard and downloads for current standards and manuals.

www.usgbc.org/LEED

T C G

U.S. Green Building Council (USGBC)

The website offers information on the LEED (Leadership in Energy and Environmental Design) Green Building Rating System, which requires building commissioning for certification.

www.epdweb.engr.wisc.edu

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University of Wisconsin Department of Engineering Professional Development (UW)

The UW's website provides training and certification for commissioning providers. UW offers 300 courses annually in engineering, design, operations, production, management, maintenance, and planning. The Department of Engineering Professional Development also offers on-site courses and distance degrees.

www.cacx.org

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