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1ST EDITION

Commissioning Guide

For New Buildings

CanmetENERGY
Leadership in ecoInnovation

Canada

COMMISSIONING (Cx) GUIDE FOR NEW BUILDINGS

This Cx Guide (the "NRCan Guide") is owned by Natural Resources Canada and is an adaptation of the document entitled *California Commissioning Guide: New Buildings* (the "CCC Guide") originally developed by Portland Energy Conservation, Inc. (PECI) for the California Commissioning Collaborative, with funding from the California Energy Commission.[1]

The Canadian adaptation of the CCC Guide has been managed by CanmetENERGY in collaboration with the Office of Energy Efficiency (OEE) and under the ecoENERGY for Buildings and Houses Program of Natural Resources Canada (NRCan)[2,3].

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Terri Meyer Boake, University of Waterloo, Waterloo, Canada.

1 The NRCan Guide has not been formally reviewed by CCC, and CCC does not endorse any products or commercial services mentioned in this publication. Furthermore, CCC and PECI make no warranty, expressed or implied, and assume no legal liability for the information in this Guide.

2 Imperial units have been converted to metric units when useful. Sometimes to reflect the market reality or because the unit conversion was not necessary to understand the concept presented, original imperial units were kept as is.

3 U.S.A. monetary units (USD, $) have been converted at-the-money (ATM) to Canadian monetary units (CDN, $) as per conversion rates published by the Bank of Canada for January 31, 2008. No other factors have been applied to account for other differences in costs that might occur between U.S.A. and Canada.

COMMISSIONING GUIDE FOR NEW BUILDINGS

1ST EDITION

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CanmetENERGY

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ABOUT THIS COMMISSIONING GUIDE

Building commissioning is an intensive quality assurance process that spans the entire concept, design, construction, and start-up process – including the first year of operation – helping ensure that the new building's operation and energy, water, and *indoor environmental quality* performance meets owner requirements.

This *Commissioning Guide for New Buildings* (hereafter simply called the "Cx 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 authority* 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 Cx Guide in the **Glossary**.

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

Indicates an important topic.

ACKNOWLEDGEMENTS

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NRCan's Cx Guide: Alexandre Monarque, Sonia Ringuette, Gilles Jean, Alexandre Prieur, Alain Trépanier, Sylvie Lavoie, from NRCan's CanmetENERGY; Philip B. Jago, Michel Lamanque, Ian Meredith, Sadettin Yilmaz, Mark Newman, from NRCan's Office of Energy Efficiency (OEE); John Kokko, David Braun and Caitlin Carpenter of Enermodal Engineering, Kirstin Pinit and Tudi Haasl of Portland Energy Conservation Inc. (PECI), Pierre-Luc Beaupré of Projet Bleu, Daniel Bourque of Kolostat, Jean Bundock of Groupe-conseil Roche, Alex Fleming of Demand Side Energy Consultants, David F. Shipley of Marbek Resource Consultant, Tom Kovendi of Cadillac Fairview Corporation, Charles E. Dorgan of University of Wisconsin-Madison, Joe Stano of Canada Green Building Council (CaGBC), and Vanessa Mitchell of the Canadian Standards Association (CSA).

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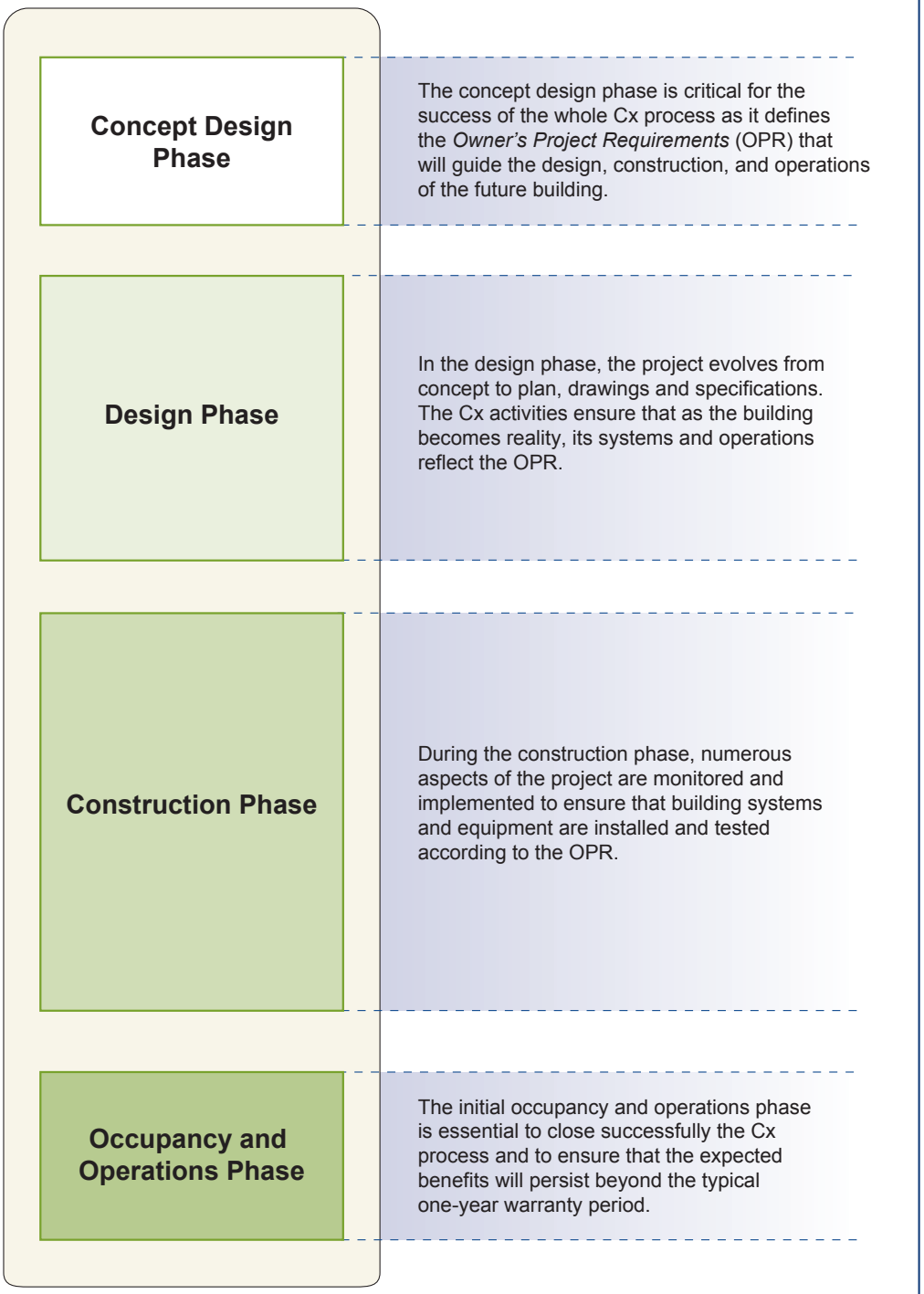
COMMISSIONING PROCESS OVERVIEW



CHAPTER 1

INTRODUCTION

This chapter introduces the building commissioning process.

This chapter answers the following questions:

- What is building commissioning?
- What are the goals of the commissioning process?
- Why is commissioning important?
- What is the connection between commissioning and LEED® Canada?

Commissioning (Cx)

Building commissioning, often abbreviated as "Cx," is a quality-oriented process for achieving, verifying, and documenting that the performance of facilities, systems, and assemblies meets defined objectives and criteria."

ASHRAE Guideline 0: The Commissioning Process.

Recommissioning (RCx)

For a full understanding of the RCx process, consult the *Recommissioning Guide for Building Owners and Managers*, available for free at: www.canmetenergy.nrcan.gc.ca/rcx_guide.html

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.

New building commissioning (Cx) is an intensive quality assurance process that begins during the concept design of a new building and continues through detailed design, construction, start-up, occupancy, and the first year of operation. Cx ensures that the new building operates as initially intended, meeting the *owner's project requirements,* and that building staff are prepared to operate and maintain its systems and equipment.

Total Building Cx, Whole Building Design Cx, Integrated Design including Cx and *Initial Cx* are terms amongst others that are also used in the context of new building commissioning. These terms share similar goals, but result in different degrees of efforts and impacts. This Cx Guide discusses all aspects covered by those specific terms.

Existing building commissioning (EBCx) encompasses *recommissioning* and *retrocommissioning*.

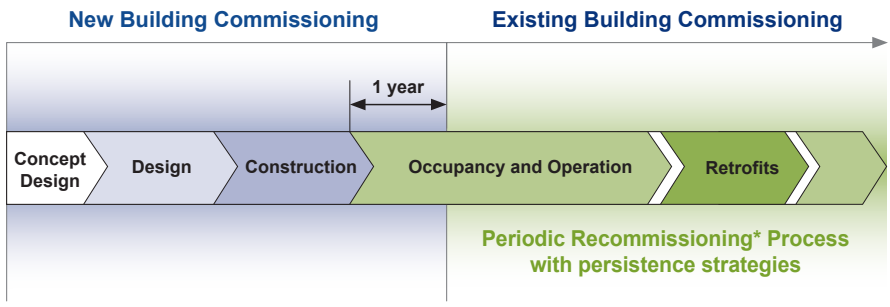
Retrocommissioning is a *commissioning* process that applies to existing buildings that were not commissioned originally. It seeks to improve how building equipment and systems function together. It often resolves problems that occurred during building design or construction, or addresses problems that have developed during the building's life. The inspection, diagnostic, and repair process ensures building equipment and systems are operating optimally to meet current occupant needs.

Recommissioning (RCx) is a re-optimization process for existing buildings that have already been either commissioned or retrocommissioned to ensure that the benefits from *commissioning* persist. It ensures building equipment and systems are operating optimally to meet current occupant needs. It provides a rigorous investigation approach to identify problems and integration issues. The primary focus of RCx is on identifying "low cost/no cost" operational improvements given the building's current usage in order to obtain comfort conditions and energy savings. It may be done alone or in concert with a retrofit project.

Important notice: *The term "recommissioning" (RCx) has been chosen as the generic term for commissioning existing buildings. Retrocommissioning, while similar, is defined as a one-time service to existing buildings that were not commissioned initially.*

Optimum building performance can be maintained over time following commissioning through recommissioning and persistence strategies such as ongoing commissioning. In ongoing commissioning, monitoring equipment and trending software is in place to allow for continuous tracking, and the scheduled maintenance activities are enhanced to include operational procedures. RCx is normally done every three to five years depending on ongoing commissioning rigor, or whenever the building experiences a significant change in use (see ***Figure 1***).

Figure 1 - Commissioning through building life cycle



* 3 to 5 years, depending on ongoing commissioning rigor and changes in building use.

Adapted from: International Energy Agency (IEA). "Commissioning tools for improved energy performance," Results of IEA ECBCS ANNEX 40, 2005, p. 14.

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 authority* (CxA) who verifies the building meets the owner's requirements at each stage of the commissioning process. Since each building project is unique, the CxA will adapt the process to meet the project's specific goals. This Cx Guide outlines a comprehensive process for reaching those goals. The scope of Cx for individual projects may differ, depending on size, complexity, and budget.

The parts of the *commissioning* process that are included in the CxA's scope of work can also vary. In the scope, the CxA typically is engaged to perform the following activities:

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 Authority/Provider/ Agent/Lead/Coordinator

These titles are often used interchangeably, and have historically been used to refer to an individual hired to lead a commissioning process.

In this guide, "*commissioning authority*" (CxA) is used and 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.

The *commissioning authority* should have past experience with that type of facility as well as a general knowledge of HVAC, lighting, controls, electrical systems, motors, and building envelope systems.

LEED® Canada requirements stipulate who is and who is not eligible to be a CxA on LEED projects (see also page 6).

D *Owner's Project Requirements* (OPR)

A document that details the owner's functional requirements for a project and expectations for how the building will be used and operated. These include project goals, measurable performance criteria, cost considerations, benchmarks, success criteria, and supporting information. Other terminology for OPR used elsewhere includes Project Intent or Owner's Requirements. OPR is used throughout this guide.

Develop *Commissioning Plan*

"Third-party commissioning has been a very good experience on this project. It has helped pick up a number of construction issues early in the project when they were easy to deal with. For example, piping changes were able to be made before the piping was filled. Just as importantly, it has highlighted how important it is that we check equipment when we receive it. We are now implementing our own QA procedure to go over equipment as soon as it arrives on site."

- Jim Domanko
Poject Manager,
Botting and Associates Alberta Ltd.
Calgary, Alberta, Canada.

Basis of Design (BOD)

BOD is the document that designers prepare to identify the decisions, systems, and selections made to satisfy each of the owner's project requirements and satisfy applicable regulatory requirements, standards, and guidelines. Equivalent terminology for BOD sometimes used includes Design Basis, Design Brief, Outline Specification, or Design Narrative. BOD is used throughout this guide.

Document the building's functional and performance requirements. The CxA 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 concept design phase of the project.

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.

Verify and document that systems perform as specified in the *OPR.* To ensure that the building will perform as expected, the CxA observes equipment start-up, writes *functional testing* procedures, 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 CxA ensures that training and documentation deliverables are included in the specifications, tracks their delivery, and produces a comprehensive training agenda (including building operations staff) for the equipment and systems.

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 building operation requires 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 is 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 optimal 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 the root cause of a problem to systematically ensure that building systems operate efficiently, effectively, and reliably, and ensures the improvements persist over time.

As this Cx 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 following employee turnover.

Because commissioning is an intensive quality assurance process that is essential to achieve high quality building delivery, it ensures the successful application of well-known building performance optimisation concepts, such as *Integrated Design Process, Net Zero Building, High Performance Building, Low Energy Building, Green Building* and *LEED*.

"Arguably the most important step in delivering the building the owner wants and paid for is ensuring the entire design and construction team commits to fundamental and best practice commissioning under the leadership of a knowledgeable and competent commissioning agent."

- Stephen Carpenter, P.Eng.
President, Enermodal Engineering Ltd.

New CSA Standard on Building Commissioning

The Canadian Standards Association (CSA) is presently developing a new national standard on Building Commissioning. The *CSA Z320 Building Commissioning Standard* is now available to the Public for a 60 day review period (May 2010) and is anticipated to be published in late 2010.

- Vanessa A. Mitchell, P. Eng.
Project Manager, Canadian Standards Association (CSA)

COMMISSIONING AND LEED® CANADA

What is the LEED Canada rating system?

The Leadership in Energy and Environmental Design (LEED) is a third-party certification program and an internationally accepted benchmark for the design, construction and operation of high performance green buildings. Managed by the Canada Green Building Council (CaGBC)[1], LEED for New Construction guidelines specify the criteria that define environmentally superior buildings in each of six categories:

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) and adapted by the Canada Green Building Council (CaGBC). It provides a standard for defining a "green building" and 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 ratings: Certified, Silver, Gold, and Platinum.

1 The Canadian rating systems are an adaptation of the US Green Building Council's (USGBC) LEED Green Building Rating System, tailored specifically for Canadian climates, construction practices and regulations. The rating systems are adapted to the Canadian market through an inclusive process that engages stakeholders and experts representing the various sectors of the Canadian industry.

"Commissioning provides owners with the understanding of how the installed systems meet their operational requirements and provides operators with ability to relate building operations back to the basis of design – these are crucial steps in an ongoing high performance building program."

- Joe Stano, *M.A.Sc., CMVP, LEED® AP*
GREEN UP Program Manager
Canada Green Building Council (CaGBC)

- Sustainable sites
- Water efficiency
- Energy and atmosphere
- Materials and Resources
- Indoor Environmental Quality
- Innovation

In order to be certified under LEED Canada NC, a project must meet all the prerequisites (seven total including Fundamental *Commissioning*) and achieve at least 40 of 110 possible points. Projects earn points by selecting credits and achieving the requirements from the six categories. The more points a project earns, the higher its LEED rating (e.g., Silver, Gold, Platinum). 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 CaGBC evaluates the certification package and grants a LEED rating along with a plaque and recognition on the CaGBC website. There are distinct rating systems for new construction (LEED Canada NC), existing buildings operation and maintenance (LEED Canada for Existing Buildings: O&M), and several other categories.

What are the LEED Canada NC commissioning requirements?

All buildings seeking LEED Canada NC (LEED Canada for New Construction and Major Renovations) certification must implement a fundamental *commissioning* process that meets the LEED Rating System guidelines. The LEED guidelines also identify a best practice *commissioning* credit 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 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 Canada certification should consult the most recent version of the LEED Canada Green Building Rating System for detailed information. More information about the LEED Canada can be found on the CaGBC's website at www.cagbc.org.

Who is Eligible to Provide LEED Canada Commissioning?

For Fundamental *Commissioning* the CxA would ideally be a person on the owner's staff. If this is not possible, a third-party firm is preferable, but for the purpose of this LEED Prerequisite the CxA can be from the same firm as one of the design team members, as long as that person is not directly responsible for project design, construction management, or supervision.

For the Best Practice *Commissioning* credit a fully independent third-party CxA is required to provide:

- Independent peer review of the schematic design
- Independent peer review of the construction documents
- Independent review of the contractor submittals

CHAPTER 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 following 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,"
Presentation to *Energy 2002*,
Palm Springs, CA, USA.

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:

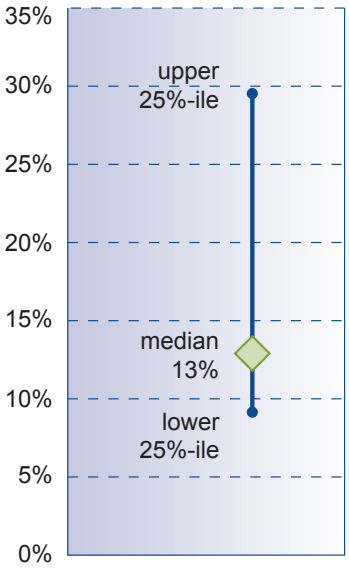
- Construction cost savings
- Improved coordination among design, construction, and occupancy
- Fewer system deficiencies at building turnover
- Energy savings
- Improved *indoor environmental quality*

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. *Commissioning* identifies and helps resolve potential problems, and therefore reduces costly change orders and contractor call-backs. This, in turn, helps keep the project on schedule and on budget.

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.

New Construction Commissioning Energy Savings



Source: Mills, E. *"Building Commissioning: A Golden Opportunity for Reducing Energy Costs and Greenhouse-Gas Emissions,"* Lawrence Berkeley National Laboratory (LBNL), 2009.

Savings from Commissioning

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 in USA found the following cost savings ranges:

Description	Range of Values
Value of Energy Savings	$0.22 - $2.58/m^2
Value of Non-Energy Savings	$3.12 - $92.86/m^2

Source: Mills, E., H. Friedman, T. Powell, N. Bourassa, D. Claridge, T. Haasl, and M.A. Piette. *"The Cost-Effectiveness of Commercial-Buildings Commissioning,"* Lawrence Berkeley National Laboratory (LBNL), 2004. http://eetd.lbl.gov/Emills/PUBS/PDF/Cx-Costs-Benefits.pdf

Improved Coordination Between Design and Construction

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 are at their peak, an owner must make important decisions in a short time frame. The CxA helps the owner with these decisions by explaining their consequences and how each choice affects the building and impacts the *Owner's Project Requirements*.

"Commissioning is more than just another energy-saving measure. It is a risk-management strategy that should be integral to any systematic approach to garnering energy savings or emissions reductions. Commissioning ensures that building owners get what they pay for when constructing or retrofitting buildings."

Source: Mills, E. ***"Building Commissioning: A Golden Opportunity for Reducing Energy Costs and Greenhouse-Gas Emissions,"*** Lawrence Berkeley National Laboratory (LBNL), 2009.

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. 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 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 call-back 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.

"In 25 years the Cx process has moved from startup Cx to a process that achieves its highest benefits during pre-design and occupancy. It forms a workable team and team leader at all phases of the project and leaves this concept with the owner for the life of the building. The quality process team focuses on the owner's project requirements and quality being delivered at all phases, from pre-design through the initial first year. In addition to delivering the 'near best' building to meet the owner's and occupants' needs, the cost benefits are high multiples of the cost reduction benefits over the life of the facility."

- Charles E. Dorgan, P.E., Ph.D, CxAP
Professor Emeritus
Engineering Professional Development
University of Wisconsin-Madison
Wisconsin, USA.

"Thanks to the work of the project's commissioning agent, this was the first time I felt relieved knowing that everything worked well before leaving the job. And we still haven't received any complaints or call-backs. The agent found that the heat wheel was not actually operating even when commanded, which is when I realized there was a value to commissioning after all. Had they not checked it out, neither I nor anyone else would have known anything was wrong."

- Al Hilcox
Nelco Mechanical contractor on Morningside Mall, Scarborough, Ontario , Canada. (LEED Canada candidate)

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 working correctly. The CxA 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 amongst the project team. The *commissioning* process identifies places where energy efficiency measures might fail, once they are integrated with the rest of the system. During construction, the CxA ensures that delivered equipment meets the *OPR,* the designer's plans, and the specifications. The CxA 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. Poor temperature control and poor 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

Many comfort and air quality issues stem from a poorly designed, installed, operated and maintained HVAC system. Commissioning addresses these problems directly through rigorous construction observation, functional tests, and staff training.

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.

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, which may lead to increased 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.

"One significant benefit of full service commissioning came to us unexpectedly. While the designers worked very hard to compile a controls sequence of operation that would meet our energy efficiency targets it ended up being too complicated for our operations staff. With the help of the independent commissioning agent, the design team was able to significantly simplify the sequences without compromising the integrity of the efficiency measures."

- Jim Sawers
Director, Campus Engineering
University of Calgary
Alberta, Canada.

"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."

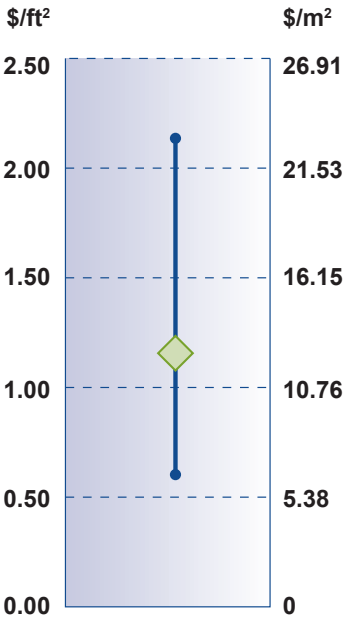
- Chad Dorgan
Commissioning Authority

COMMISSIONING COSTS

The cost of commissioning is different for each project, and depends on the project's size and 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 CxA'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 included. It is hard to precisely define the cost of *commissioning*, so it 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.

New Construction Commissioning Cost



Source: Mills, E., *"Building Commissioning A Golden Opportunity for Reducing Energy Costs and Greenhouse Gas Emissions,"* Lawrence Berkeley National Laboratory (LBNL), 2009.

Commissioning Costs

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

Description	Value or Ranges
Total Cx Cost	$6.56 - $22.17/m²
Cx Authority Fee as % of Total Commissioning Cost	74 - 86%
Cx Authority Fee as % of Total Construction Cost	0.3 - 1.1%

Source: Mills, E., H. Friedman, T. Powell, N. Bourassa, D. Claridge, T. Haasl, and M.A. Piette. *"The Cost-Effectiveness of Commercial-Buildings Commissioning,"* Lawrence Berkeley National Laboratory (LBNL), 2004. http://eetd.lbl.gov/Emills/PUBS/PDF/Cx-Costs-Benefits.pdf

It is important to note that when the dollar value of *commissioning* benefits is 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.

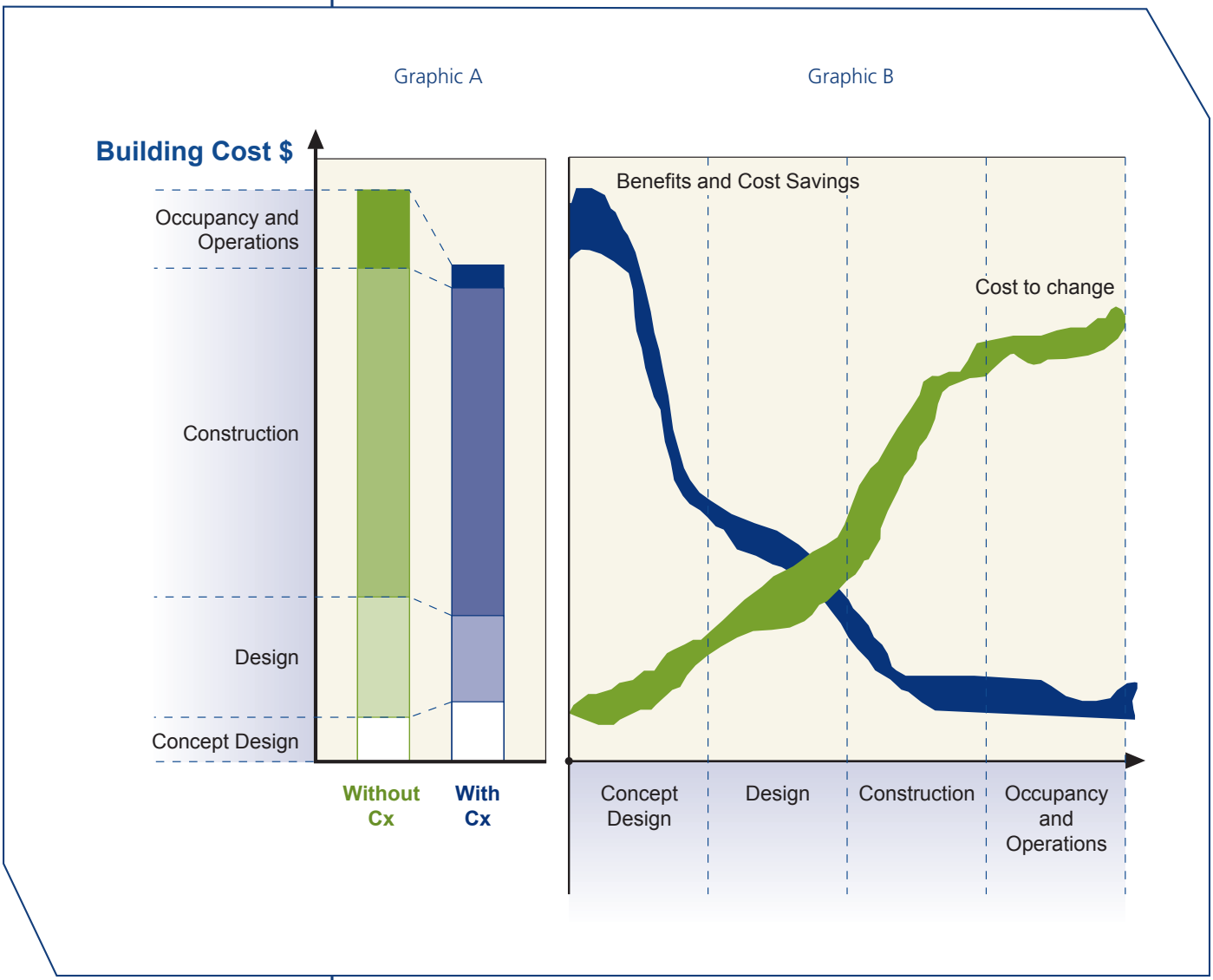
There are other factors that affect the cost of *commissioning*:

- Project Size – The cost for Cx ($/m²) decreases as project size increases because some of the documentation costs (such as developing *owner's project requirements*) are relatively fixed.
- Complexity of HVAC Systems – Some systems require large amounts of time to commission (such as under floor air distribution), whereas some types of equipment are simpler and sampling methods can be used (such as basic terminal units).
- Project Schedule – The longer the construction span, the more *commissioning* meetings there are required. Construction staff turnover can also increase, resulting in additional *commissioning* effort to coordinate among parties involved.
- Project Sustainability Goals – If the project is pursuing a green building rating, time and effort should be budgeted for unique requirements and specified documentation.
- Project Team's Familiarity with *Commissioning* – Owners, architects, engineers, and contractors familiar with *commissioning* require much less oversight during essential *commissioning* tasks.
- Level of Experience that the Operations / Maintenance Staff possesses – Highly experienced maintenance personnel require less training but may request more in-depth information from the contractors and *Commissioning* Authority during training sessions.
- Type of Construction Contract – *Commissioning* Authority involvement in projects occurs at different times, and with different levels of effort, than in traditional design-bid-build projects.

Figure 2 - The Commissioning Process: a true shift in project costs that results in real savings

Graphic A: Building costs comparison between projects with and without a Cx process in place.

Graphic B: Benefits and cost savings potential versus cost to implement change during Cx phases.



Adapted from: "The Commissioning Process for Delivering Quality Constructed Projects," University of Wisconsin-Madison, 2009.

CHAPTER 3

THE COMMISSIONING TEAM

Assembling the commissioning team is usually the first step – and one of the most important components – of kicking off a commissioning project.

This chapter answers the following questions:

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

Possible Commissioning Team Members

- Commissioning Authority (CxA)
- Building Owner or Owner's Representative
- Building Manager and Staff
- Design Professionals
- Contractors', Sub-Contractors', and Manufacturers' Representatives
- System Specialists

The Commissioning Team's Role

The commissioning team does not manage the design and construction of the project. Its purpose is to evaluate design and construction decisions based on the OPR, identify problems with equipment and systems installation and functional operation, and collaborate on how commissioning procedures will be scheduled into the construction process.

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.

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 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 CxA 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 CxA 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 CxA 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 CxA 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* (see Chapter 4).

Commissioning Authority (CxA)

The CxA can either be a member of the owner's staff, a design professional or contractor, or an *independent third-party commissioning provider*. The CxA is responsible for delivering the *commissioning* requirements for the building. The CxA leads the *commissioning* process and planning, and schedules, and coordinates the *commissioning* activities. During the design phase, the CxA 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 peer review comments on the design professionals' submissions, including the *Basis of Design*, design drawings and specifications.

During construction, the CxA visits the job site frequently, documents any concerns in the *issues log*, chairs *commissioning team* meetings and produces meeting minutes, oversees system start-up, directs *functional testing* of systems and their components, and verifies that all necessary documentation and training are completed fully and accurately. During occupancy and operations, the CxA 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.

CxA's Responsibilities

- Organize and lead the *commissioning team*
- Ensure that the owner's expectations are adequately documented in the *Owner's Project Requirements*
- Peer review design submittals
- Assist in documenting the *commissioning* requirements to be included in the specification
- Prepare and update the *Commissioning Plan*
- Review contractor submittals
- Organize, chair, and prepare meeting minutes for *commissioning* meetings
- Develop and maintain all review documents and issues logs (e.g., *design reviews*, submittal reviews, construction reviews, site visit reviews, start-up reviews, *functional testing* reports, training reviews, O&M manual review, end of warranty reviews)
- Observe construction
- Observe and document *functional testing*
- Review O&M documentation to ensure it is complete and applicable
- Produce the *Systems Manual*
- Prepare an agenda for staff training plans and teaching 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 the *commissioning* process. The owner's primary responsibilities are to support the *commissioning team* and to clearly communicate expectations about how the building should operate. It is equally important for the owner to be a strong advocate for *commissioning*. This means not only supporting the CxA's role, but also supporting the team's responsibility to resolve any issues that may arise. The owner's support enables the *commissioning* process to proceed smoothly, correct building problems, and thus maximize the benefits of *commissioning*.

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.

Building Owner Staff's Responsibilities

- Clearly communicate their expectations and goals for the project (e.g. define OPR)
- Determine Cx budget and hire the CxA
- Assign staff to represent the owner's interests during the commissioning process
- Work with the CxA to determine the scope and goals of the commissioning process
- Review and comment on reports submitted by the CxA
- Approve start-up and functional test completion
- Include future building staff in the process as soon as possible
- Consider the recommendations of the CxA when directing the construction team or accepting building 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.

During concept design, the building 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. Valuable insights 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 and original design intent well in advance of turnover and occupancy. Observing *functional tests* and participating in trainings provided by the contractors and the CxA 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, however, are limited to what appears in the specifications.

If specified, it is 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 CxA to ensure that *commissioning* milestones are integrated into the construction schedule, conducting performance tests (developed by the CxA) on the systems they install, helping resolve any deficiencies, and documenting system start-up. They are also responsible for providing system O&M documentation and training building staff.

Developing the Basis for Design

Consultants are responsible for developing the Basis of Design (BOD), which documents how each criterion in the Owner's Project Requirements is implemented in the design.

Contractors' or Manufacturers' Representatives Responsibilities

The contractors' and manufacturers' representatives required activities for commissioning are documented in the specifications. They would include:

- Attend pre-bid and pre-construction meetings
- Integrate commissioning milestones into the construction schedule
- Supply the CxA with all requested shop drawings and respond to requests for information
- Review *functional tests* developed by the CxA
- Assist the CxA during the functional test
- Work with the commissioning team to remedy deficiencies
- Prepare O&M manuals
- 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 CxA to document the owner's expectations for building operations in the *OPR* document, prepare their respective Bases of Design, and work with the Cx 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 CxA and ensure that *commissioning* is detailed in the specifications. During construction and into occupancy and operation they assist in resolving any design, equipment, installation or operational issues that arise. In complex projects, the design professionals may review *commissioning* and functional test plans and witness some *functional tests*.

It is important to note that *commissioning* does not relieve the consultants of responsibility for their design, site reviews, or sign-off with respect to any of the systems they have designed.

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*, construction observation and/or testing. Test results and recommendations from these specialists should be submitted to the CxA 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 AUTHORITY (CxA)

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

As discussed earlier in this chapter, the CxA heads up the *commissioning team*, facilitates and is responsible for the entire *commissioning* process. They must thoroughly understand the *commissioning* process and be able to develop the *commissioning* specifications. The CxA need not be a technical expert and can employ or partner with technology specialists. The CxA should, however, have hands-on experience with HVAC systems and controls. Since each project is unique, it is important to select a CxA whose expertise and experience most closely match the project's specific objectives and scope.

CxA Qualifications

The more complex the project, the more experience is required of the CxA. On projects with special or mission-critical needs like hospitals or labs, it is particularly important to select a CxA with directly relevant experience. Individual projects may require a CxA 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 CxA should have experience and up-to-date technical knowledge in the related fields of design, construction, and building operations. The CxA should also have extensive and recent hands-on field experience in all aspects of the *commissioning* process. The CxA can employ or partner with technology specialists who have expertise in systems with which the CxA is not experienced. The HVAC and controls systems are so central to *commissioning* that the CxA should have a good technical knowledge of the fundamentals, design, and operation of HVAC systems, and the implementation of controls systems.

"The Corporation of the City of Cambridge engaged a Commissioning Authority to review the building design, develop and incorporate a commissioning plan, verify best functional performance, equipment installation, and training, and write a commissioning report. The commissioning authority's systematic approach and quality assurance program were enormous contributors in achieving our LEED gold certification. We are assured that all building systems meet the operational, energy efficiency and comfort criteria providing a healthy work environment for city staff and the public."

- Slobodanka Lekic
Manager of Building Construction
City of Cambridge,
Ontario, Canada.

"I want to underline the immense benefits of having the Commissioning Agent as part of the Design Team from the outset for the project with one caveat: You need to identify the "right" Commissioning Agent. The CxA must have the required technical know-how, the operating experience with buildings and building systems, the training and the disciplined approach to documentation and verification expertise."

- Tom Kovendi, P.Eng.
Director, Portfolio Operations,
Toronto Office Portfolio,
The Cadillac Fairview
Corporation Ltd.
Toronto, Ontario, Canada.

Relevant experience

The CxA must have experience troubleshooting commissioned systems. The CxA should have previously served in a similar capacity on projects with similar needs. The adequate number of past similar projects required to determinate the CxA experience would depend on the complexity of the commissioning project to perform.

Communication and organizational skills

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

Objectivity

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

CxA Arrangements

The CxA'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. To prevent a *conflict of interest*, the CxA should report directly to the owner. For projects intended to be certified under LEED Canada, refer to the section "Who is Eligible to Provide LEED Canada Commissioning" in Chapter 1.

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 CxA. Owners that have multiple building projects can build internal *commissioning teams* to fulfill the CxA role in their facilities. When the owner's staff serves as the CxA, the lessons learned during the *commissioning* process can be invaluable in helping sustain building performance. Owners should, however, 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 CxA. The design professional's familiarity with the project may speed up the project schedule. When one is immersed in a project, however, 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 one's own work in an unbiased way.

In cases where the design professional also serves as the CxA, the potential for *conflict of interest* must be addressed. The design firm should present its 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 CxA, 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, such as obtaining and analyzing data from portable data loggers or the building automation system (Energy Management and Control System (EMCS) see Page 40) or troubleshooting systems. Third, with a design engineer or architect in charge of *commissioning*, 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 CxA, 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 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.

! Evaluating CxA Qualifications

When evaluating CxA qualifications, owners should take the following steps:

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

D *Conflict of Interest*

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

Independent Third-Party CxA

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

Sample Documents

Sample RFP documents are available for download at: www.canmetenergy.nrcan.gc.ca/cx_tools.html

Independent Third-Party CxA

An independent third-party CxA is an individual consultant or firm hired directly by the owner. The CxA can be contracted through the designer's firm, but a third-party CxA 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 design or construction. This arrangement offers owners the greatest assurance of CxA objectivity. When choosing a third-party CxA, owners should carefully assess their experience *commissioning* similar projects.

The Selection Process

As when evaluating CxA 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 CxA 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 CxAs are offering comparable scopes of work.

Selection by Qualification

With selection by qualification, the lead authority 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 CxAs' 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 online at the CanmetENERGY Website[2]. Each has its own set of requirements and gives a different title to the individuals 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. It is however important to remember that certification is not a substitute for relevant experience. Owners should carefully evaluate the CxA's qualifications, regardless of whether or not they are certified.

"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 clients 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

2 See: www.canmetenergy.nrcan.gc.ca/cx_authority_certification.html

CHAPTER 4

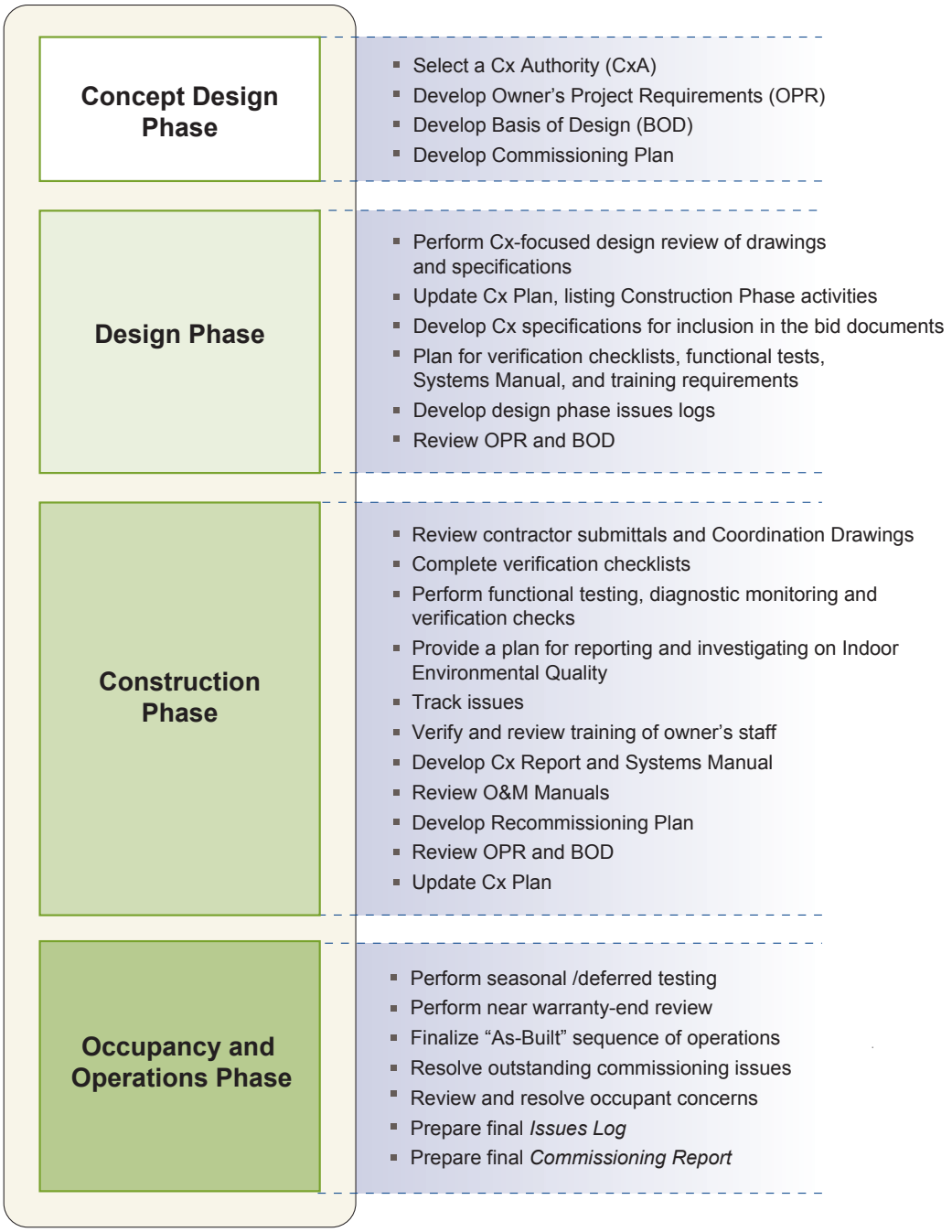
THE COMMISSIONING PROCESS

Commissioning starts at concept design and continues through the first year of occupancy and operation. In a sense, however, commissioning never ends. Even after occupancy, *recommissioning* is necessary to maintain the building's proper 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?

COMMISSIONING (CX) PROCESS MAIN ACTIVITIES AND DELIVERABLES



THE COMMISSIONING PROCESS

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

This chapter describes the typical *commissioning* activities which occur during each phase of the building project; concept design, detailed design, construction, 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 CxA 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.

CONCEPT DESIGN

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

During concept design the CxA helps develop the *Owner's Project Requirements*. This important document will guide the design, construction, and operations of the future building.

Select a CxA

During concept 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 CxA.

Concept Design Phase Deliverables

- *Owner's Project Requirements* (OPR) Document
- Consultants' *Basis of Design* (BOD)
- *Commissioning Plan* outline listing design phase activities

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 state-wide new-construction energy efficiency program in California. Additionally, various organizations such as ASHRAE, BCA, NEBB, ACG and CCC all make sample documents available.

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

LEED® Canada Requirements

The commissioning prerequisite in LEED requires:

- Organizational chart of the commissioning team
- Owner's projects requirements
- Basis of design
- Commissioning plan
- Table of contents of operation and maintenance manuals
- Commissioning report

"The commissioning process builds upfront the achievable benefits and success of a project by establishing the essential elements on which decisions and actions should be based during the process. The investment to start Cx early and correctly in a project results in higher and earlier benefits for the owners of the buildings constructed."

- Alexandre Monarque, eng.
C. Adm. QCxP, CMVP
Project Manager, CanmetENERGY
Natural Resources Canada

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

A well-qualified CxA 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 CxA into the project early has several advantages:

- Architects and design engineers will find it easier to implement the CxA's suggestions when they are received during concept design. Pivotal decisions like system selection are often made at this time, and even informal discussions between the CxA and the design team can have a significant impact.
- The CxA'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 CxA's presence as a team member from the beginning increases the likelihood that other team members will recognize and appreciate the value of *commissioning*.

Basis of Design (BOD)

A written BOD describes the concepts and features the designer intends to incorporate into the design to meet the *Owner's Project Requirements*. The BOD is a living document and is updated as the owners change or the building requirements evolve. At a minimum, the *BOD* includes:

- Objectives and purpose of each system, and how this objectives will be met
- Indoor/outdoor design conditions
- Occupancy, usage, and schedule assumptions
- Internal loads assumptions
- Zoning descriptions
- Ventilation requirements
- Envelope requirements
- Equipment sizing and criteria used
- Basic sequences of operation
- Energy and water efficiency strategies
- Design intent for efficiency measures
- Reference to pertinent local, provincial, or federal compliance documents

Hold a Concept Design Phase Commissioning Meeting

The concept design phase *commissioning* meeting introduces the CxA to the team and helps refine the scope, budget and rigor of the *commissioning* effort. The CxA 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 CxA begin to identify each team member's responsibilities and communicate the owner's expectations for building operation.

Develop the Owner's Project Requirements (OPR)

The *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 *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 CxA to evaluate the project's development.

The CxA's primary role in concept 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 CxA. 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*. On LEED projects, the *OPR* is developed during concept design in tandem with LEED goals.

Develop the Basis of Design (BOD)

A *BOD* is developed by each of the design consultants for their discipline. The *BOD* lays out the major owner's requirements such as as local climatic conditions, occupancy levels, space conditions required, process and efficiency requirements. It documents concept design decisions on the systems and types of products selected for incorporation. It lays out the applicable regulatory requirements, standards, and guidelines to be followed. It includes both narrative descriptions and lists of individual items that the design will be based on. Each *BOD* is a living document that the CxA reviews and works with the consultants to update throughout design to ensure the *OPR* is met.

D *Owners Project Requirements (OPR)*

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

D Developing the *OPR*

A workshop can be used to develop the *OPR*. A guide to developing the workshop is available online at: www.canmetenergy.nrcan.gc.ca/cx_opr_workshop_guide.html

See the LEED Canada NC 2009 Reference Guide for more information on developing an *OPR*.

D *Basis of Design (BOD)*

BOD is the document that designers prepare to identify the decisions, systems, and selections made to satisfy each of the owners project requirements and satisfy applicable regulatory requirements, standards, and guidelines. Equivalent terminology for *BOD* sometimes used includes Design Basis, Design Brief, Outline Specification, or Design Narrative. *BOD* is used throughout this guide.

Model *Cx Plan*

A Model *Commissioning Plan* and Guide Specifications available from PECI details the commissioning process for new equipment during both the design and construction phases for larger projects. Going beyond commissioning guidelines, the document provides boilerplate language, content, format and forms for specifying and executing commissioning.

PECI Model Commissioning Plan and Guide Specification

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 CxA 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 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 concept 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 concept 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.

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, with descriptions of the activities and work products in each phase of design and construction
- 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 and verification procedures
- Detailed description of monitoring procedures
- Recommended training activities and agenda
- Construction documents and contractor submittal review procedure

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 reality, its systems and operations continue to reflect the owner's goals.

During design, the CxA reviews design and construction documents, incorporates *commissioning* into bid documents, and plans for *commissioning* activities that will occur during construction. Throughout, the CxA keeps a *issues log* to track issues that require further attention.

Design Phase Deliverables

- Regular commissioning progress reports
- Reviews of the *OPR* and *BOD* documents
- Design Phase *Issues Logs*
- Updated *Commissioning Plan,* listing:
  - » Construction Phase activities
  - » Commissioning specifications for inclusion in the bid documents
- Verification checklists and test procedures

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 CxA carefully reviews design documents for clarity, completeness and compliance with the *OPR.* This includes the *Basis of Design*, in which designers describe in detail the concepts and features they intend to incorporate during the schematics phase and explain their reasoning and assumptions for choices made. The CxA will also develop 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.*

LEED® Canada Requirements

The Fundamental commissioning prerequisite in LEED requires the CxA to conduct a review of the *Owner's Project Requirements (OPR)* and *The Basis of Design (BOD)* documents during concept design documents phase and to back-check the design documents against the OPR and BOD in subsequent design submissions.

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.*

LEED® Canada Requirements

The Best Practice Commissioning credit in LEED requires CxA review of contractor's submittals.

! *Design Review*

Design Review is a process in which the CxA examines design documents to help ensure a design is likely to meet the *owner's project requirements*. *Design reviews* both enhance design and foster 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

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

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

Some of the most important decisions for the CxA 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 to identify equipment faults during *functional testing*
- Identification and access of test ports, sensors, and in-situ measurement devices for use in *functional testing* and re*commissioning*
- Identification of any potential barriers to good O&M in the facility design and suggestions for alternative approaches

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

The CxA should carefully explain the impacts of the issues he or she raises; however, it is not the role of the CxA to approve recommendations resulting from the *Issues Log*. It is the owner's responsibility to evaluate the CxA's recommendations, discuss them with the design team, and decide whether or not to require that the issue be resolved.

Update the *Commissioning Plan*

During the design phase, the following elements should be updated and/or added to the *Commissioning Plan:*

- Components, systems and assemblies to be commissioned
- *Commissioning* schedule during construction and occupancy to the end of 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 Specifications

Commissioning specifications define the contractors' *commissioning*-related responsibilities, including equipment installation, start-up, documentation, and *functional testing*. It is essential to include *commissioning* specifications in the *contract documents*. 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* specifications, although in practice, the CxA will likely draft the language and review the specifications before they are released. The *commissioning* specifications should describe:

- How contractors are expected to interface with the CxA'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 information required for the equipment *Operation and Maintenance (O&M) Manuals* and the deadline for their delivery to the CxA

LEED® Canada Requirements

The Fundamental Commissioning prerequisite in LEED requires that a commissioning specification be included in the construction documents.

! 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.

D Issues Log

A formal and ongoing record of problems or concerns, and their resolution, that have been raised by the CxA or any member of the commissioning team during the course of construction. Issues logs usually deal with three areas: installation related reviews, start-up reviews, and functional performance testing.

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 CxA to discuss the process and its requirements at a pre-bid meeting and by providing sample *test protocol*s and other documentation to contractors in advance of the submission deadline.

Begin Planning for Verification Checks, Functional Performance Tests, O&M and Systems Manuals, and Training Requirements

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

Maintain Commissioning Issues Log during Construction

The CxA should maintain formal and ongoing record of problems or concerns, and their resolution, that have been raised by the CxA or any member of the *commissioning team* during the course of construction. Sometimes called a deficiency list, an *Issues Log* usually deals with three areas: installation related reviews, start-up reviews, and functional performance testing.

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

CONSTRUCTION

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

The CxA continues to track issues that need further attention in an *Issues Log*. If *commissioning* has not started before construction, the CxA can still conduct all the activities of the construction, occupancy and operations phases. The CxA will, however, still have to review the design in order to understand it, and will still have to review the *OPR and BOD*. If *commissioning* requirements were not included in the original specifications, their inclusion during construction may well result in change orders, which will be an added expense to the owner. However, recommendations from the CxA will usually result in reduced operating and maintenance costs down the road. The sooner the CxA can be brought in, the better. Even with a late start, *commissioning* can significantly benefit overall building operations.

Construction Phase Deliverables

- Updated OPR and BOD
- Updated *Commissioning Plan*, with construction schedule
- CxA reviews of contractor submittals
- Completed *verification checklists* and functional performance test results
- Report of training completion
- Draft *Systems Manual*
- Minutes from commissioning meetings
- Ongoing *Issues Log* updates
- Periodic commissioning progress reports
- Draft *Commissioning Report*

Commissioning and MasterFormat™

MasterFormat™ is the specifications-writing standard for commercial building design and construction. In the *2004 Edition,* (Updated January 2009), it states that a summary of the commissioning scope should be placed in Division 01, "General Requirements," under 01 91 13 General Commissioning Requirements

In each of the other divisions there are titles for commissioning, where requirements relevant to that division should be placed (e.g., 23 08 00 Commissioning of HVAC, 25 08 00 Commissioning of Integrated Automation and 26 08 00 Commissioning of Electrical Systems). 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 Construction Specifications Canada website: www.canmetenergy.nrcan.gc.ca/cx_canada_construction_documents.html.

Installation & Performance

The Fundamental Commissioning prerequisite in LEED Canada requires verification of the installation and performance of the systems to be commissioned.

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.

LEED® Canada Requirements

Submittals Reviews
The Best Practice commissioning credit in LEED requires Cx review of contractor's submittals.

Installation & Performance
The Fundamental Commissioning prerequisite in LEED requires verification of the installation and performance of the systems to be commissioned.

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.

Conduct Construction Phase Meetings

Periodic meetings of the *commissioning team* are at the heart of the *commissioning* process. The CxA 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 *commissioning* kick-off meeting introduces the team members to the schedule of *commissioning* activities, roles and 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 CxA for inclusion in the *Commissioning Plan*.

Throughout the construction process, the CxA attends planning and job site meetings to stay informed on the construction progress. As needed, the CxA attends regular construction meetings and holds a line item on the agenda. Later in construction, the CxA 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 Construction Related Documents

The CxA needs to 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:

- Reviews of contractor submittals for details on energy efficiency, maintenance requirements and other details required to ensure compliance with the OPR
- Equipment and sensor selection and testing tolerances
- Manufacturers' recommended start-up tests
- Warranty data
- Controls submittals for inclusion of required control points
- Controls submittals for functional capabilities in trending points
- *Operation and Maintenance (O&M) Manual* content

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

Review *Operation and Maintenance Manuals*

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 CxA ensures that the *O&M Manuals* are complete, relevant, and organized, and verifies that the information is clear, correct, and available for use during observation, testing, and training.

Perform Ongoing Construction Observation

Throughout construction, the CxA attends job site meetings, observes the construction process, and updates the *Issues Log*. If the CxA finds any conditions that might affect the ability of the building's systems or their operation to meet the owner's performance expectations, they are recorded in the *Issues Log*. The CxA also uses the *Issues Log* to track the resolution of these findings. 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 CxA verify correct installation and, after building turnover, help building staff in their maintenance tasks.

The CxA is usually responsible for creating the *verification checklists*, but may use checklists developed by others (e.g., the manufacturer or generic lists from organizations such as PECI) after review and editing as required to ensure they are appropriate and applicable to the particular job. Contractors complete the checklists as they execute equipment start-up, often with CxA oversight. In some cases, it may be possible for the CxA to use spot checks or sampling to ensure that *verification checklists* have been completed accurately.

Perform Functional Performance Testing

Nearing the end of the construction phase, the CxA will spend a great deal of time doing functional performance testing and monitoring to gather data on how the systems operate. Testing and monitoring 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*.

! Managing the Construction Schedule

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

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*.

Functional Performance Testing (FPT)

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

Automatic Building Controls

These systems have different names. This Guide uses the term energy management control system (EMCS) when referring to automatic building controls. Other commonly used terms include:

BAS – Building Automation System

BMS – Building Management System

DDC – Direct Digital Control System

SCADA – Supervisory Control and Data Acquisition System

Data Logger

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

In most cases, it is impossible to naturally observe every possible operating regime. The *commissioning team* must, therefore, conduct functional performance tests to take the system through its paces while observing, measuring, and recording its performance in all the key operating modes.

Test procedures are prepared, witnessed, and documented by the CxA and conducted by the contractors, although other arrangements are possible. The CxA 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 CxA will meticulously record all the activities and observations on a pre-defined data sheet, and then ensure that all systems are returned to a "normal" state. During functional performance testing, the CxA uses an *Issues Log* to track any performance issues that may arise, along with 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.

As equipment or systems come on-line, their performance can begin to be monitored. Meters, portable data loggers, and the building's energy management control system (EMCS) are used to gather data that allow for observation of the building's performance under various modes and operating conditions. Time series data is collected and analyzed, allowing sampling and storing of various parameters at appropriate intervals.

Some of the variables typically trended include operating parameters, weather data, equipment status and runtimes, actuator positions, and set points. From this collected data, the *commissioning team* can calculate key metrics and perform statistical analysis, create data plots that show hourly, daily, weekly, or monthly trends, or illustrate how one parameter varies with respect to changes in another. By analyzing this information, the CxA can characterize the performance and verify 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 different systems. The extent of these capabilities determines 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.

When Equipment Fails to Perform

If equipment does not perform as specified during functional performance testing, the CxA will document the issue in the *Issues Log* and work with the project team to find a proper solution. For issues outside the contractor's original scope of work the CxA will communicate the potential consequences to the owner, who must decide whether corrective measures justify additional costs. Additional scope should be added for the CxA to work with the project team to achieve acceptable performance on these additional items.

Test Protocol

A *test protocol* is a 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 for the test
- *Acceptance criteria*
- Precautions
- Prerequisites for testing
- Detailed procedural steps for testing
- Procedure for returning equipment to normal operating conditions
- Required analysis
- Required sign-offs

Develop Commissioning Report and Systems Manual

After all construction phase *commissioning* tasks are complete, the CxA 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 requirements of 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 CxA, if it is in the *commissioning* scope of work. The *Systems Manual* should not be confused with the *O&M Manuals,* which makes up only part of the more comprehensive *Systems Manual.* The *Systems Manual* also includes information collected during the *commissioning* process and provides a system-based, rather than equipment-based perspective on the building.

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 within the specifications. The control system may be used to help test equipment performance and system interactions.

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 concept design and the most critical or failure – prone components and systems must be weighted most heavily when selecting the sample. The CxA's scope of services and the specification should define this in detail.

Resource

Prepared by PECI and LBNL for the U.S.-Department of Energy (DOE) and the California Energy Commission's Public Interest Energy Research program, a library of functional performance test forms and guidance documents is available in the Functional Testing Guide, available online at: www.canmetenergy.nrcan.gc.ca/cx_ftguide.html.

LEED® Canada Requirements

The Fundamental Commissioning prerequisite of LEED requires a *Commissioning Report* and that training requirements have been completed. The additional Best Practice Credit requires a *Systems Manual* be developed.

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 CxA and provides an overview of the commissioning program undertaken and the result achieved. It usually includes:

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

Develop Recommissioning (RCx) 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. After occupancy the *commissioning* work is not over, because maintaining the building's optimal performance requires periodic *recommissioning*. A *Recommissioning Plan* will help owners and building staff plan and prepare for *recommissioning*. The CxA can help draft the *recommissioning* plan. 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

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 CxA 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 CxA will interview *commissioning team* members, including the building staff, to determine training needs. The requirements for training must be outlined in the specification, so that the CxA can verify that they are carried out as intended.

If the *contract documents* specify that contractors', designers', or manufacturers' representatives are to conduct trainings, the CxA may recommend agenda items or oversee these sessions and provide a written review on the completeness of the training.

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 video-record training sessions so future staff members can benefit from the training.

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 CxA during the initial occupancy period is essential to the success of the commissioning process.

LEED® Canada Requirements

The Best Practice Commissioning credit in LEED requires a plan for resolving occupant Indoor Air Quality (IAQ) concerns, a plan for resolution of outstanding Cx issues within 1 year of construction completion and a 10-month review of building operation to address the issues identified.

Resolution of Outstanding Commissioning Issues

It is common for some *commissioning* issues to remain unresolved, even after turnover. When this is the case, the CxA can assist the owner in coordinating contractor call-backs, 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, rather than the CxA, to decide whether or not to resolve a particular issue. This is particularly true if there are additional costs involved.

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 the most reliable results. Testing that was delayed due to site and equipment conditions or inclement weather will also be completed during occupancy.

Near Warranty-End Review

Shortly before the expiration of the contractor's usual one-year warranty, the CxA should return to the building to review system operation and interview building staff. The CxA can assist staff in addressing any outstanding issues from construction, performance problems or warranty issues. The CxA may also add information about the facility to the *Commissioning Report* at this time.

"Commissioning services provided quality assurance to ensure systems were installed properly and operated as designed and intended. This service is a crucial step in developing our sustainable buildings. Advanced-level BAS knowledge delivered by the commissioning team was a critical component to the success of the project."

- Richard Zhang P.Eng.
Sustainable Building Engineer
The Regional Municipality of York,
Ontario, Canada.

Occupancy and Operations Phase Deliverables

- Summary report from seasonal testing
- Warranty review of each system
- "As -Built" sequence of operations
- Findings from the Occupancy and Operations Phase for inclusion in the final *Issues Log*
- Final *Issues Log*
- Final *Commissioning Report*
- Plan for *recommissioning* or ongoing Cx

CHAPTER 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 O&M 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?

D ***Recommissioning*** (RCx) is a re-optimization process for existing buildings that ensures the benefits from *commissioning* persist. It ensures building equipment and systems are operating optimally to meet current occupant requirements. It provides a rigorous investigation approach to identify problems and integration issues. The primary focus of RCx is on identifying operational improvements given the building's current usage in order to obtain comfort conditions and energy savings. It may be done alone or in concert with a retrofit project.

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:

- Considering O&M during the design phase
- Developing well laid out and complete *O&M Manuals*
- Writing clear and concise *"As-Built" Sequences of Operation*
- Conducting ongoing training of building staff
- Preparing preventive maintenance plans
- Implementing performance tracking
- 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 concept design and design. At this time, the CxA will identify any potential barriers to good O&M in the facility design and suggest alternative approaches. CxA recommendations may include the following:

- Adequate maintenance clearance and easy access for changing filters; greasing bearings; tightening belts, cleaning evaporators and condensers; removing and replacing coils, motors, etc; winterizing cooling equipment; and so on.
- 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 will result in significant improvements to ongoing operations such as 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 created early in the project, it can also serve as a checklist to ensure all contents have been received. It may 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 after occupancy. If the CxA 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 CxA may use information gathered during the *commissioning* process, such as equipment submittals, design documents, control strategies, as-built sequences of operations, and copies of the *commissioning* tests to form the *Systems Manual*. 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.

It is important to note that contractors are generally required to produce the *O&M Manuals* as written in the specifications. For manuals to be optimally useful, the specifications should include the level of detail, the layout and organization requirements, all items required in the manuals and their due date.

The CxA scope should include providing a detailed outline of the *O&M Manuals'* requirements for the specifications and reviewing the draft and final manuals to ensure they meets the specifications and the owner's needs.

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 should provide a good overview, but they generally need to be updated and expanded for the as-built version. This version can then be included in the *Systems Manual.* 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.

O&M Manuals typically include:

- Installing contractor contact information
- Supplier's and or manufacturer's contact information
- Product data (tag number, make, model, serial number, all options identified)
- Test data and performance curves (for pumps, fans, chillers, etc.)
- Installation instructions
- Operation requirements
- Preventive maintenance requirements
- Parts lists (replacement parts, special tools, local sources)
- Troubleshooting procedures specific to the equipment design and application
- Equipment submittals
- Design documents
- Control strategies
- *Sequences of Operations*
- Copies of commissioning test reports
- Copy of Testing, Adjusting and Balancing report
- Warranty information
- Single line schematic of control drawings
- Field wiring diagrams for line voltage and controls connections

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 the systems and equipment installed in their building. Staff observation of *functional testing* may be their first training experience in the new building.

The CxA 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, hands-on site demonstrations, and a site orientation. This is best done during construction, while the building's walls are still open and access points are visible. This is 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 *Owners' Project Requirements* and *Basis of Design*. This gives building managers and operators a thorough understanding of why the facility was constructed, how it is intended to operate, and its limitations.

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

Ongoing Training

Well-trained operators who have learned 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 training courses offered by local training organizations and equipment manufacturers.

! 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 CxA'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.

Suggested Building Staff Training Topics

- Description of systems/equipment and their warranties
- Operating 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 sensitive equipment
- Common 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 *O&M Manuals*, and their location onsite
- Building walk-through
- Review of related *OPR* 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

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 should consist 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, and 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. This is 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 assess 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 that 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 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*.

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.

- Unique equipment identification number
- Name plate information
- Manufacturer's name
- Vendor's name and telephone number
- Equipment location
- Date installed
- 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 experience tenant complaints, high energy costs, or unexpected equipment failure. In fact, some 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 their buildings and prioritize improvements. A building should be benchmarked at the end of the first year of occupancy.

Several online resources are available to help with building benchmarking. One of the most comprehensive and widely applicable is the ENERGY STAR® Portfolio Manager [3] from the US Environmental Protection Agency. There are also Canadian initiatives available or underway. Natural Resources Canada (NRCan), through the Office of Energy Energy (OEE), has a national energy use database known as the Commercial and Institutional Energy Use Survey 2000 on the OEE website.

ENERGY STAR Portfolio Manager is an interactive energy management tool that allows tracking and assessing energy and water consumption across a portfolio of buildings. It can help set investment priorities, identify under-performing buildings, verify efficiency improvements, and receive recognition for superior energy performance. This web-based tool uses 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.

Benchmarking Tools

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

Commercial and Institutional Energy Use Survey 2000
http://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/data_e/databases.cfm?attr=0

LEED® Canada Requirements

Measurement and Verification Energy & Atmosphere Credit 5 (EAc5) uses monitoring for ongoing accountability and optimization of building energy and water use over time.

Resources

Energy Information Systems (EIS) can be used to harvest the data from a control system, and perform powerful analysis and reporting.

Software for ongoing optimization

CanmetENERGY has developed a software which continuously scans the electromechanical components of the building. With 800 logical rules and 275 indices of performance, it detects and diagnoses the inconsistancies of operation and bad system performance while also anticipating failures. Its diagnoses make it possible to maintain long-term optimized operation and to prevent comfort problems and overconsumption of energy. The use of the software, commercialised under the name of DABO™, has led to energy saving of 10% to 25%. Source: www.canmetenergy.rncan.gc.ca/cx_ongoing_software.html

3 During the completion of the present Cx Guide, Natural Resources Canada's Office of Energy Efficiency (OEE) was involve in the development of a Canadian version of the US based ENERGY STAR® Portfolio Manager. Additional information will be available online at: www.canmetenergy.nrcan.gc.ca

"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 recommissioned the three buildings and discovered another $273,000 in savings!"

- George Denise
General Manager for Facilities
Cushman & Wakefield
at Adobe Systems Incorporated
San Jose, Cal, USA

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 understand how the building is operating by analyzing data on systems operations over time. In order to be useful, a control system must have enough memory to trend and some way to archive data. It is important to understand how much data the system stores and whether it can be downloaded and saved to a hard drive.

When building staff are not familiar with the trending capabilities of the control system, or are unskilled in setting up trends and retrieving collected data, it may be helpful to bring in the controls vendor or CxA 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, important metrics can be defined and evaluated. Illustrative diagnostic charts can be "canned" to allow collected data to be reviewed in the most informative format to diagnose particular problems in a specific building.

If it is part of the *Commissioning Plan*, a skilled *commissioning team* member can set up "smart alarms" in the control system which 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 recommissioninig (RCx) occurs when a building that has already been commissioned undergoes another commissioning process to help keep it operating optimally.

A plan for *recommissioning* should be 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.

Recommissioning is similar to *new building commissioning*, although the phases and goals are slightly different. *Recommissioning* typically begins with the establishment of the Current Facility Requirements (CFR) which is a review of the *Owner's Project Requirements* to determine if there have been any changes. When changes have occurred, systems are reviewed to determine if corresponding changes in equipment or operations are necessary. Next, systems are inspected, 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 whether 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 whether updates or additional training are required. Finally, the CFR is produced (e.g. *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 to apply towards performing subsequent *recommissioning* projects.

Time to Recommission?

Affirmative 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 controls 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 buildings over 50,000 square feet: Has it been five years or more since the previous commissioning or recommissioning process?
- Have any major energy consuming systems or controls been replaced recently?

Note : See also Chapter 4 of the ***Recommissioning Guide,*** and the ***RCx Pre-Screening Tool*** available for free at: www.canmetenergy.nrcan.gc.ca/eng/rcx_guide.html.

Recommissioning (RCx) Guide

This free RCx Guide illustrates how to successfully use RCx as a cost-effective method to reduce expenses and increase revenue through improved building operations. This document is a guide to better understand the impact of the RCx process and communicate to others about issues, benefits, and need for staff involvement. Download this RCx Guide at: www.canmetenergy.nrcan.gc.ca/rcx_guide.html.

Recommissioning (RCx) Pre-Screening Tool

This free tool helps select the best building candidate(s) for RCx. Prioritizing a portfolio of buildings and selecting those with the greatest likelihood for success can assist with long-term planning and enable owners to capitalize on short term paybacks. This tool is designed to be used in the planning phase of the standardized RCx process. Download this RCx Tool at: www.canmetenergy.nrcan.gc.ca/rcx_pre-screening_tool.html.

Recommissioning (RCx) Resources

Natural Resources Canada's CanmetENERGY and Office of Energy Efficiency (OEE) develop RCx standards, guides, tools, technical training, case studies, etc. More information is available online at: www.canmetenergy.nrcan.gc.ca/eng/rcx.html.

LEED Canada EB: O&M 2009

LEED Canada for Existing Buildings: Operations and Maintenance 2009 (LEED Canada EB: O&M 2009) is a certification system designed to improve the energy, systems, and operational performance of existing buildings. This LEED rating system helps building owners and operators measure operations, improvements and maintenance on a consistent scale, with the goal of maximizing operational efficiency while minimizing environmental impacts. It addresses whole-building cleaning and maintenance issues (including chemical use), recycling programs, exterior maintenance programs, and systems upgrades.

The credit deal with conducting energy audits and then implementing energy/water recommendations. Cx includes an ongoing Cx program that has elements of planning, system testing, performance verification, corrective action response, ongoing measurement, and documentation to pro-actively address operating problems. Best management practices including documenting and assessing regulated O&M practices are used to ensure energy and water efficiency achieved and persist.

Ongoing Commissioning

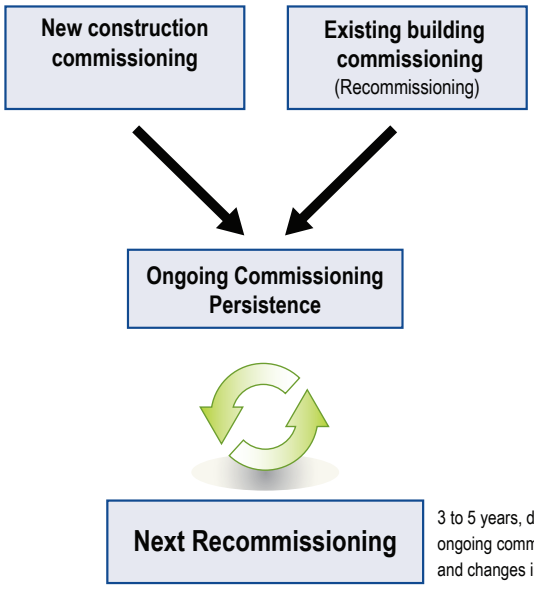
Optimum building performance can be maintained over time following commissioning through persistence strategies such as ongoing commissioning which is an iterative process of RCx actions that ensure persistence between RCx rounds. In ongoing Cx, monitoring equipment and trending software is in place to allow for continuous tracking, and the scheduled maintenance activities are enhanced to include operational procedures. RCx is normally done every three to five years depending on ongoing Cx rigor, or whenever the building experiences a significant change in use (see ***Figure 3***).

Ongoing *commissioning* provides building staff with detailed instructions on performing strategic O&M tasks that help retain both Cx and RCx benefits. While RCx is often performed every three to five years and provides a snapshot of how a building is operating at a given time, ongoing Cx is more continuous and dynamic in that in encompasses performance tracking strategies.

Ongoing Cx involves both the building staff and monitoring equipment for ongoing diagnostics. It has an emphasis on training of the building staff, and empowering them to use the monitoring equipment through analysis training, automation of diagnostics, and "smart" alarms.

Ongoing monitoring is used to establish a baseline of appropriate operation. Deviations from that baseline indicate opportunities for operational improvements and equipment repairs. While RCx is still needed, it should be required at less-frequent intervals, and should be much more tightly focused because of the availability of trained staff and the analysis of monitored data due to the ongoing Cx activities in place.

Figure 3 - Building operation optimization approaches over lifetime of a building.



Source: Natural Resource Canada's CanmetENERGY. "Recommissioning (RCx) Guide for Building Owners," ISBN 978-1-100-10035-7, Cat. M39-123/2008E-PDF, 2008, available at: www.canmetenergie.rncan.gc.ca/rcx_guide.html.

D Ongoing commissioning, Monitoring Based Commissioning (MBCx) and Continuous Commissioning® (Registered to the Texas Engineering Experiment Station) are all different names and methods for doing building performance tracking and monitoring over time.

CHAPTER 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

The growing awareness of Cx in the market has led to the development of several helpful tools and resources. To become informed about commissioning, start exploring the resources listed in this Guide, explore online resources, and begin talking to others about their experiences, including designers and contractors. An up-to-date list of Cx resources is maintained at the Natural Resources Canada's CanmetENERGY Website: www.canmetenergy.nrcan.gc.ca/cx_e.html.

Determine what local, utility and government resources are available

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

Start early! Identify an upcoming project that could benefit from commissioning – possibly 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 CxA to explain its benefits to staff. Identify any individuals who may need convincing and be sure they are present.

Identify a project for commissioning and specify the project scope and objectives

Identify CxAs working in the area and begin investigating their qualifications. Ask whether the CxA's experience is relevant to the project's needs. Once a CxA is selected, the owner and CxA must work together to clearly scope the *commissioning* process and define its objectives. Introduce the CxA to the design team and ensure all parties understand their roles and responsibilities including how and when peer review of the design and reviews of submittals from the contractor will be handled.

The owner should require the CxA to create a detailed *commissioning plan*, hold a kick-off meeting, conduct site inspections, and deliver progress reports, an *Issues Log*, and 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 construction 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, take the lead. Others in your organization will follow. 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.

Natural Resources Canada's Resources

- CanmetENERGY's website: www.canmetenergy.nrcan.gc.ca
- Office of Energy Efficiency's website: oee.nrcan.gc.ca

APPENDIX A

ACRONYMS

ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BAS	Building Automation System
BOD	Basis of Design
CaGBC	Canada Green Building Council
CCC	California Commissioning Collaborative
CFR	Current Facility Requirements
CMMS	Computerized Maintenance Management System
CMVP	Certified Measurement & Verification Professional
CSC	Construction Specifications Canada
Cx	Commissioning
CxA	Commissioning Authority
DDC	Direct Digital Control
EIS	Energy Information System
EMCS	Energy Management Control System
EPA	Environmental Protection Agency
EPC	Energy Performance Contract
ESCO	Energy Service Company
FDD	Fault Detection and Diagnostics
HVAC	Heating, Ventilation, and Air Conditioning
IAQ	Indoor Air Quality
IEQ	Indoor Environmental Quality
IPMVP	International Performance Measurement and Verification Protocol
LEED	Leadership in Energy and Environmental Design
M&V	Measurement and Verification
NEI	Non-Energy Impact
NEB	Non-Energy Benefit

NRCan	Natural Resources Canada
OEE	Office of Energy Efficiency
O&M	Operation & Maintenance
OPR	Owner's Project Requirements
PECI	Portland Energy Conservation, Inc.
RCx	Recommissioning
RFP	Request for Proposal
RFQ	Request for Qualifications
PM	Preventive Maintenance
ROI	Return On Investment
QCxP	Qualified Commissioning Process Provider (accredited)
TAB	Test and Balance
USGBC	U.S. Green Building Council
VFD	Variable Frequency Drive
W	Watt

APPENDIX B

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)

BOD is the document that designers prepare to identify the decisions, systems, and selections made to satisfy each of the owners project requirements and satisfy applicable regulatory requirements, standards, and guidelines. Equivalent terminology for BOD sometimes used includes Design Basis, Design Brief, Outline Specification, or Design Narrative. BOD is used throughout this Guide.

Building Commissioning (Cx)

Commissioning is an intensive quality assurance process that begins during the design of a new building and continues through construction, start-up, occupancy and the first year of operation. Cx ensures that the new building operates as initially intended and meets the *owner's project requirements,* and that building staff are prepared to operate and maintain its systems and equipment.

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 Authority (CxA)

The person who coordinates the *commissioning* process. This can be either a third-party *commissioning* provider or an experienced in-house staff member.

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 CxA, *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.

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 Review

Design Review is a process in which the CxA examines design documents to help ensure a design is likely to meet the *Owner's Project Requirements*.

Existing Building Commissioning (EB Cx)

See ***Recommissioning (RCx)***.

Functional Tests/Testing

Also called functional performance tests, these 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* Authority 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)

Characteristics that 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 CxA 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 the building 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 (RCx)

Recommissioning (RCx) is a re-optimization process for existing buildings that ensures benefits from commissioning persist. It seeks to improve how building equipment and systems function together and ensures building equipment and systems are operating optimally to meet current facility requirements. It provides a rigorous investigation approach to identify problems and integration issues. It may be done alone or in concert with a retrofit project. RCx has been chosen as the generic term for the process of commissioning existing buildings. Retrocommissioning, while similar, is defined as a one-time service to existing buildings that were not commissioned initially.

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 may be helpful, including 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

See ***Recommissioning (RCx).***

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 including all energy efficiency strategies.

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*.

CanmetENERGY

www.canmetenergy.nrcan.gc.ca