

California Commissioning Guide: New Buildings





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Acknowledgements

The information in this document is drawn from several existing guides to commissioning: American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE). *Guideline 0-2005, The Commissioning Process* (2005).

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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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California Commissioning Guide: New Buildings



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

This guideline, along with its companion document on retro-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.

Handwritten signature of Jackalynne Pfannenstiel in black ink.

JACKALYNE PFANNENSTIEL
Chairman
Presiding Member, Efficiency Committee
Committee

Handwritten signature of Arthur Rosenfeld in black ink.

ARTHUR ROSENFELD
Commissioner
Associate Member, Efficiency

About this Guide

Building commissioning is a quality assurance process that spans the entire design and construction process, helping ensure that the new building's performance meets owner expectations.

This Guide:

- Describes the building commissioning process. You can read it cover-to-cover, or skip around to find only the information you need.
- Is written for building owners, managers, and operators, but others involved in the commissioning process will also find it useful.
- Answers the following questions:
 - What is building commissioning and why should I implement the process?
 - What are the benefits and costs of commissioning?
 - How do I hire a commissioning lead and integrate them into my existing team?
 - What happens during the commissioning process and how does it relate to design and construction?
 - How will the commissioning process ensure efficient operations at my facility over the long term?
 - How do I get started with commissioning?

Helpful Hints



Indicates a definition. Definitions can be found throughout the text and at the end of the guide in the **Glossary** (p. 63).



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



Indicates an important topic.





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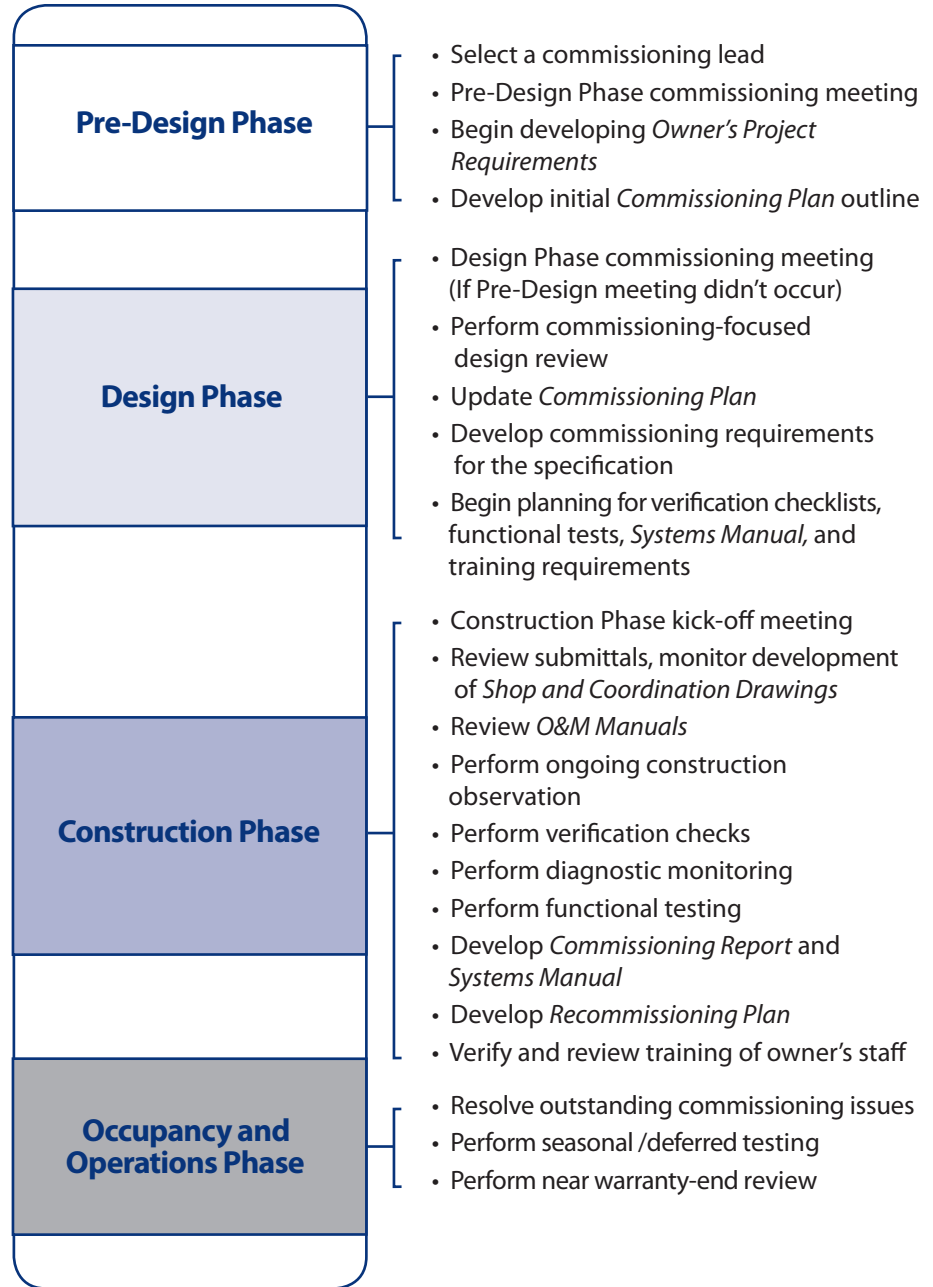
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Commissioning Process Overview



1. Introduction

This chapter introduces the building commissioning process. It answers the questions:

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

d Commissioning (Cx)

Building commissioning, often abbreviated as “Cx,” is a systematic quality assurance process that spans the entire design and construction process, helping ensure that the new building’s performance meets owner expectations.

! Retrocommissioning (RCx)

For more information on retrocommissioning, consult the *California Commissioning Guide: Existing Buildings*, a companion to this publication.

+ More on Recommissioning

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

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 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 as the owner intended and that building staff are prepared to operate and maintain its systems and equipment.

Retrocommissioning is the application of the same process to existing buildings. Retrocommissioning is a process that seeks to improve how building equipment and systems are operating and functioning 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.

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 the steps that can be taken to ensure that retrocommissioning and other efficiency measures last and to ensure the persistence

of their associated benefits. The State of California also requires that all large State buildings receive a United States Green Building Council (USGBC) LEED®-EB rating, which requires retrocommissioning. LEED requirements are discussed in more detail on page 6.

Goals of the Commissioning 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.

The commissioning process is a team effort, usually led by a commissioning lead, who verifies that the building meets the owner's expectations at each stage of the design and construction process. Since each building project is unique, 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 parts of the commissioning process that are included in the commissioning lead's scope of work can also vary. In the scope, the lead typically is engaged to perform the following activities:

Document the building's functional and performance requirements. The commissioning lead works with the owner and design team to ensure that the *Owner's Project Requirements (OPR)* document clearly describes the owner's performance and maintainability criteria. Ideally, this occurs during the design phase of the project. This document is also sometimes called the *Design Intent Document*.

Provide tools and documentation to improve the project team's deliverables. These include *Issues Logs*, which track issues from identification to resolution at each phase of development, and a *Commissioning Report*, which documents the results of inspections and functional performance tests.

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.

d Commissioning Lead/ Provider/Authority/ Agent/Coordinator

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

d Owner's Project Requirements (OPR)

A document that details the owner's functional requirements for a project and expectations for how it will be used and operated. These include project goals, measurable performance criteria, cost considerations, benchmarks, success criteria, and supporting information.

"My experience in the contracting world has made me a believer in commissioning. Commissioning is a process that assures that the design intent is met when the building becomes operational. It has become a critical process because it assures that systems perform as intended, efficiently and dependably. There are no other options to assure a functional and efficient system while focusing on a low first cost. Commissioning is the only answer."

- John Wimer

Chief Operating Officer
National Center for Energy
Management and Building
Technologies

Verify and document that systems perform as specified in the OPR. To ensure that the building will perform as expected, the commissioning lead observes equipment start-up, writes and observes functional testing, verifies that control system calibration and testing, adjusting, and balancing have been performed satisfactorily, and documents these activities.

Verify that the building owner and manager receive adequate and accurate system documentation and staff training. The commissioning lead ensures that these requirements are included in the specifications, tracks their delivery, and may oversee the work of training leads in developing curriculum and conducting training sessions.

Bring a holistic perspective to the design and construction process that integrates and enhances its traditionally separate functions. The commissioning process brings project team members together on a regular basis and encourages the group to work together to solve problems.

Why is Commissioning Important?

In today's complex buildings, systems are highly interactive. Increased system interactivity, together with the nearly universal presence of sophisticated control systems, results in a trickle-down effect on building operations — small problems have big effects on performance.

No matter how carefully a building is designed, if the systems, equipment and materials are not installed and operating as intended, the building will not perform well.

Now more than ever, effective operations require subsystems and components that work effectively and reliably and a building staff with the knowledge and resources to operate and maintain them. But in today's construction environment, project team members are more cost-conscious than ever, and seldom is there adequate budget allocated to quality assurance processes.

The result of this situation? Poorly performing buildings where:

- System and equipment problems result in higher than necessary utility bills.
- Unexpected or excessive equipment repair and replacements due to premature failures 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.

Building commissioning is a proven way to achieve improved building performance. As a process, rather than a set of prescriptive measures, building commissioning adapts to meet the unique needs of each building's owner, design team, and future occupants. When appropriately applied, the process avoids quick-fix solutions and addresses root causes to systematically ensure that building systems operate efficiently, effectively, and reliably, and ensures the improvements persist over time.

As this guide explains, commissioning accomplishes the following:

- Brings the owner's needs and project requirements to the forefront at each phase of the project to ensure that the finished product will meet expectations.
- Improves the building's overall performance by optimizing energy-efficient design features and directly addressing issues like equipment performance testing and system integration.
- Verifies that building staff members are well-trained and possess the documentation they need to operate and maintain the building's systems and equipment after turnover.

"The commissioning provider found dampers that weren't functioning properly and that would not have been found without commissioning. From a LEED compliance standpoint, the commissioning provider found that the mechanical engineer had specified a system with HCFCs, a refrigerant that is prohibited and would have resulted in the projects not being able to qualify for LEED."

- Lesley L. Miles, AIA

President
Weston Miles Architects, Inc.

Commissioning and LEED®

What is the USGBC's LEED® rating system?

The LEED guidelines specify the 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-NC commissioning requirements?

All buildings seeking LEED-NC certification must implement a commissioning process that meets the LEED-NC Rating System guidelines. The LEED-NC guidelines also identify more advanced commissioning tasks that may be incorporated to earn an additional point. Many of the measures that will be incorporated to achieve the level of energy efficiency required for a LEED-NC rating are sophisticated and interdependent. Therefore, commissioning would be advisable even if it weren't required, to ensure that the building performs as well in reality as it did on paper.

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

! What is LEED®?

LEED stands for Leadership in Energy and Environmental Design, a green building rating system 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.

New buildings can receive one of four LEED for New Construction (LEED-NC) ratings: Certified, Silver, Gold, and Platinum.

2. Benefits and Costs of Commissioning New Buildings

The benefits of starting commissioning early in a new building project are numerous. They include construction cost savings, energy savings, improved indoor environmental quality, more effective and efficient building operation, improved coordination among team members during design and construction, a smoother turnover process, and fewer warranty claims. This chapter discusses what a building owner, manager, or operator should expect in benefits as well as costs.

This chapter answers the questions:

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

! Construction Phase Savings

One study of six new construction projects found that commissioning reduced change orders by 87% and contractor call-backs by 90%, thus reducing the total construction cost by an estimated 4% to 9%.

Joy Altwies, "Information from a Commissioning Process Case History," PowerPoint presentation to Energy 2002, Palm Springs, CA.

Commissioning Benefits

Commissioning benefits are far-reaching. Each of the participants in the design and construction process will benefit from commissioning, and so will the building's owner, staff, and future occupants.

These benefits include but are not limited to:

- Construction cost savings
- Improved coordination between design, construction, and occupancy
- Fewer system deficiencies at building turnover
- Energy savings
- Improved indoor environmental quality

Cost Savings: The Benefit of an Early Start

When commissioning starts during the design phase of a new construction project, the result is significant cost savings. Errors caught on paper, rather than on the job site, are much less expensive to fix. Because commissioning identifies and helps resolve potential problems, it reduces costly change orders and contractor call-backs. This in turn helps keep the project on schedule and on budget.

Savings from Commissioning¹

Commissioning can produce significant cost savings in a new building project. Cost savings are usually presented as a range, since actual savings vary depending on the building type, its location, and the scope of the commissioning process. A comprehensive study found the following cost savings ranges:

Description	Range of Values
Value of Energy Savings	\$0.02 - \$0.19/sqft
Value of Non-Energy Savings	\$0.23 - \$6.96/sqft

¹Mills, E., H. Friedman, T. Powell, N. Bourassa, D. Claridge, T. Haas, 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>

Owners who wonder how they will pay for commissioning with a limited design and construction budget should think about transferring construction phase cost savings to the design and commissioning budgets. When construction cost savings are taken into account, commissioning can pay for itself.

Improved Coordination Between Design, Construction, and Occupancy

Commissioning improves communication between all team members. Without clear and frequent communication, there is little chance the new building will meet the owner's expectations. Throughout the project, commissioning tracks and resolves issues, focusing communication on pressing problems. During commissioning meetings, participants are encouraged to consider one another's perspectives while maintaining a consistent focus on the owner's expectations for building performance. This improves the ability of the project team to identify the best long-term solutions for problems, and as a result, ensures that systems function as intended. This can avoid common problems like oversized and inefficiently functioning systems, installation of the wrong equipment, and incorrect programming of the sequences of operation.

As occupancy nears and the number of issues is at its peak, an owner must make important decisions in a short time frame. The commissioning lead helps the owner with these decisions by explaining their consequences and how each choice affects the building and impacts the *Owner's Project Requirements (OPR)*.

Fewer System Deficiencies at Building Turnover

During the last few months before turnover, the project team often focuses its attention on the systems and equipment most critical to obtaining permits and readying the building for occupancy. At this stage it is easy to overlook incomplete or deficient systems, but problems that remain after turnover do not go away without attention.

Deficiencies may go undetected for years, negatively affecting building control, energy use, equipment reliability, and occupant comfort. Some will come to the attention of building staff either through occupant complaints or in the course of

"We find the greatest advantage of commissioning comes because we are long-term residents - we've been here over 100 years and we're here for the long haul. Having a building commissioned properly improves its longevity and the ability of maintenance and operations to care for it throughout its life."

- Bob Vanderwall

Director of Facilities and Bond Projects
South Pasadena
Unified School District

"Our company's estimate for the provision of control systems for a commissioned building is more accurate than for buildings that are not commissioned. On commissioned projects I am thus able to provide a more competitive price."

- Robert Gleeson
President
Alamo Controls

routine maintenance. Others may never be found, causing excessive energy consumption, unacceptable indoor environmental quality, and increased need for maintenance.

Even with proper training and documentation, building staff may not have the time or knowledge to correct these lingering issues, or may only be able to address the symptoms without fixing the underlying problem. When a building has deficiencies that can only be corrected by bringing the contractor back to the site, building staff are often left to coordinate the callback and help resolve the problem.

Commissioning reduces the likelihood that problems will remain after turnover. It helps the project team identify system deficiencies as early as possible and tracks their status until they are corrected. By identifying deficiencies early and using a systematic process to track them, commissioning assists the project team in providing a building that functions properly at turnover.

Energy Savings

More and more building owners want to reduce energy use in their facilities. Building commissioning ensures that the building's systems and equipment, as well as any special energy efficient features, are installed and work correctly.

The commissioning lead ensures that the delivered building realizes the owner's energy efficiency goals. When a new building operates as efficiently as possible while meeting the owner's expectations, commissioning has been successful.

The commissioning process employs several strategies to reduce a building's energy use. Early in the design phase, energy issues are discussed among the project team. In design review, they look for design issues that may lead to inefficient system operation and wasted energy. The commissioning process also identifies places where energy efficiency measures might fail, once they are integrated with the rest of the system.

During construction, the commissioning lead ensures that delivered equipment meets the *OPR*, the designer's plans, and the specifications. The commissioning lead also observes installation to make certain that the equipment is installed, maintainable, and working correctly. Functional testing extends this quality assurance

to establish that building systems work together correctly and perform effectively. For example, during functional testing, commissioning helps resolve controls system programming deficiencies that would result in inefficient operations.

Although it is difficult to quantify energy savings for new buildings without the necessary baseline data, commissioning will ensure that energy efficiency strategies work effectively.

Improved Indoor Environmental Quality

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

Poor indoor air quality can have many causes, including:

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

Incorrect building pressurization can 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 commissioning ensures that pressure differentials between spaces are correct.

Commissioning reduces the risk of indoor environmental quality problems. Many comfort and air quality issues stem from a poorly designed and maintained HVAC system, a problem that commissioning addresses directly through rigorous construction observation, functional tests, and staff training. For example, commissioning can help prevent the growth of mold in the building envelope



Energy Efficiency Goals

Building commissioning is an effective way to meet energy efficiency goals. The State of California has committed to reducing the energy consumption of its buildings by 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 air 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.

by identifying issues that contribute to mold growth during design, catching installation issues during construction before they are covered up by walls or ceilings, testing control algorithms over a range of operating modes, and ensuring that building staff have sufficient training and documentation to effectively manage moisture in the building.

The Cost of Discomfort

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

Reduced Productivity

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

Commissioning Costs

The cost of commissioning is different for each project, and depends on the project's size, complexity, and the scope of the commissioning process.

Commissioning costs are difficult to estimate. There is no standard convention for determining which costs are included in the total cost of commissioning. The commissioning lead's fee is the most obvious cost, but sometimes the costs to other team members who participate in the commissioning process, and the cost of correcting problems identified by commissioning are also counted.

Because it is hard to define precisely, the cost of commissioning is most commonly and accurately presented as a range of potential costs rather than a specific dollar amount. No matter how it is defined, however, the cost of commissioning accounts for only a very small part of the overall construction budget, and an even smaller part of the building's lifecycle costs.

"Over the past 20 years we have tracked the issues identified and resolved through the commissioning process. We find that in a typical project, the owner has recovered the full cost of the commissioning process about 80% of the way through design as a result of eliminated change orders and requests for information, improved system operation, and reduced maintenance."

- Chad Dorgan
Commissioning Provider

Commissioning Costs²

Actual commissioning costs, as reported in a study of 69 commissioning projects

Description	Value or Ranges
Total Cx Cost	\$0.49 - \$1.66/sqft
Cx Provider Fee as % of Total Commissioning Cost	74 - 86%
Provider Fee as % of Total Construction Cost	0.3 - 1.1%
Design Review	18%
Construction Observation	14%
Acceptance Testing	64%
Warranty	4%

²Mills, 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>

It is important to note that when the dollar value of commissioning's benefits are taken into account, the cost of commissioning is often offset by more than 50%. This results from commissioning's ability to reduce a building's net life-cycle costs and its potential to reduce first costs, when commissioning begins early in the design phase of the project.

3. The Commissioning Team

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

This chapter answers the questions:

- Who should be on the commissioning team, and how are responsibilities usually assigned?
- What is the role of the commissioning lead, and who are the different parties that can fill this position?
- How can commissioning lead qualifications be evaluated?
- What is the commissioning lead selection process?
- What commissioning provider certification programs are available?

Possible Commissioning Team Members

- Commissioning Lead
- Building Owner or Owner's Representative
- Building Manager and Staff
- Design Professionals
- Contractors
- Manufacturer's Representatives
- Testing Specialists

The Commissioning Team's Role

The commissioning team does not manage the design and construction of the project. Its purpose is to promote communication among team members, identify and resolve problems early in the process, and document the performance of the building.

Commissioning Team Members and Their Responsibilities

The commissioning team works together to identify and resolve problems early in the design and construction process, and follows them through to their eventual resolution, ensuring that the final delivered building meets the owner's needs.

Clearly defining and documenting the responsibilities of each team member is vital to the success of the commissioning project.

It is important to note that neither the commissioning team nor the commissioning lead manages the design and construction process. Team members are not authorized to direct work, nor accept a building or system. Rather, their purpose is to facilitate communication, resolve issues, and document performance.

Together, the commissioning lead and the owner assign roles and responsibilities to members of the commissioning team. Budgets and special project characteristics will affect the team's structure, and the commissioning lead can help the owner assemble a team that best matches the size and complexity of the project.

Roles and responsibilities are usually outlined at a commissioning scoping meeting, which should occur early in the project and which all team members are required to attend. At this meeting, the owner and commissioning lead describe each team member's responsibilities, as well as the commissioning scope, process, and schedule. These roles and responsibilities are also outlined in the *Commissioning Plan*. Each team member's responsibilities are outlined below. Of course, actual responsibilities will vary.

Commissioning Lead

The commissioning lead can either be a member of the owner's staff, a design professional or contractor, or an independent third-party commissioning provider. They are responsible for leading the commissioning process and planning, scheduling, and coordinating the commissioning activities. In design, the lead

works with the project team to ensure that the owner's expectations for building operations are adequately documented in the *Owner's Project Requirements* and submits comments on the design professionals' submissions, including the *Basis of Design* and the *Design Narrative*. During construction, the commissioning lead visits the job site frequently, documents any deficiencies in an *Issues Log*, attends team meetings, oversees the start-up and functional testing of systems and their components, and verifies that all necessary documentation and training are completed. During occupancy and operations, the lead makes periodic visits to the site, conducts testing that could not be conducted during construction and, if it is in the scope, continues to help the owner and building staff resolve any remaining operational issues.

The Commissioning Lead's Responsibilities

- Organize and lead the commissioning team
- Ensure that the owner's expectations are adequately documented in the *Owner's Project Requirements*, *Basis of Design*, and *Design Narrative*
- Review design submittals
- Assist in documenting the commissioning requirements to be included in the specification
- Prepare and update the *Commissioning Plan*
- Organize and lead commissioning meetings
- Develop and maintain an *Issues Log*
- Observe construction
- Observe and document functional testing
- Verify that the *Systems Manual* is complete
- Review staff training plans and materials, attend sessions, and verify that training is acceptable
- Prepare and submit the final *Commissioning Report*
- Conduct periodic site visits during first year of occupancy, conduct any deferred testing, and serve as a resource to building staff

Building Owner or Owner's Representative

The owner makes crucial contributions to the success of any commissioning process. The owner's primary responsibilities are to support the commissioning



Communication is Key

Members of a design and construction team must communicate clearly and openly in order to accomplish their goals. The commissioning process facilitates good communication by setting clear performance goals and requiring regular meetings among all team members.

team and to clearly communicate expectations about how the building should operate. However, it is equally important for the owner to be a strong advocate for commissioning. This means not only supporting the commissioning lead's responsibility to identify issues, but the rest of the team's responsibility to resolve them. The owner's support enables the commissioning process to proceed more smoothly, correct more building problems, and thus produce greater benefits.

In addition to affirming the roles and responsibilities of the commissioning team, the owner guides the process by clearly articulating the expectations for how the building will operate. These expectations should be well-documented because they serve as the foundation not only for commissioning but for almost every decision to be made during design and construction.

Owner's Responsibilities

- Clearly communicate their expectations for the project
- Hire the commissioning lead
- Assign staff to represent the owner's interests during the commissioning process
- Work with the commissioning lead to determine the scope and goals of the commissioning process
- Review and comment on reports submitted by the commissioning lead
- Approve startup and functional test completion
- Begin including future building staff in the process as soon as possible
- Consider the recommendations of the commissioning lead when directing the construction team or accepting building or systems

Building Manager and Staff

The building's future staff can both contribute to and benefit from the commissioning process. In order to realize these benefits, building staff must be selected and brought to the table as early in the process as possible.

In pre-design, the manager or operator should contribute to the development of the *OPR*. In the final phases of design, the insights of a manager or operator can lead to no-cost changes that significantly improve the staff's ability to

operate and maintain the building. These may include modifications to point naming conventions, alarm messages and graphic layouts of the energy management system. Building staff may also comment on system choices, layout, and other factors that affect maintainability.

By participating in the commissioning process, building staff will gain an understanding of the building's systems and their interactions well in advance of turnover and occupancy. Observing functional tests and participating in trainings provided by the contractors and the commissioning lead will also improve the staff's understanding of equipment and control strategies.

Building Staff's Responsibilities

- Review designs for maintainability
- Participate in periodic site walk-throughs
- Participate in commissioning process meetings
- Observe functional testing
- Participate in training sessions

Contractors and Manufacturers' Representatives

Contractors and manufacturers' representatives construct the facility. They provide, install, start-up, and often test the building's systems and their components. Their commissioning responsibilities are limited, however, to what appears in the specifications.

If it is specified, it will be the responsibility of contractors and manufacturers' representatives to ensure that the completed building systems operate as intended. Their specific tasks usually include working with the commissioning lead to ensure that commissioning milestones are integrated into the construction schedule, conducting performance tests (developed by the commissioning lead) on the systems they install, helping resolve any deficiencies, and documenting system startup. They are also responsible for providing system documentation and training building staff.

Contractor or Manufacturers' Representatives Responsibilities

Commissioning responsibilities must be documented in the specification, or contractors and manufacturers' reps will not be responsible for completing them.

- Attend pre-bid and pre-construction meetings
- Integrate commissioning milestones into the construction schedule
- Supply the commissioning lead with all requested drawings and respond to requests for information and change orders
- Approve and carry out functional testing
- Work with the commissioning team to remedy deficiencies
- Provide documentation for the *Systems Manual*
- Develop and conduct training for building staff

Design Professionals

Design professionals may include the architect, mechanical design engineer, electrical design engineer, or other specialty sub-consultants. The design professionals develop plans and specifications for the building that meet the owner's needs and expectations. Their role in commissioning is to work with the commissioning lead to document the owner's expectations for building operations in the *OPR* document and work with the team to resolve issues that arise during design and construction.

Design professionals' commissioning-related responsibilities may vary, depending on their interests and the owner's needs. During design they respond to issues raised by the commissioning lead and ensure that commissioning is detailed in the specifications. During construction they assist in resolving any construction or operational issues. In complex projects, the design professionals may review commissioning and functional test plans, and may witness some functional tests.

System Specialists

If the design of the project requires special systems, a specialist may be used in the commissioning. These specialists may perform design reviews and construction observation. They may also perform testing. Test results and recommendations

from these specialists should be submitted to the commissioning lead 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.

As discussed earlier in this chapter, the commissioning lead heads up the commissioning team and facilitates the entire commissioning process. They must thoroughly understand the commissioning process and be able to develop the commissioning specifications. The commissioning lead need not 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. Since each project is unique, it is important to select a commissioning lead whose expertise and experience most closely match the project's specific objectives and scope.

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 commissioning projects, the commissioning lead should have experience and up-to-date technical knowledge in the related fields of design, construction and building operations. The lead should also have extensive and recent hands-on field experience in all aspects of the commissioning process. The commissioning lead can employ or partner with technology specialists who have expertise

LEED® Requirements

The commissioning prerequisite in LEED-NC Version 2.2 requires that the commissioning lead be independent of the project's design and construction management, though they may be employees of the firms providing those services. For projects smaller than 50,000 gross square feet, the commissioning lead may include qualified persons on the design or construction teams who have the required experience.

To earn the additional commissioning point, the commissioning lead must be independent of the work of design and construction, not an employee of the design firm, and not an employee of, or contracted through, the contractor.

For both the prerequisite and the additional point, the commissioning lead may be a qualified employee or consultant of the owner.



Evaluating Lead Qualifications

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

1. Evaluate the lead's technical knowledge and experience with similar building systems and problems.
2. Evaluate the lead'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.

in systems with which the lead is not experienced. However, the HVAC and controls systems are so central to commissioning that the commissioning lead should have a good technical knowledge of the fundamentals, design, and operation of the HVAC system and the implementation of controls systems.

Relevant experience

The commissioning lead must have experience troubleshooting commissioned systems. The lead should have served in a similar capacity on at least two other projects with similar needs. In a more complex project, the commissioning lead 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 are also essential. Organizational skills are equally important.

References and sample work products

The commissioning lead should provide references and work products from other, similar commissioning projects.

Objectivity

In all commissioning projects, the commissioning lead should be able to provide an objective and unbiased point of view.

Commissioning Lead Arrangements

The commissioning lead's role can be filled by several different parties. In deciding who will provide commissioning services, building owners and managers have at least four distinct options from which to choose: their own staff, the design engineer or architect, a contractor, or an independent third-party provider.

Owner's Staff

When members of the owner's staff have previous experience in commissioning, or have both expert level knowledge of building systems and the opportunity to receive training in the commissioning process, they can be a highly effective commissioning lead.

Owners that have multiple building projects can build internal commissioning teams to fulfill the commissioning lead role in their facilities.

When the owner's staff serves as the commissioning lead, the lessons learned during the commissioning process can be invaluable in helping sustain building performance. However, owners should carefully consider whether their staff has the time and qualifications to play this role.

Design Engineer or Architect

Some design engineers or architects are qualified to act as the commissioning lead. The design professional's familiarity with the project may speed up the project schedule. However, when one is immersed in a project, it may be easy to overlook issues that may appear obvious to someone with a fresh perspective. It also can be very difficult to review their own work in an unbiased way.

In cases where the design professional also serves as the commissioning lead, the potential for conflict of interest must be addressed. The design firm should present their plan for mitigating any potential problems, and commissioning requirements must be included in the design professional's contract. In this situation, it would be appropriate to have some tasks, like design reviews, performed by an independent third-party consultant.

When employing the design professional as commissioning lead, owners should keep three points in mind. First, commissioning is usually not included in the design professional's fees. Second, not all design professionals have the skills necessary to oversee all aspects of the commissioning process, for example analyzing trends or troubleshooting systems. Third, the owner may have to exercise a higher degree of engagement in overseeing the commissioning activities.

Contractor

Contractors often have the knowledge and capability to test the equipment they install, especially in projects with clearly detailed commissioning requirements. When the contractor serves as the commissioning lead, the potential for conflict of interest should not be ignored. A test engineer may be hired to commission the equipment and report test results directly to the owner. Again, the owner or the design team will have

d Conflict of Interest

A situation in which a person in a position of trust has competing professional and/or personal interests.

"The majority of building owners never realize that their building is not functioning as it should. The function and installation of Mechanical, Electrical and Plumbing systems are examples of systems in which clients are typically not getting what they have paid for. The commissioning process, performed by an independent commissioning provider, is the best way to ensure that the client gets a building that is installed with all the specified components and which functions in accordance with the design intent."

- Richard Puczkowski

Project Executive
Bovis Lend Lease

Independent Third-Party Commissioning Provider

A commissioning consultant hired directly by the building owner and not responsible to, or affiliated with, any other member of the design and construction team.

to exercise more diligence in overseeing the commissioning activities, and a plan for mitigating conflicts of interest should be developed.

Owners should also keep in mind that although contractors may be capable of testing the systems they install, they may not be skilled at testing other equipment or diagnosing system integration problems. Also, complete commissioning requirements are probably not included in the contractor's fee.

Independent Third-Party Provider

An independent third-party commissioning provider is an individual consultant or firm hired directly by the owner. The provider can be contracted through the designer's firm, but a third-party provider should still be solely responsible to the building owner, playing an objective role in ensuring that the project team delivers a building that meets the owner's expectations. The third-party can be a designer or contractor, but should not be on the team delivering the project. This arrangement offers owners the greatest assurance of commissioning lead objectivity.

If choosing a third-party provider, owners should carefully assess their experience commissioning similar projects.

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.

Commissioning Certification Programs

There are at least five organizations that offer commissioning certification programs. Some of the organizations that provide certifications are indicated in the Resources section at the end of this guide. Each has its own set of requirements and gives a different title to the providers it certifies. Some certifications require the applicant to pass a test, while others require a demonstration of suitable experience with commissioning projects. Some are focused on commissioning process issues, while others are more focused on technical competence. The California Commissioning Collaborative offers a comprehensive and up-to-date comparison of provider certification programs at www.cacx.org.

It is important to remember that certification is not a substitute for relevant experience. Owners should carefully evaluate the commissioning lead's qualifications, regardless of whether they are certified.



Sample Documents

Sample RFP documents are available for download at the CCC website: www.cacx.org.

4. The Commissioning Process

Commissioning begins in pre-design and lasts throughout the construction process. Commissioning activities usually conclude during a building's occupancy and operations period. In a sense, however, commissioning never ends. Even after occupancy, periodic recommissioning is necessary to maintain the building's level of performance.

This chapter answers the following questions:

- What are the phases of the commissioning process?
- What are the steps in preparing for a project?
- What kind of documentation is typically developed during a commissioning process?
- What roles do trending, data logging, and functional testing play in commissioning?
- Who typically defines and carries out a functional test?



Sample Documents

Documentation is a cornerstone of the commissioning process. To facilitate preparation of this documentation, there are many sources for sample documents and templates.

Cx Assistant is a free, web-based tool that helps owners and designers choose the appropriate range of commissioning services for their project. *Cx Assistant* outlines three types of commissioning projects and provides sample documents for each.

Cx Assistant was developed by Energy Design Resources, the educational component of Savings By Design, a statewide new-construction energy efficiency program in California.

Additionally, various organizations such as ASHRAE, BCA, NEBB, ACG and CCC all make sample documents available.

The Commissioning Process

There is no one-size-fits-all approach to commissioning, since every building project is unique.

This chapter describes the typical commissioning activities during each phase of the building project; pre-design, design, construction, and occupancy and operation. It is important to note that the commissioning process must be adapted to meet the needs of each individual building project.

During all phases of commissioning, the commissioning lead will interact with several members of the design, construction, and operations teams. In order to get the full benefit of commissioning, it is very important to establish a clear process for sharing information early in the process.

Pre-Design

Pre-design activities are critical to the success of the project. They build a strong foundation for both commissioning and construction activities.

During pre-design the commissioning lead helps develop the *Owner's Project Requirements (OPR)*. This important document will guide the design, construction, and operations of the future building.

Select a Commissioning Lead

During pre-design, the building owner works with the architect to establish a vision for the project. Together they determine how the building will look and function. This is the ideal time to select a commissioning lead.

Pre-Design Phase Deliverables

- *Owner's Project Requirements* document
- *Commissioning Plan* outline listing design phase activities

The commissioning lead has many responsibilities. They ensure that the project team members understand their role in the commissioning process. The lead fosters communication and promotes a positive, team-based approach to problem solving.

A well-qualified commissioning lead has a depth of troubleshooting and problem solving experience, and the diagnostic monitoring, testing, and analysis expertise needed to uncover potential problems and select the most cost-effective solutions. Bringing the lead into the project early has several advantages:

- Architects and design engineers will find it easier to implement the lead's suggestions when they are received during pre-design. Pivotal decisions like system selection are often made at this time, and even informal discussions between the commissioning lead and the design team can have a significant impact.
- The lead's attention to the effects of design choices on operations and maintenance practices will result in a building that is easier to operate and maintain.
- The lead's presence as a team member from the beginning increases the likelihood that other team members will recognize and appreciate the value of commissioning.

Hold a Pre-Design Phase Commissioning Meeting

The pre-design phase commissioning meeting helps refine the scope, budget and rigor of the commissioning effort. The commissioning lead organizes and runs the meeting. Participants may include the owner or owner's representative, design professionals, the owner's construction manager, and representatives of the operations staff or future building occupants. Although the commissioning team will evolve over the course of the project, at this meeting the owner and commissioning lead begin to identify each team member's responsibilities and communicate the owner's expectations for building operation.

Develop the Owner's Project Requirements

The *Owner's Project Requirements (OPR)* document details the owner's expectations of how the facility will be used and operated. It describes the building's physical and functional characteristics and sets performance and acceptance criteria.



The responsibilities of the commissioning lead and other commissioning team members are discussed in *Chapter 3: The Commissioning Team*.



d Owners Project Requirements (OPR)

A document that details the owner's functional requirements for a project and expectations for how it will be used and operated. These include project goals, measurable performance criteria, cost considerations, benchmarks, success criteria, and supporting information.

! Developing the OPR

A workshop can be used to develop the *OPR*. A guide to developing the workshop is available at the CCC website: www.cacx.org

The *OPR* is an essential document because it serves as a baseline for decision making throughout the rest of the design and construction process, and will be used by the commissioning lead to evaluate the project's development.

The commissioning lead's primary role in pre-design is to help the owner and the project team document the *OPR*. Developing the *OPR* is a team effort involving the owner, design team, and commissioning lead. There are many ways to divide the responsibilities, and it is essential for owners to clearly specify the role they expect each team member to play.

The level of detail in the *OPR* varies according to the size and complexity of the project, the owner's preferences, and the experience of the design team. At a minimum, the *OPR* should state the owner's goals and objectives for the building. Ideally, each item listed in the document will have defined performance and acceptance criteria.

Develop Initial Outline for the *Commissioning Plan*

Every commissioning project will have a *Commissioning Plan*, which defines the scope and budget of the commissioning process. This deliverable is created by the commissioning lead with input from the designer, and serves as a guideline for team members to follow because it identifies the processes and procedures that will be undertaken, a schedule of activities, and the roles and responsibilities of team members. It also includes forms and templates that will be used to document the commissioning activities.

The *Commissioning Plan* is an evolving document that takes shape throughout the commissioning process, and the owner or owner's representative should expect to review it at certain milestones. For example, during pre-design it is advantageous to specify commissioning-related tasks for the design phase. Although specific construction phase tasks usually cannot be determined yet, developing an initial plan during pre-design helps focus the scope of commissioning efforts. During the design phase, the construction phase activities will be articulated, and documented in both the *Commissioning Plan* and the project specifications. At that point, it is possible to outline the types of tests that will be conducted, and the commissioning milestones that will be integrated into the construction schedule.

LEED® Requirements

The commissioning prerequisite in LEED-NC Version 2.2 requires the *Owner's Project Requirements, Basis of Design and Commissioning Plan* documents.

Commissioning Plan

The *Commissioning Plan* is an evolving document that defines the project's commissioning activities, schedule, documentation requirements, and the roles and responsibilities of team members.

The final *Commissioning Plan* should include:

- General building information and contact information
- Project goals
- An overview of the commissioning process, including the scope of commissioning
- Building and systems description, including a list of components and systems that will be commissioned
- Commissioning schedule
- List of team members, their responsibilities, and expected deliverables
- Description of communications, reporting, and management protocols
- Detailed description of testing procedures
- Detailed description of monitoring procedures
- Recommended training activities

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

Design

In design, the project evolves from concept to plan, as architects and engineers develop drawings, draft construction documents and write specifications. Commissioning ensures that as the building becomes a reality, its systems and operations continue to reflect the owner's goals.

During design, the commissioning lead reviews design and construction

Design Phase Deliverables

- Regular commissioning progress reports
- Comments on the *Basis of Design* and *Design Narrative* documents
- *Issues Log*
- Update *Commissioning Plan*, listing Construction Phase activities
- Commissioning specifications for inclusion in the bid documents

d Acceptance Criteria

The conditions that must be met in order for an aspect of the project to meet defined requirements, thus permitting subsequent activities to proceed.

Acceptance criteria should be included in the *Owner's Project Requirements*.

d Basis of Design (BOD)

A document that records the concepts, calculations, decisions, and product selections used to meet the *Owner's Project Requirements* and to satisfy applicable regulatory requirements, standards, and guidelines.

LEED® Requirements

The additional commissioning point in LEED-NC Version 2.2 requires the commissioning lead to conduct a design review of the *Owner's Project Requirements (OPR)*, *Basis of Design (BOD)*, and design documents prior to mid-construction documents phase, and to back-check the review comments in the subsequent design submission.

documents, incorporates commissioning into bid documents, and plans for commissioning activities that will occur during construction. Throughout, the lead keeps an *Issues Log* to track issues that require further attention.

Perform Commissioning-Focused Design Review

During design, the design team makes decisions about how to accomplish the owner's goals as they are described in the *OPR*. The commissioning lead carefully reviews design documents for clarity, completeness and compliance with the *OPR*. This includes the *Design Narrative*, in which designers describe in detail the concepts and features they intend to incorporate during schematics, and the *Basis of Design*, in which designers explain their reasoning and assumptions for choices made in the *Design Narrative*.

The commissioning lead will also review the acceptance criteria to ensure that during functional testing, systems will be shown to meet both the *Owner's Project Requirements* and the *Basis of Design*.

The design review process has several steps and takes place throughout the design phase of the project:

1. During schematics, the commissioning lead does a general review to ensure that a basic level of quality is present, checking for items such as legibility, labeling, and continuation of items from sheet to sheet. Next, the lead examines the implications of system choices to ensure that the design will meet the specifications in the *OPR*.
2. About midway through the design process the lead performs a coordination review to examine how systems will interact and whether there are any potential conflicts.
3. Near the end of design the lead conducts a final check. When the specifications are drafted, the lead does a detailed check for errors.

Some of the most important decisions for the commissioning lead to review during the design phase include:

- Sizing and selection of building systems and equipment
- Accessibility of equipment for operations and maintenance

- Energy impact of design decisions
- Details of the controls design relative to equipment being controlled
- Ability of controls interface to facilitate trending and identification of equipment faults during functional testing
- Identification and access of test ports, sensors, and in-situ measurement devices for use in functional testing and recommissioning

Issues requiring further attention are noted in the *Design Phase Issues Log*, with their eventual resolutions. The commissioning lead will update the *Issues Log* regularly and submit it to the owner and the design team for discussion at design meetings.

It is not the role of the commissioning lead to approve recommendations resulting from the *Issues Log*. It is the owner's responsibility to evaluate the lead's recommendations, discuss them with the design team, and decide whether or not to require that the issue be resolved.

Design Narrative

A written description of the concepts and features the designer intends, during schematics, to incorporate into the design to meet the *Owner's Project Requirements*. A *Design Narrative* accompanies each design submittal. At a minimum, the *Design Narrative* includes:

- Objectives and purpose of each system
- How the objectives will be met
- Indoor/outdoor design conditions
- Occupancy, usage, and schedule assumptions
- Internal loads assumptions
- Zoning descriptions
- Ventilation requirements
- Envelope requirements
- Equipment sizing calculations and criteria
- All sequences of operation
- Energy efficiency control strategies
- Design intent for all efficiency measures
- Reference to pertinent local or state compliance documents



Design Review

Design Review is a process in which the commissioning lead examines design documents to help ensure a design is likely to meet the owner's project requirements. Design review both enhances design and fosters communication between designers, owners, and builders. These reviews can address:

- Barriers to functional testing
- System performance problems
- Energy-efficiency improvements
- Indoor environmental/air quality issues
- Operation and maintenance issues

LEED® Requirements

The commissioning prerequisite in LEED-NC Version 2.2 requires that the commissioning requirements be included in the construction documents.

d **Issues Log**

A formal and ongoing record of problems or concerns, and their resolution, that have been raised by the commissioning lead or any member of the commissioning team during the course of the commissioning process. There are usually three different *Issues Logs* created in the course of the commissioning process: design review, construction observation, and functional testing.

The commissioning lead's *Issues Log* is not a substitute for the punch list usually developed during construction. The two serve very different goals. Punch lists verify that equipment has been delivered and installed as required by the specification. The *Issues Log* documents findings that affect the way equipment operates and systems interact. *Issues Logs* and punch lists are also developed differently. The punch list is created during a walk-through, which usually occurs near construction completion. *Issues Logs* are kept throughout the commissioning process.

Update the Commissioning Plan

During the design phase, the following elements should be added to the *Commissioning Plan*:

- Systems and assemblies to be verified and tested
- Commissioning schedule during construction and during warranty
- Roles and responsibilities of team members
- Documentation and reporting requirements, including procedures and formats
- Communication protocols
- Commissioning procedures
- References throughout to project specifications

Develop Commissioning Requirements for the Specifications

Commissioning requirements define the contractors' commissioning-related responsibilities, including equipment installation and start-up, documentation, and functional testing. It is *essential* to include commissioning requirements in the specifications. If commissioning is *not* included, the owner should expect to receive a change order for the additional commissioning tasks.

The designer is responsible for developing detailed commissioning requirements, although in practice, the commissioning lead will likely draft the language and review the requirements before they are released. The commissioning requirements should describe:

- How potential contractors are expected to interface with the commissioning lead's construction oversight and testing procedures
- Appropriate staff training requirements, especially if installing contractors or manufacturer's representatives will be required to participate
- Special equipment or instrumentation that must be installed to obtain measurements during performance testing
- The party or parties responsible for compiling the equipment, *O&M Manuals*, and the deadline for their delivery to the commissioning lead

Many aspects of the commissioning process, particularly comprehensive system testing, may be new to contractors. When this is the case, owners must ensure that contractors are correctly informed about what commissioning requires of

them before contractors submit their bids. Owners can do this by inviting the commissioning lead to discuss the process and its requirements at a pre-bid meeting and by providing sample test protocols and other documentation to contractors in advance of the submission deadline.

Begin Planning for Verification Checklists, Functional Tests, Systems Manual, and Training Requirements

Towards the end of the construction process, verification checks (or prefunctional tests) and functional tests will be conducted. The *Systems Manual* will be developed, and staff training will be provided. (All of these are described in more detail in the Construction section). Since these require careful planning, the commissioning lead will usually start preparing for them even before construction begins.

Construction

During construction, the commissioning lead monitors numerous aspects of the project to ensure that building systems and equipment are installed and tested according to the owner's requirements.

The lead tracks issues that need further attention in an *Issues Log*.

If commissioning has not started before construction, the lead can still conduct all the activities of the construction and the occupancy and operations phases. However, the commissioning lead will still have to review the design in order to understand it, and will still have to develop the *OPR*. If commissioning requirements were not included in the specifications, the lead's recommendations are very likely to involve change

Construction Phase Deliverables

- Updated *Commissioning Plan*, with construction schedule
- Reports of submittal reviews
- Completed verification checklists and functional tests
- Report of training completion
- Reviewed *Systems Manual*
- Minutes from commissioning meetings
- *Issues Log*
- Periodic commissioning progress reports
- Draft *Commissioning Report*

Commissioning Requirements in the Specifications



It is very important to include commissioning requirements in the specifications. If commissioning is not included, the owner should expect to receive a change order for the additional commissioning tasks.

Commissioning and MasterFormat™



MasterFormat™ is the specifications-writing standard for commercial building design and construction. In the *2004 Edition*, it states that a summary of the commissioning scope should be placed in Division 01, 019100, "General Requirements."

In each of the other divisions there are titles for commissioning, where requirements relevant to that division should be placed. This is a very important step to ensure that all parties understand the commissioning requirements that apply to them. The *MasterFormat 2004 Edition* is available at the CSI website: www.csinet.org/masterformat.

Commissioning Guidelines for Contractors

Since the comprehensive system testing that occurs during the commissioning process is new to many contractors, it may be helpful to provide them with sample test protocols, to give them a sense of the expected rigor. A clear description of roles and responsibilities during testing is also very important.

Managing the Construction Schedule

The general contractor develops the project schedule and the commissioning lead should provide dates for commissioning milestones and testing. The lead also reviews the schedule to look for potential conflicts and to ensure there is sufficient time for testing towards the end of the project.

orders and addendums, resulting in added expense to the owner. The sooner the lead can be brought in, the better. Even with a late start, commissioning can significantly benefit overall building operations.

Construction Phase Meetings

Periodic meetings of the commissioning team are at the heart of the commissioning process. The commissioning lead coordinates the kick-off meeting with the owner, construction manager, design team, and representatives from each of the subcontractors (general contractor, mechanical, electrical, controls, and the testing and balancing specialist). Ideally this meeting takes place before construction begins. The kick-off meeting introduces the team members to the schedule of commissioning activities, responsibilities, and procedures for documenting and resolving issues and communicating expectations. The kick-off meeting also provides an opportunity for the team members to offer their ideas and suggestions to the commissioning lead for inclusion in the *Commissioning Plan*.

Throughout the construction process, the commissioning lead attends planning and job site meetings to stay informed of construction progress. As needed, the commissioning lead attends regular construction meetings and holds a line item on the agenda. Later in construction, the commissioning lead will typically conduct separate meetings devoted to commissioning issues. The owner's representative(s) should attend commissioning team meetings in order to stay up-to-date on changes that may affect the project's ability to achieve requirements in the *OPR*, commissioning issues, and the scheduling of training for building staff.

Review Submittals, Monitor Development of Shop and Coordination Drawings

It is helpful if the commissioning lead can review construction documentation to verify that it complies with the *OPR* and to collect information that will be used to write functional tests and develop the *Systems Manual*. This may include:

- Equipment and sensor selection and testing tolerances
- Manufacturers' recommended startup tests
- Warranty data
- Controls submittals, for inclusion of required control points

- Controls submittals, for functional capabilities in trending points
- *Operation and Maintenance Manual* content

The owner's support can be critical in helping the commissioning lead obtain documentation in a timely manner. The lead pays close attention to any proposed substitutions or deviations from earlier documents, checking to see if they will have any adverse effects.

Review *Operation and Maintenance Manuals*

Operation and Maintenance (O&M) Manuals ensure that operational knowledge stays with the facility, even if the staff does not. The *O&M Manuals* are also a valuable reference for construction phase commissioning activities, and the specifications should require that contractors provide these at the same time as the submittals. The commissioning lead ensures that the *O&M Manuals* are complete and on time, and verifies that the information is clear, correct and available for use during observation, testing, and training.

Perform Ongoing Construction Observation

Throughout construction, the commissioning lead attends job site meetings, observes the construction process, and keeps a *Issues Log*. If the lead finds any conditions that might affect the ability of the building's systems or operations to meet the owner's performance expectations, they are recorded in the *Issues Log*. The lead also uses the *Issues Log* to track the resolution of these findings, and will frequently refer to it during regular construction meetings. The completed *Issues Log* becomes part of the permanent construction record.

Complete Verification Checklists

Verification checklists are used by contractors during start-up as equipment comes online. They are sometimes called "prefunctional tests" and list activities that must be completed prior to and during start-up to ensure equipment is properly installed and ready for functional testing. Once complete, they provide vital information about the equipment, its condition upon delivery, and issues that arose during start-up. The checklists help the commissioning lead verify correct installation and, after building turnover, help building staff in their maintenance tasks.

LEED® Requirements

Submittals

The additional commissioning point in LEED-NC Version 2.2 requires review of submittals.

Installation & Performance

The commissioning prerequisite in LEED-NC Version 2.2 requires verification of the installation and performance of the systems to be commissioned.

d Verification Checklist

A document that identifies the steps that must be taken to verify the readiness of a piece of equipment for functional testing.

d Functional Test

Tests that evaluate the dynamic operation of equipment and systems using manual or automated monitoring methods and either passive observation or active testing. Functional testing is the assessment of the system's ability to meet the *OPR*. Functional tests are not usually performed on systems tested and approved by regulatory authorities. However, the lead's scope may be drafted to include participation in these tests, if the owner desires.

! The Controls Contractor and Functional Testing

The control system contractor is an important participant in the commissioning process, and it is important to document their role in the specifications. The control system may be used to help test equipment performance and system interactions.

Responsibility for developing the verification checklists varies. Contractors are usually responsible for creating them, but only if this requirement is documented in the specifications. The commissioning lead reviews the checklists and may assist in developing or enhancing them. Contractors complete the checklists when they execute equipment start-up, often with lead oversight. In some cases, it may be possible for the lead to use spot checks or sampling to ensure that verification checklists have been completed accurately.

When Equipment Fails to Perform

If equipment does not perform as specified during functional testing, the commissioning lead will document the issue in the *Issues Log* and bring it to the attention of the project team. The lead will communicate the potential consequences to the owner, who must decide whether to require corrective measures. If it is in the commissioning scope, the lead may work with the project team to achieve acceptable performance.

Perform Diagnostic Monitoring

Throughout the construction phase, the commissioning lead will spend a great deal of time gathering data on how the systems operate through functional testing and monitoring. This verifies that the systems as a whole, as well as individual pieces of equipment and their components, function properly and meet the performance requirements specified in the *OPR*.

As equipment or systems come on-line, their performance can begin to be monitored. The use of meters, portable data loggers, and the building's energy management control systems (EMCS) gather data that allow for observation of the building's performance under various modes and operating conditions. 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 operating parameters, weather data, equipment status and runtimes, actuator positions, and setpoints.

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.

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. Of course, the EMCS must be installed, operational, and tested before it can be used to collect performance data on the rest of the system. The controls contractor may be involved in setting up the necessary trends.

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 allowing data to be downloaded, 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 many cases, however, it is impossible to naturally observe every possible operating regime, and the commissioning team conducts functional performance tests to take the system through its paces, observing, measuring, and recording its performance in all the key operating modes.

Test procedures are often prepared, witnessed, and documented by the commissioning lead and conducted by the contractors, although other arrangements are possible. The commissioning lead and contractors 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 commissioning lead will meticulously record all their activities and observations on a pre-defined data

d 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 operational information.

! 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.



Sampling Pros and Cons

Sampling can be an effective way to minimize the costs of commissioning. Rather than reviewing, inspecting, or testing every item, only a random sample is selected. In order for sampling to be effective, however, commissioning must begin during pre-design and the most critical or failure-prone components and systems must be weighted most heavily when selecting the sample. The lead's scope of services and the specification should define this in detail.

sheet, and then ensure that all systems are returned to a “normal” state. During functional testing, the commissioning lead uses an *Issues Log* to track any performance issues that may arise, and their resolutions.

Having future building operators participate in testing enhances the process and is a unique opportunity to deepen their understanding of the systems and controls.

Test Protocol

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

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

Develop Commissioning Report and Systems Manual

After all construction phase commissioning tasks are complete, the commissioning lead delivers the *Commissioning Report* and the *Systems Manual* to the owner. The *Commissioning Report* is an essential document that summarizes the commissioning effort and evaluates whether each piece of commissioned equipment meets the specifications in the *OPR*. The *Systems Manual* is a comprehensive package of documentation that assists the owner in better understanding, operating, and maintaining the building's systems. This document is assembled by the commissioning lead, if it is in the commissioning scope of work. The *Systems Manual* should not be confused with the *O&M Manuals*, which is only one part of the more comprehensive package. The *Systems Manual* includes information collected during the commissioning process and provides a perspective on the building that is system-based, rather than equipment-based. It may include a *Recommissioning Plan*, although the plan may also be developed later, after occupancy.

LEED® Requirements

The commissioning prerequisite of LEED-NC Version 2.2 requires a *Commissioning Report*. The additional commissioning point requires that training requirements have been completed, and a *Systems Manual* developed.

Develop Recommissioning Plan

Commissioning produces high performance buildings – those that meet the owner’s expectations, operate efficiently, and provide a safe and comfortable indoor environment for occupants. But after occupancy, the work is not over. Maintaining the building’s optimal performance requires periodic recommissioning. A *Recommissioning Plan* will help owners and building staff plan and prepare for recommissioning. The commissioning lead can help draft the plan, if it is in his or her scope. The best time to produce this plan is at the end of the initial commissioning process, because the *Owner’s Project Requirements* and the building system performance are well documented at this point.

Verify Training of Owner’s Staff and Review

Operations and maintenance documentation and training are vital to the long-term operational health of the facility.

Thorough training by the contractor gives staff the information they need to operate the facility. Because of its role in assuring long term benefits, the importance of this step should not be underestimated. The commissioning lead works with the owner’s representative(s) and building staff to ensure that training agendas meet the specifications in the contract documents and the *OPR*. Often the lead will interview team members, including the building staff, to determine training needs. The requirements for training must be outlined in the specification, and the commissioning lead will verify that they are carried out as specified.

If contract documents specified that contractors, designers, and/or manufacturers’ representatives are to conduct trainings, the commissioning lead may recommend agenda items and/or oversee these sessions.

Additional Training Options

There are multiple formats for staff training. A manufacturer’s representative can conduct onsite sessions, staff can be sent to an offsite location such as the factory, or training can be held virtually using internet or video technology. Content can be equally diverse. Training sessions may include focused walk-throughs of the facility during construction as well as classroom work. It is usually helpful to record training sessions so future staff members can benefit from the training.

d *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.

d *Commissioning Report*

The *Commissioning Report* is written by the commissioning lead and provides an overview of the commissioning process. It usually includes:

- A written narrative offering the lead’s assessment of each of the commissioned system’s compliance with both contract documents and the *OPR*, as well as any unresolved commissioning issues.
- Copies of project documentation: the *Commissioning Plan*, functional tests, individual commissioning reports and reviews, *Issues Logs*, and all major communications, such as emails, memos, and letters.

Ongoing Training Opportunities

Building Operator Certification (BOC)

The BOC's 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 and municipal utilities have customer training centers to educate their customers on matters related to smart energy use. Their workshops and seminars 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 Co. 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/>

Occupancy and Operations

Upon turnover, the building is in the hands of the owner and operators. Although the project is considered complete, some commissioning tasks continue during the typical one-year warranty period.

The active involvement of the commissioning lead during the initial occupancy period is essential to the success of the commissioning process.

Occupancy and Operations Phase Deliverables

- Summary report from seasonal testing
- Warranty review of each system
- “As operated” sequence of operations (developed either by the commissioning lead or the controls contractor)
- Findings from the Occupancy and Operations Phase for inclusion in the final *Commissioning Report*
- Final *Issues Log*
- Final *Commissioning Report*

Help Resolve Outstanding Commissioning Issues

It is common for some commissioning issues to remain unresolved, even after turnover. When this is the case, the commissioning lead can assist the owner in coordinating contractor callbacks, since he or she has been involved in the project for some time and can identify how best to resolve an issue. It is up to the owner to decide whether or not to resolve a particular issue.

Perform Seasonal and Deferred Testing

Seasonal testing is conducted to verify proper system operation during different seasons – at minimum winter and summer. Some testing of heating and cooling systems can be performed under simulated conditions during the off-season, but natural conditions usually provide more reliable results. Testing that was delayed due to site and equipment conditions or inclement weather will also be completed during occupancy.

Perform Near Warranty-End Review

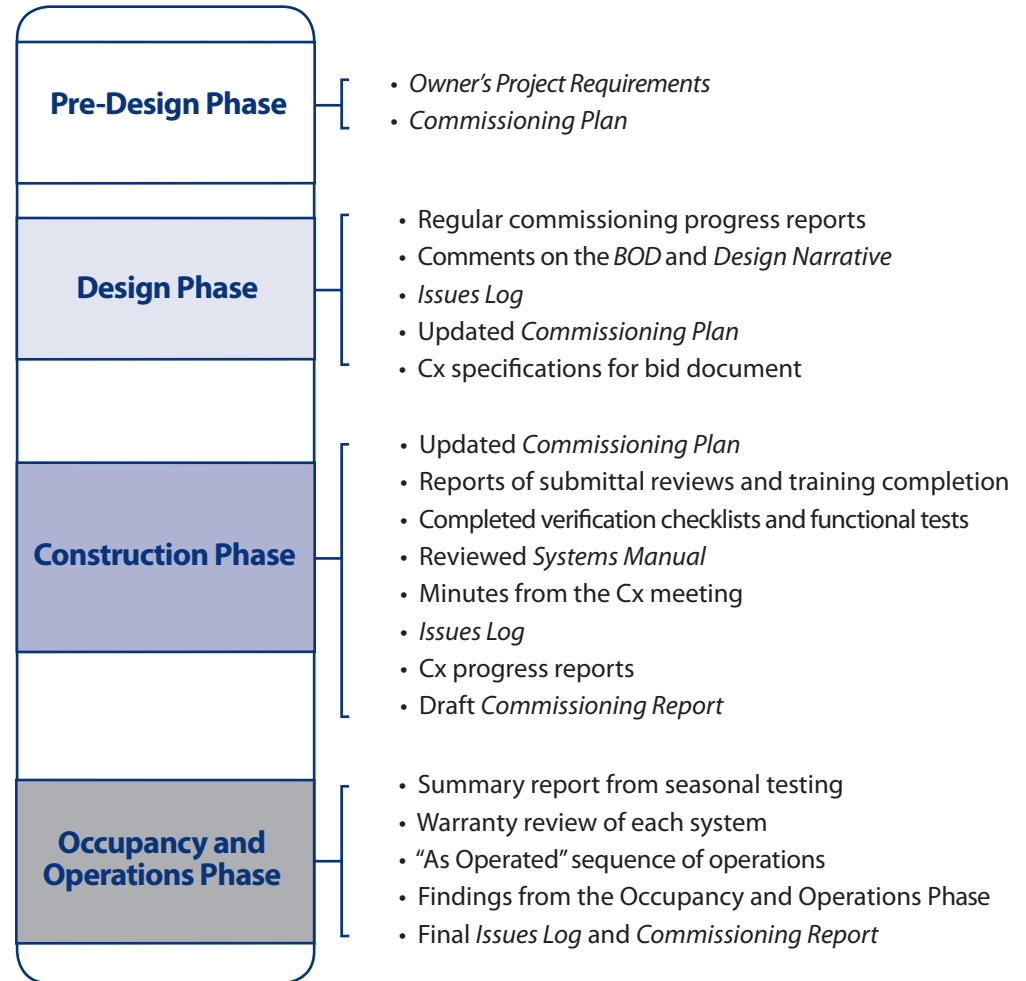
Shortly before the expiration of the contractor’s one-year warranty, the commissioning

LEED® Requirements

The additional commissioning point in LEED-NC Version 2.2 requires a 10-month review of operation and a plan for resolution of outstanding issues.

lead may return to the building to review system operation and interview building staff. The lead can assist staff in addressing any performance problems or warranty issues. The commissioning lead may also add information about the facility to the *Commissioning Report* at this time.

Summary of Recommended Deliverables by Commissioning Phase



5. Strategies for Ensuring Persistence of Benefits

Now that the new building has been delivered with all its systems working well, what can an owner, building manager, or operator do to keep it operating efficiently?

This chapter answers the following questions:

- How can good building design and construction facilitate good operations and maintenance practices?
- What should be in the comprehensive *O&M Manuals* for all building equipment and systems?
- When should training for building staff begin?
- What should a preventive maintenance program for all building equipment and systems consist of?
- How can building performance be tracked?
- How often will the building need to be recommissioned?

"It's equally important to commission a new building or major renovation properly, and to have monitoring devices in place to make sure it stays at its peak performance level.

During design, our in-house commissioning/start-up/life-safety group worked with the property management group to assure that our facility was designed as efficiently as possible, and installed and commissioned to perform at 100%. We made sure we could continue to maintain and operate the building at this level throughout its life by investing in 100% direct digital controls (DDC) and a real-time web-based building management system (BMS).

Now, after our renovation, our energy consumption is down quite a bit. And we paid for the DDC and BMS systems in under two years with our energy savings."

- Bill Krill,
Operations Manager
Green Building Chairman,
Swinerton Inc.

Strategies for Ensuring Persistence of Benefits

There are a few key factors that can make the difference between commissioning benefits that are short-lived and those that endure over time. These can include: introducing O&M during the design phase, development of *O&M Manuals* and *Sequences of Operation*, training building staff, preventive maintenance, performance tracking, and developing a *Recommissioning Plan*.

Good O&M Begins During Design

Like commissioning, successful O&M begins in the design phase of a project.

Commissioning brings O&M considerations to the table during pre-design and design. At this time, the commissioning lead will identify any potential barriers to good O&M in the facility design and suggest alternative approaches.

Design Considerations that Facilitate Good O&M

- Ground-floor access to the chiller room through a connected loading dock
- One or more roll-up doors of sufficient size to permit removal and replacement of chillers or other major equipment without the need to disassemble equipment
- Sufficient clearance on all sides of the chiller and other major equipment to perform all maintenance
- Hoist or crane equipment over banks of chillers or other major equipment
- Sufficient valves to permit the isolation of an individual chiller without having to shut down the entire system
- Walkways around elevated equipment
- Roof access with adequate openings via stairs, not ladders
- Direct ceiling access to each terminal box

Commissioning also provides a forum for soliciting input from building staff during the early stages of design. Building staff have an excellent perspective on how design choices affect their ability to maintain the building, and can often identify items that result in significant improvements to ongoing operations. For example, ensuring consistency with point naming conventions, considering staff skill levels when selecting equipment, and ensuring that all equipment is accessible for routine maintenance, repair, and replacement.

O&M Manuals and Sequences of Operation

***O&M Manuals and Sequences of Operation* contain essential information about building equipment and will be used for years to come.**

O&M Manuals

The final, as-built *O&M Manuals* must be well-organized, detailed, and delivered in time for staff training.

In order for building staff to use *O&M Manuals* effectively, the information they contain must be well-organized. An index or table of contents will improve usability, and if it created early in the project, can also serve as a checklist to ensure all contents have been received. It may also be helpful to organize the manuals by system, rather than specification number.

The information in the *O&M Manuals* must be detailed enough to help building staff operate, maintain, and troubleshoot equipment. Too often, contractors wait until the last minute to submit their sections of the *O&M Manuals*. This may be at the end of construction, or even later, after occupancy. If the commissioning lead plans to use the *O&M Manuals* to develop functional tests or as a reference during staff training, the due date should be included in the specifications and set as soon as possible after submittals are approved.

The process of keeping the *O&M Manuals* up-to-date begins almost as soon as

they are completed. After functional testing and staff training, the commissioning lead may add information gathered during the commissioning process, such as equipment submittals, design documents, control strategies, sequences of operations, and copies of the commissioning tests. After occupancy, building staff are responsible for updating the manuals as new material becomes available. This may include checklists and updates to reflect changes to equipment or operations.

O&M Manuals

O&M Manuals are the product of a team effort, and individual responsibilities will vary on each project. In the most common arrangement, designers produce sections on the equipment they specify and compile the *O&M Manual*. The commissioning lead reviews the manual to ensure it meets the owner's needs and may also provide a detailed outline of the manual's contents in the specifications.

It is important to note that contractors are not required to produce *O&M Manual* materials unless it is written in the specifications. For manuals to be optimally useful, the specifications should include the level of detail required in the materials and their due date.

The *O&M Manual* typically includes:

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



Systems Manual

If the scope of work calls for a *Systems Manual*, the *O&M Manual* and *Sequences of Operation* will become an important part of that manual.

Sequences of Operation

Sequences of Operation help building staff understand how the control system should operate. Without detailed sequences, staff will have difficulty verifying correct operation and troubleshooting problems. The sequences provided in the

contract drawings and specifications provide a good overview, but they may need to be supplemented for the *Systems Manual*. For example, the *Systems Manual* should address any critical system interaction details that the *Sequences of Operation* do not cover. At a minimum, a detailed *Sequence of Operations* should be created for each HVAC and lighting system.

Building Staff Training

One of the essential components of an excellent O&M program is training. Unless operators and managers have the right knowledge and skills, it will be impossible for the building to perform optimally over time.

Training for building staff should occur throughout the project, starting during construction and prior to substantial completion. Training during construction gives staff the best opportunity to learn about building systems and equipment. The staff's observation of functional testing may be their first training experience in the new building.

The commissioning lead works with the owner to develop a training plan that will prepare building staff to maintain building performance after turnover. Training will likely occur over several days and may include classroom work and hands-on site demonstrations. Training should also include site orientation. This is best done during construction, while the building's walls are still open and access points are visible – a key reason to start thinking about training during design.

If staff is brought into the project at the end of construction, it is helpful if their first training session provides an overview of the project, including a discussion of the project's goals in the *Owners Project Requirements* and *Basis of Design*. This gives building managers and operators a thorough understanding of why the facility was constructed and how it is intended to operate, as well as its limitations.

In buildings where O&M activities are led by a facility manager who does not have a technical background, the commissioning lead will work with contractors

Training

Requirements in the Specifications

To ensure that rigorous training occurs, training requirements must be clearly detailed in the specifications, and oversight of the training must be included in the commissioning lead's scope of work. Important points to include are:

- Contractors' requirements regarding developing training materials and conducting training sessions
- Training topics and length
- Who should attend
- When and how the training will be conducted (onsite, factory, classroom, before or after construction)
- How the training will be documented (written documentation, video)

! Training after construction

If training will not begin until after construction is complete, it is important to hold a site tour for facility staff before finished walls go up, so they can see how systems connect first-hand, rather than just on paper. As an alternative, contractors can be asked to video or photograph systems immediately after installation.

to ensure that the manager understands the capabilities, intended function, and required maintenance of the building systems. Emphasis should be placed on preparing the facility manager to respond to occupant complaints without circumventing design intent. It will also be important to provide the facility manager with a list of resources for maintenance assistance.

Suggested Training Topics³

- Descriptions of systems/equipment and their warranties
- Operation instructions and procedures: seasonal changeover and manual/automatic control
- Emergency instructions and procedures
- Operation and adjustment of dampers, valves, and controls
- Adjustment instructions: information for maintaining operational parameters
- Requirements and schedules for maintenance on all operation and maintenance-sensitive equipment
- Common troubleshooting problems, their causes, and corrective actions
- Indoor air quality, health, visual comfort, acoustic comfort, and safety issues
- Recommendations for special tools and spare parts inventory
- Hands-on operation of equipment and systems
- Review of operation and maintenance manuals, and their location onsite
- Building walk-through
- Review of related design intent documents
- Energy management control system (EMCS) operation and programming
- Control sequences and strategies
- Thermostat programming
- Relevant commissioning reports and documents
- When and how to recommission building systems
- Sound energy management practices
- Exotic or special equipment like scrubbers, fume hoods, or water features/fountains

Ongoing Training

Well-trained operators with opportunities to study how to optimize building operations are more 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.

³From *CHPS Best Practices Manual*, 2002, p. 437, and *ASHRAE Guideline 0 – 2005*, p. 12.

Preventive Maintenance

Preventive maintenance saves energy, increases equipment life, and helps prevent unexpected equipment failure.

Good preventive maintenance practices require building staff to continuously monitor building equipment and document all maintenance activities.

Developing a *Preventive Maintenance Plan*

While a *Preventive Maintenance Plan* can be implemented using a computerized maintenance management system (CMMS), it can also be implemented manually. The plan consists of a checklist of maintenance tasks and a schedule for performing them. Most of the required information will have been gathered during the commissioning process, or can be obtained from the *O&M Manuals*.

Preventive maintenance checklists should be kept separately for each piece of equipment and updated after maintenance tasks are performed. It may be helpful to structure checklists as logs, with room for at least two people to sign off: the technician who performs the maintenance task and the supervisor who verifies the task was performed.

The preventive maintenance schedule is usually determined by the manufacturer's recommended service intervals, often measured in hours of equipment run time.

Many major controls contractors offer preventative maintenance modules for their software that automatically track activities and alert staff when maintenance is needed. These systems can provide valuable information to building staff, especially if they are operational prior to occupancy and the staff is well-trained in using them.

It may be helpful to review the *Preventive Maintenance Plan* at a yearly “lessons learned” meeting with building staff, consultants, and the owner. This meeting allows all parties to review whether the building's operating intent has changed, review maintenance activities, and share information about plans and requirements during the coming year. It may be beneficial to bring in a third-party facilitator to run the meeting, so attendees can focus on the discussion.

Preventive Maintenance

Preventive maintenance can save building owners time and money by:

- Maintaining efficient facility operations
- Extending equipment life
- Increasing energy savings
- Preventing loss of equipment, time, productivity, and the resulting revenue

Maintenance Service Contracts

A service contract should cover all the manufacturer's recommended preventive maintenance procedures, as described in the *O&M Manual*. 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 *O&M Best Practices Series*. All seven are available in the CCC library: www.resources.cacx.org/library/.

The Preventive Maintenance Plan

The *Preventive Maintenance Plan* should include an up-to-date equipment list. For each piece of equipment, the following information should be included. Much of this will be gathered during the commissioning process.

Required information

- Unique equipment identification number
- Name plate information
- Manufacturer's name
- Vendor's name and telephone number
- Equipment location
- Date installed

Desirable information

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

Outsourcing Preventive Maintenance

When building staff is not available or trained to perform preventive maintenance tasks, it may be advisable to purchase a maintenance service contract from the equipment vendor, installing contractor, or a maintenance service contractor. Service contractors hired during the construction phase should receive the same training as would have been provided to in-house staff. In cases where maintenance is outsourced, the *O&M Manuals* need to be easily accessible by the maintenance service contractor.

Performance Tracking

Tracking building performance helps building staff detect problems early, before they lead to tenant 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 trend analysis.

Benchmarking

Benchmarking is a way for building owners and operators to track their building's

energy use over time and compare it to other buildings. Owners of multiple buildings can use benchmarking to compare buildings 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 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.

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 input of 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 Portfolio Manager, but it does not take into account the effects of parameters like weather and occupancy on energy use.



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

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/cbenchmark.htm>

Cal-Arch Building Energy Reference Tool

<http://poet.lbl.gov/cal-arch/>

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, 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).

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?

When building staff are not familiar with the trending capabilities of the control system, or are unskilled in how to set up trends and retrieve collected data, it may be helpful to bring in the control vendor or commissioning lead to train at least one or two building operators on the topic. 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 *Commissioning Plan*, a skilled commissioning team member can set up “smart alarms” in the control system. These look at concurrent values of several variables at one time 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 (ReCx) occurs when a building that has already been commissioned undergoes another commissioning process to help keep it operating optimally.

Ideally, a plan for recommissioning is established as part of a new building's original commissioning process.

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 over 50,000 square feet on a recurring five-year cycle, or whenever major energy consuming systems or controls are replaced.

Recommissioning is similar to new building commissioning, although the phases and goals are slightly different. Recommissioning typically begins with a review of the *Owner's Project Requirements* of the building 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, just as they would be in new building commissioning, and any issues are recorded in an *Issues Log*.

Functional performance tests and trend data 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 will also be reviewed to determine if updates or trainings are required. Finally, the *OPR* document is updated to reflect any changes in building systems and functions.

Although a third party may have led the original commissioning 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 commissioning effort is the experience they gain for performing subsequent recommissioning projects.

"A well-run building should be recommissioned 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 re-commissioned the three buildings and discovered another \$273,000 in savings!"

- George Denise

General Manager for Facilities
Cushman & Wakefield at Adobe
Systems Incorporated

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?
- 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?

Continuous Commissioning® and Monitoring-Based Commissioning (MBCx)

Continuous Commissioning® and Monitoring-Based Commissioning are two processes that use retrocommissioning 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 commissioning? There are a few key steps that will help get a new commissioning project off to a strong start:

Become informed about commissioning

Explore the resources listed in this guide, explore online resources, and begin talking to others about their experiences, including designers and contractors.

Determine what local, utility and government resources are available

Contact utility representatives and government agencies to learn about the incentives they offer for commissioning and other energy efficiency products and services.

Start early! Identify an upcoming project that could benefit from commissioning – preferably one not yet in design

Begin thinking about the special needs of the project and the commissioning scope that will be required to meet them. Consider holding a “lessons learned” workshop on a recently completed project to identify issues that commissioning could have addressed. If a full commissioning process cannot be implemented, think about how to employ selected commissioning strategies.

Obtain buy-in from members of the organization

Consider giving a presentation on commissioning or inviting a commissioning lead to explain its benefits to staff. Identify any individuals who may need convincing and be sure they are present.

Hire a commissioning lead, and specify the project scope and objectives

Identify commissioning leads working in the area and begin investigating their qualifications. Ask whether the lead’s experience is relevant to the project’s needs. Once a lead is selected, the owner and lead must work together to clearly scope the commissioning process and define its objectives. The owner should require the lead

"We have found the Cx Guide valuable for our internal commissioning efforts, and also as a source of information in setting scope when we hire third party commissioning agents. Clean turnover of a construction project team to store operations is very important to Target. We look at the commissioning process as a way to help minimize operational disruptions to the store operation teams as they concentrate on serving guests in our new stores."

- Scott D. Williams, PE

Manager,
Mechanical Engineering,
Target Property Development

to create a detailed commissioning plan, hold a kick-off meeting, conduct site inspections, deliver progress reports and *Issues Log*, and produce a *Commissioning Report*.

Identify in-house commissioning resources

Designate a member of the owner's project team to represent the owner during the commissioning process, and make it an early priority to identify members of the building's O&M staff who will be involved from start to finish.

Include commissioning requirements in the specifications

It is absolutely essential to include commissioning requirements in the specifications. Without them, contractors will not be required to participate in the commissioning process and may issue change orders if asked to complete commissioning tasks.

Become an advocate for commissioning 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 commissioning process, communicate your expectations and become an active and interested participant in the process. You will achieve maximum benefits and others will recognize the value of commissioning as well.

7. Appendix





Acronyms

ASHRAE	American Society of Heating, Refrigerating and Air Conditioning Engineers
BOD	Basis of Design
CC®	Continuous Commissioning®
CMMS	Computerized Maintenance Management System
Cx	Commissioning
CxP	Commissioning Provider
EIS	Energy Information System
EMCS	Energy Management and Control System
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
O&M	Operations and Maintenance
OPR	Owner's Project Requirements
PM	Preventive Maintenance
RCx	Retrocommissioning
ReCx	Recommissioning
RFI	Request for Information
RFP	Request for Proposals
RFQ	Request for Qualifications
TAB	Testing, Adjusting, and Balancing

Glossary

Acceptance Criteria

The conditions that must be met in order for an aspect of the project to meet defined requirements, thus permitting subsequent activities to proceed.

Basis of Design (BOD)

A document that records the concepts, calculations, decisions, and product selections used to meet the *Owner's Project Requirements* and to satisfy applicable regulatory requirements, standards, and guidelines.

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 Project 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 (Cx)

See **Building Commissioning**.

Commissioning Plan

A document that outlines the organization, schedule, allocation of resources, and documentation requirements of the commissioning project.





Commissioning Lead

The person who coordinates the commissioning 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.

Commissioning 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.

Conflict of Interest

A situation in which a person in a position of trust has competing professional and/or personal interests.

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.

Contract Documents

A wide range of documents binding on all parties involved in the construction of the project, which may include: specifications, price agreements, construction management processes, subcontractor agreements or requirements, submittal procedures or requirements, drawings, specifications, change orders, addenda, requests for information, and the *Commissioning Plan*.

Coordination Drawings

Drawings showing the work of all trades created to eliminate any logistical and spatial conflicts between equipment and systems.

Design Intent Documents

See *Owner's Project Requirements*

Design Narrative

A written description of the concepts and features the designer intends, during schematics, to incorporate into the design to meet the *Owner's Project Requirements*. A design narrative accompanies each design submittal.

Design Review

A process of review in which the commissioning lead examines design documents to help ensure that a design is likely to meet the *Owner's Project Requirements*. Design review both enhances design and fosters communication between designers, owners, and builders.

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 meet the *Owner's Project Requirements*.

Independent Third-Party Commissioning Provider

A commissioning consultant hired directly by the building owner and not responsible to, or affiliated with, any other member of the design and construction team.

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.





Issues Log

A formal and ongoing record of problems or concerns, and their resolution, that have been raised by the commissioning lead or any member of the commissioning team during the course of the commissioning process. There are usually three different issues logs created in the course of the commissioning process: design review, construction observation, and functional testing.

Non-Energy Benefits

Benefits that go beyond energy savings. Common non-energy benefits include environmental benefits, enhanced property value, extended equipment life and reduced down time, improved occupant comfort and productivity, and reduced risk.

Owner's Project Requirements (OPR)

A document that details the owner's functional requirements for a project and expectations for how it will be used and operated. These include project goals, measurable performance criteria, cost considerations, benchmarks, success criteria, and supporting information.

O&M Manuals

Documents that provide all the information necessary for operating and maintaining installed equipment.

Pre-functional Checklist

See *Verification Checklist*

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.

Sequence 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.

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.

Verification Checklist

A written checklist identifying the steps which must be taken to verify that a piece of equipment has been properly installed and started up in preparation for full operation and functional testing.





Commissioning Resources

Look for quick reference icons in this section for indication of the following:

Training **T**

Certification **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



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



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



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 commissioning 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



Collaborative for High Performance Schools (CHPS)

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



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



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



ENERGY STAR®

A U.S. Environmental Protection Agency sponsored program to help individuals and businesses achieve superior energy efficiency. The website contains energy advice and building energy benchmarking tools.

[www.eere.energy.gov/femp/
operations_maintenance/](http://www.eere.energy.gov/femp/operations_maintenance/)



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



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



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



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



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



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/



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



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.sdenenergy.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



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/>



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/>



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



www.epdweb.engr.wisc.edu



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.

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.





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www.cacx.org