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BUILDING OPERATION OPTIMIZATION

Recommissioning Guide

For Building Owners and Managers

Canada

RECOMMISSIONING (RCx) GUIDE FOR BUILDING OWNERS AND MANAGERS

This RCx Guide is owned by Natural Resources Canada (the "NRCan Guide") and is an adaptation of the document entitled *A Retrocommissioning Guide for Building Owners* (the "US-EPA Guide") originally developed by Portland Energy Conservation, Inc. (PECI) with funding from the U.S. Environmental Protection Agency (US-EPA) ENERGY STAR® Program (Assistance Agreement No. XA 831954-01)[1].

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The Canadian adaptation of the US-EPA Guide has been managed by the CanmetENERGY in collaboration with the Office of Energy Efficiency (OEE) and under the ecoENERGY for Buildings Program of Natural Resources Canada (NRCan) [2, 3, 4, 5].

Cover Page Photo Credit:
Terri Meyer Boake, University of Waterloo (building picture to the left).

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[1] The US-EPA Guide and the NRCan Guide have not been formally reviewed by EPA, and EPA does not endorse any products or commercial services mentioned in this publication. Furthermore, EPA 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 was 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 31st 2008. No other conversion rate factors have been applied to take also account of other differences in the costs that might happen between U.S.A. and Canada.

[4] U.S.A. related case studies included in the original text have been moved to Appendix G.

[5] See the RCx Glossary for definitions of the terminology used by Natural Resources Canada: www.canmetenergy.nrcan.gc.ca/glossary_RCx.html

BUILDING OPERATION OPTIMIZATION

RECOMMISSIONING GUIDE FOR BUILDING OWNERS AND MANAGERS

1ST EDITION

ADAPTED BY CanmetENERGY
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« Guide de recommissioning (RCx) pour les propriétaires et les gestionnaires de bâtiments ».

ABOUT THIS RCx GUIDE

This *Recommissioning Guide for Building Owners and Managers* (the "RCx Guide") illustrates how building owners and managers can successfully use recommissioning as a cost-effective method to reduce expenses and increase revenue through improved building operations. The more an owner is involved in the recommissioning process, the lower the costs, the larger the benefits, and the longer the impact. This guide was created to address the opportunities that owners and managers have to significantly increase the benefits of recommissioning in their buildings. Additionally, it is intended to provide guidance for recommissioning participants by setting expectations regarding the process and outcomes of recommissioning.

This guide will be useful to all professionals involved in building design, management and operation:

- Director or chief of engineering
- Property or facility manager
- Property management firms
- Operation and maintenance staff
- Control technicians and building automation supervisors
- Recommissioning service provider
- Consultants in energy management
- Professors and students in building science and engineering

Building owners and managers can use this document as a guide to better understand the impact of the recommissioning (RCx) process and communicate to others about issues, benefits, and need for staff involvement. As the recommissioning team moves through each phase of the RCx process, the individual charged with leading the effort on the owner's side (referred to as the owner's representative or simply "owner" throughout the remainder of this document) can use this guide as a reference to gain a better understanding of each phase and to lead the team in taking the appropriate steps to ensure success.

The RCx Guide is designed to guide the owner in achieving the following components of a successful and cost-effective recommissioning project:

- Facility staff is able to complete a portion of the work – reducing the budget required to pay the recommissioning provider or subcontractor.
- Building staff learn about enhancing the operation of their building as they work alongside the recommissioning professionals, improving their ability to maintain the performance of systems after the project is complete.
- Budgeting for recommissioning flows smoothly because the owner understands the associated benefits.

- Short and long-term plans for implementing improvements are created; recommissioning opportunities are assessed for risk management and the potential to generate revenue and reduce expense, and the costs are integrated with budget planning.
- Benefits are long lasting through the implementation of persistence strategies.

The first two chapters of this guide, "Building Performance as a Business Strategy" and "Investing in Recommissioning" are written with the financial decision maker in mind. In some cases, that may be a corporate financial officer (CFO) or a designated energy manager. In other situations, it may be a private building owner or owner's representative. It is critical that the person in control of allocating operational budgets understands the financial rationale and economic opportunity of recommissioning.

The chapter entitled "Project Basics" includes a quick summary of the recommissioning process, an explanation of the roles and responsibilities of the team, and a final checklist of "Key Strategies for Success." The **"Key Strategies for Success"** checklist acts as a portal into the rest of the document and provides quick links to critical information as the reader embarks on and moves through a recommissioning project.

The remainder of the Guide expands on the process steps summarized in the "Project Basics" chapter and is divided into six parts:

- Project Planning – Part 1: Building(s) Pre-screening Selection
- Project Planning – Part 2: Selected Building RCx Scoping
- Investigation
- Implementation
- Project Hand-Off
- Making Recommissioning Benefits Last

All along the RCx Guide, links to complementary resources and tools are provided to help understanding and managing the recommissioning process. Those resources build on existing ones and address new concepts and practices in the industry. They provide a comprehensive range of sample documents for both recommissioning customers and practitioners.

This RCx Guide is intended to increase clarity and consistency of market standards for both recommissioning providers and building owners. It also presents a clear methodology to improve a building's energy performance and create a long-term energy management strategy by recommissioning appropriate buildings from a portfolio of buildings.

Natural Resources Canada's CanmetENERGY provides the RCx Guide to help improve whole building performance through persistent, cost-effective building operations improvements that are in line with building owners' budgets and practical needs.

For additional information on CanmetENERGY national program on recommissioning and its related RCx tools and resources, visit the following CanmetENERGY's Website: www.canmetenergy.nrcan.gc.ca.

ACKNOWLEDGEMENTS

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As part of the various consultations conducted, numerous other organisations provided comments and suggestions for improvements. Their efforts are also gratefully acknowledged.

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LIST OF ACRONYMS

AHU	Air Handling Unit
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BAS	Building Automation System
CaGBC	Canada Green Building Council
Cx	Commissioning
DDC	Direct Device Control
DP	Differential Pressure
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
IEQ	Indoor Environmental Quality
kW	Kilowatt
kWh	Kilowatt hour
LEED	Leadership in Energy and Environmental Design
LEED AP	LEED Accredited Professional
LEED-EB™	LEED for Existing Building
LEED-NC™	LEED for new construction
m	Metre
NEI	Non-Energy Impact
NEB	Non-Energy Benefit
NLL	Night Low Limit
NRCan	Natural Resources Canada
OEE	Office of Energy Efficiency
O&M	Operation & Maintenance
PECI	Portland Energy Conservation, Inc.
RCx	Recommissioning
RFP	Request for Proposal
RFQ	Request for Qualifications
ROI	Return On Investment
TAB	Test And Balance
USGBC	U.S. Green Building Council
VFD	Variable Frequency Drive
W	Watt

CHAPTER 1

BUILDING PERFORMANCE AS A BUSINESS STRATEGY

How well a building performs not only affects energy utility bills and operating costs, it also can influence property value, the productivity of occupants, and the business bottom line. Although high energy use is sometimes accepted as an unavoidable cost of doing business, it is often the best cost centre for cost reduction. It may also be an indicator of opportunities for reducing inefficiency and waste linked to building performance issues and gaps in how operation and maintenance (O&M) activities are carried out. By actively pursuing building operating improvements, building owners and managers can reduce operating costs to increase the profitability of their business and gain a competitive edge in the marketplace.

This chapter describes the potential for broad gains from activities aimed at improving building performance and introduces the concept of recommissioning (RCx) and its benefits.

Highlights:

- What is recommissioning?
- How can recommissioning improve building profitability and reduce risk?
- How important is recommissioning?

A CASE FOR IMPROVING BUILDING PERFORMANCE

No matter how well building operators and service contractors maintain equipment, if it operates inefficiently or more often than needed, energy waste and reliability problems can occur. Also, over time, building uses change – occupants move, spaces are reconfigured, new equipment is added – possibly rendering previous systems and settings ineffective.

Today's buildings are complex, employing highly inter-dependent systems with sophisticated controls; therefore, even small operational problems can have big impacts on performance. Even if building staff have been able to work out most of the operational "bugs," they are often forced to solve daily problems under severe time constraints and without the benefit of appropriate or complete documentation or training on system-integration issues.

Achieving optimum building performance requires an approach that helps to ensure that equipment and systems perform together effectively and efficiently to meet the building owner's operating requirements and expectations. When this process occurs during the construction of the building, it is referred to as "commissioning." Applying a similar process to existing buildings and their operations is referred to as "retrocommissioning" or "recommissioning" as shown in following ***Table 1***.

Table 1: Improving building performance approaches.

Terminology	New Construction	Existing Building	Previously Commissioned	Not Previously Commissioned
Commissioning	✓			
Retrocommissioning		✓		✓
Recommissioning		✓	✓	

Adapted from: Jim Poulos. "Existing Building Commissioning," ASHRAE Journal, Sept. 2007, pages 66-78.

COMMISSIONING TERMINOLOGY

Commissioning (Cx) is an intensive quality assurance process that begins during the design of a new building and continues through construction, occupancy, and operation. Cx ensures that the new building operates as the owner initially intended and that building staff are prepared to operate and maintain its systems and equipment.

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 ReCx 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. 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 RCx primary focus is on identifying "low cost/no cost" operational improvements given the building's current usage to obtain comfort and energy savings. It may be done alone or in concert with a retrofit project.

Important notice: *For the purposes of this Guide, the term "recommissioning" (RCx) has been chosen as the generic term for commissioning existing buildings.[6] Retrocommissioning, while similar, is defined as a one-time service to existing buildings that have not been commissioned initially.*

[6] For the purposes of this RCx Guide, NRCan uses terminology commonly understood in the Canadian market that is slightly different from the US-EPA Guide.

RECOMMISSIONING CAN HELP

Recommissioning is a collaborative process that looks at how and why a building's systems are operated and maintained as they are, and then identifies ways to improve overall building performance. As a process, rather than a set of prescriptive measures, recommissioning adapts to meet the specific needs of each building owner. Recommissioning plays an important role in addressing whole building performance. The whole building perspective looks at buildings as integrated systems, rather than a set of individual components.[7]

Since occupant comfort complaints and high energy use can often go hand-in-hand, recommissioning can help to correct both. Specifically, recommissioning:

- Improves the building's overall performance by optimizing energy efficient design features and directly addressing equipment performance and system integration issues.
- Ensures that building staff have the knowledge and documentation needed to operate and maintain the building.
- Evaluates the building's environmental quality to reduce occupant complaints by optimizing existing systems for current loads and configuration.

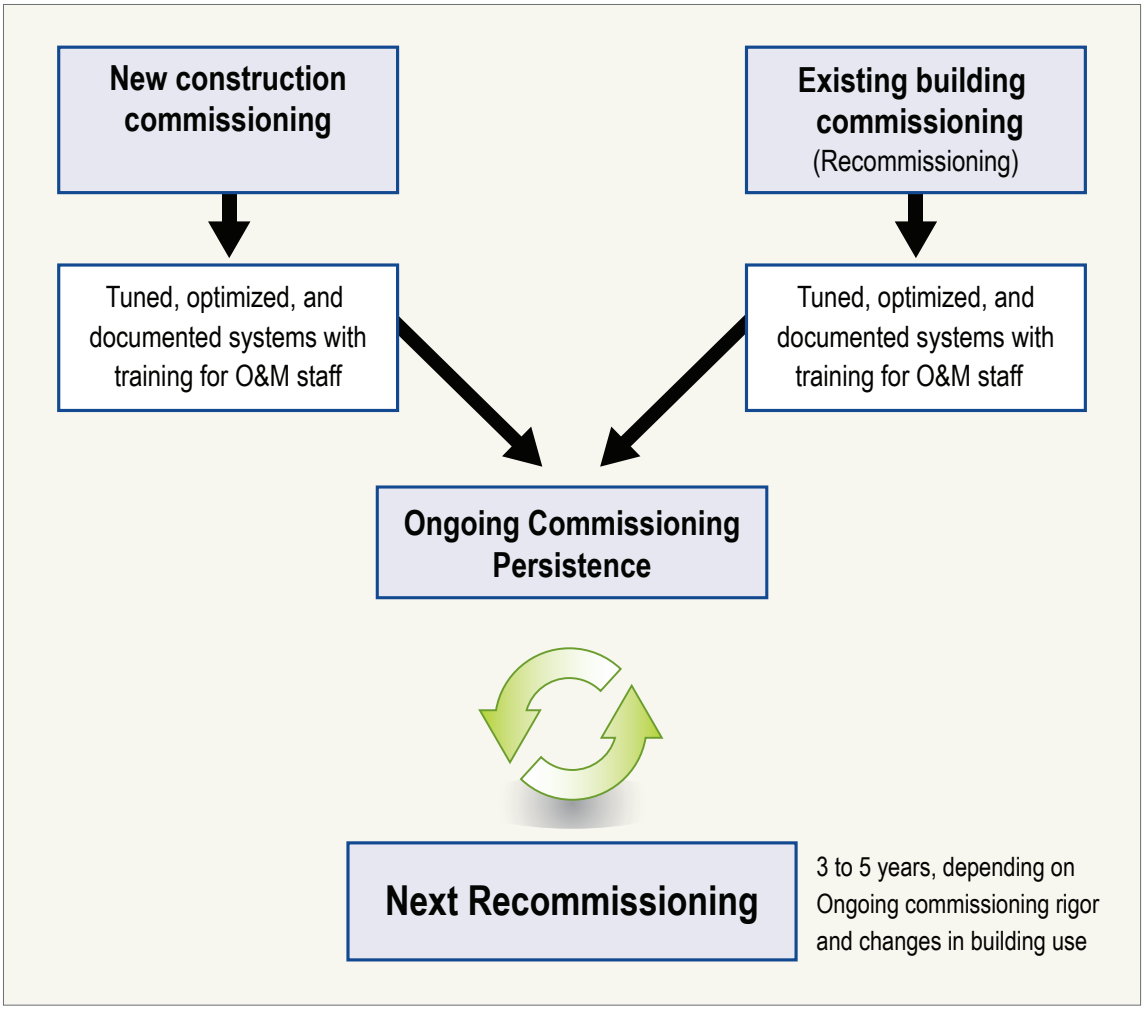
Optimum building performance can be maintained over time following recommissioning through persistence strategies such as ongoing commissioning.

In ongoing commissioning,[8] monitoring equipment and trending software is left in place to allow for continuous tracking, and the scheduled maintenance activities are enhanced to include operational procedures. For ongoing commissioning to be highly effective, the building owner must retain high quality staff or service contractors that are trained and have the time and budget to not only gather and analyse data, but also to implement the solutions that come out of the analysis. Recommissioning 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***).

[7] See the US-EPA Guide related case study "Target Retrocommissioning Program" in Appendix G.

[8] Ongoing commissioning is an iterative process of recommissioning actions that ensure persistence between recommissioning rounds.

Figure 1: Building operation optimization approaches over lifetime of a building.



RECOMMISSIONING AS PART OF YOUR BUSINESS STRATEGY

Recommissioning can benefit a building owner in a number of ways:

- **Reduce utility costs.** Through recommissioning, whole-building energy use may be reduced by an average of 5% to 15%. In some cases, annual savings of as much as 30% are possible.[9]
- **Protect or enhance property value.** Reducing operating costs helps to maintain high occupancy rates, reduces tenant turnover, and enables an owner to gain a competitive edge in the marketplace.
- **Protect against future liability.** A building's indoor environmental quality affects the health, comfort, and productivity of its occupants and ranges from mildly inconvenient to very serious. Recommissioning can help identify and address problems that can lead to future liability.
- **Reduce repair and replacement cost.** Recommissioning improves system performance, increases equipment life, and reduces the need for repairs, which can save money and result in fewer comfort complaints.
- **Increase building's energy performance efficiency.** More and more tenants are becoming concerned about environmental issues and how their work place measures up. Companies that adopt energy performance goals are increasingly receiving public recognition and positive press coverage.

PUTTING THE "O" IN O&M

Preventive and predictive maintenance programs, out of necessity, focus on component by component care and seldom include comprehensive investigation of how systems operate together. Recommissioning goes beyond the scheduled maintenance of a building to address the "O" in O&M by providing a thorough assessment of the operation of mechanical equipment, lighting, and related controls to improve how the building operates as an integrated system.

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

Recommissioning enhances a preventive maintenance program by including methods for ensuring that operating improvements remain functioning as intended. For buildings that do not have an active preventive maintenance program, recommissioning can be a key element in re-establishing control over the building's maintenance processes and procedures.

Recommissioning has to be distinguished from a traditional energy audit. As shown in the following ***Table 2*** and ***Table 3***, the primary focus of recommissioning is to identify O&M improvements leading to energy cost savings that are relatively fast and inexpensive to implement.

Table 2: Recommissioning vs energy audit primary focus.

Service	Operations and Maintenance (O&M) Improvements	No-Cost / Low-Cost Savings Opportunities	Capital Retrofit Savings Opportunities
Recommissioning (RCx)	Primary	Primary	Secondary
Energy Audit	Secondary	Primary	Primary

Adapted from: Jim Poulos. *"Existing Building Commissioning,"* ASHRAE Journal, Sept. 2007, pp. 66-78.

Table 3: Differences between an energy audit and an O&M assessment.

Energy Audit	O&M Assessment
Emphasizes investigating existing building systems for equipment replacement (retrofit) opportunities leading to energy cost savings	Emphasizes investigating existing building systems to identify low-cost O&M improvements leading to energy cost savings
Seldom includes functional testing of present building systems	Generally includes some degree of functional testing of present building systems
Generally performed by an outside consultant	Generally performed by an outside consultant
May include building simulation models	Rarely includes building simulation models
Results in a list of energy conservation retrofit measures	Results in a master list of O&M improvements
Typical recommendations are time consuming and expensive to implement	Typical recommendations are fast and inexpensive to implement
Typical projects provide attractive rates of return sometimes more than 30% with a payback often greater than three years	Typical paybacks are estimated at less than two years and often less than one year
Generally requires an outside contractor to implement equipment replacements	In-house staff can often implement many O&M improvements

Adapted from: PECI. *"Operation and Maintenance Assessments – A Best Practice for Energy-Efficient Building Operations"*, O&M Best Practices Series, funded by the US EPA and US DOE, September 1999.

RECOMMISSIONING IN CANADA

Recommissioning (RCx) is underutilized in Canada. Recently, however it has been promoted by Natural Resources Canada via capacity-building activities, the Canada Green Building Council (CaGBC) through a sponsored building certification program, and also by some Canadian utilities as a conservation program to reduce energy consumption in buildings and reduce peak demand.

Natural Resources Canada (NRCan)

The NRCan's CanmetENERGY develops a national RCx program to build RCx knowledge and expertise in Canada. It helps deploy training and provide tools for efficient and cost-effective RCx implementation. CanmetENERGY works in collaboration with the Office of Energy Efficiency (OEE) under the ecoENERGY for Buildings Program of Natural Resources Canada (www.canmetenergy.nrcan.gc.ca).

Canada Green Building Council (CaGBC)

CaGBC accelerates the design and construction of green buildings in Canada and includes representatives from different segments of the design and building industry. In early 2008, CaGBC updated the LEED® Canada Green Building Rating System[10] to address existing as well as new buildings of all types. A CaGBC taskforce is developing terms of reference and a timeline for the potential adaptation of the U.S. Green Building Council's LEED for Existing Buildings (LEED-EB™) for the Canadian market.

The LEED-EB™ rating system has 4 certification levels: Platinum, Gold, Silver and Certified. Existing buildings seeking LEED-EB™ certification can receive points based on the energy performance. Implementing an RCx process will help achieve the minimum performance rating required by LEED™. At the time of this writing, more than 3,000 Canadian practitioners from all sectors of the industry are now LEED accredited professionals, and around 200 buildings in Canada are registered with the CaGBC (www.cagbc.ca).

Canadian Utilities

Some Canadian utilities have formally adopted RCx programs. Manitoba Hydro launched its program in 2006 and BC Hydro ramped up its RCx program in early 2008. Other utilities in Ontario are about to do the same by introducing their own RCx programs. Hydro Québec is currently running a pilot project to assess client interest in and benefits from the RCx process. The RCx programs offered by Canadian utilities are targeting large conventional buildings where the energy bills are the highest. It is expected that other Canadian utilities will also deploy RCx programs in the coming years.

[10] LEED is a series of green building rating systems developed by the U.S. Green Building Council (USGBC) that goes beyond energy performance to include additional sustainability measures. It recognizes buildings where environmental best practices have been implemented into operations. There are distinct rating systems for new construction (LEED-NC™), existing buildings (LEED-EB™), and several other situations. LEED-EB™ is applicable to building operations, processes, system upgrades, and minor space changes, and can be used by buildings new to LEED certification, or as a recertification vehicle for buildings that have previously achieved a LEED rating. LEED-NC™ requirement for commissioning has helped the building industry realize the importance of both commissioning of new buildings and ongoing commissioning of existing buildings.

CHAPTER 2

INVESTING IN RECOMMISSIONING

How does a business make the decision to invest in recommissioning? Simple payback for a recommissioning project is often less than two years. In addition, the process secures better and longer performance out of existing equipment, and the benefits reach far beyond energy savings. If this is true, why aren't all building owners adopting this strategy?

The answer may be in the perception of this type of investment. Each type of business has its own pressures that affect investment choices: healthcare is subject to constant regulation, real estate investment trusts (REITs) need to improve the value of their holdings and effectively manage leasable space, and service businesses are focused on sales and customer service. In these environments, putting money into a building to increase operating efficiencies may not be seen as a high priority. This chapter describes the benefits and costs of a recommissioning project and concludes with guidelines for developing a business case for recommissioning that wins senior management support and approval.

Highlights:

- Reducing a building's energy use through recommissioning
- Improving building performance and overall asset value
- Understanding the costs of recommissioning
- Strategies for reducing recommissioning costs
- Keys to building the business case for your recommissioning project

DIRECT BENEFITS (ENERGY SAVINGS)

A prevailing myth is that the many expenses associated with operating and maintaining a building are an unavoidable cost of doing business. The reality, however, is that the majority of buildings can operate at equivalent or improved levels of comfort and function for less money. Recommissioning addresses inefficiency by reducing operating costs through low-cost actions with high rates of return.

Cost savings from recommissioning can be significant; however, they can also vary significantly depending on building type and location, and the scope of the recommissioning process. A comprehensive study found average cost savings in the following ranges:

Value of Energy Savings[11]	$1.00 - $8.00 /m^2
Value of Non-Energy Savings[12]	$1.00 - $4.75 /m^2

These indirect benefits are described in the following sections.

There are certain economies of scale associated with recommissioning. For example, base costs are linked to the number of systems in a building. Consequently, for a large and small building with the same number of systems, per square meter costs of recommissioning will be lower for the larger building. Although it can be more challenging, smaller building owners can still achieve cost-effective recommissioning with payback times under two years. Also, payback periods typically decline with increases in facility energy costs. For example, a study conducted by Lawrence Berkeley National Laboratory (LBNL) found that laboratories, which have the highest energy cost per square meter ($/m^2), had the shortest payback periods. In contrast, schools, with relatively low energy costs per square meter ($/m^2), had longer payback periods.

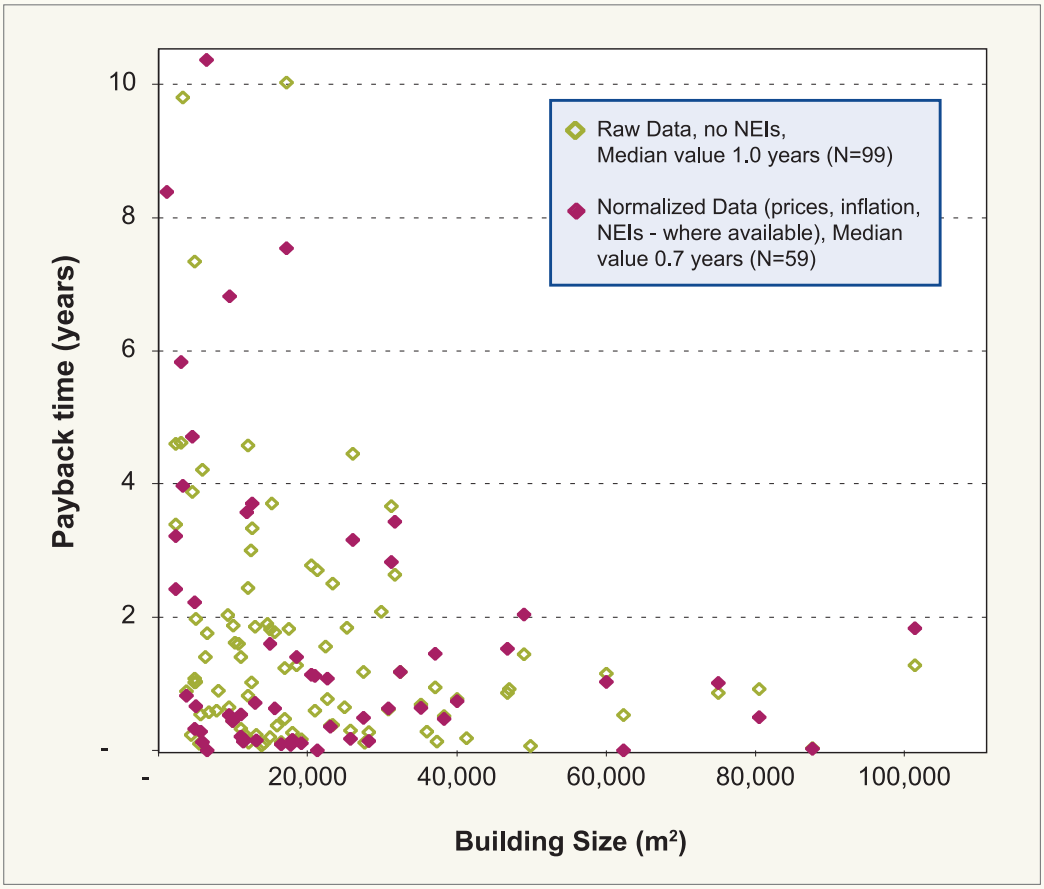
[11] $0.10 - $0.75/ft^2

[12] $0.10 - $0.45/ft^2

SAVINGS FROM RECOMMISSIONING

Significant cost savings from a recommissioning process often result from reduced energy use. A 2004 study conducted by Lawrence Berkeley National Laboratory (LBNL) aggregated recommissioning results from 100 buildings[13] and found overall electricity savings ranging from 5% to 15% and gas savings ranging from 1% to 23%. Corresponding payback times ranged from 0.2 to 2.1 years.[14] The median project energy savings found through this study was approximately $45,000 per year per building (in 2003 dollars), and ranged as high as $1.8 million per year. Payback times typically decline with increasing building size, especially for buildings with floor areas above 10,000 m² (see ***Figure 2***).

Figure 2: Commissioning payback time vs. building size (existing buildings)



NEIs = Non-Energy Impacts
Adapted from: Lawrence Berkeley National Laboratory, "The Cost Effectiveness of Commercial-Buildings Commissioning," December 2004.

[13] The data in this section is based on information provided in the following publication: Mills, E., H. Friedman, T. Powell, N. Bourassa, D. Claridge, T. Haasl, and M.A. Piette. 2004. "The Cost-Effectiveness of Commercial-Buildings Commissioning," Lawrence Berkeley National Laboratory.

[14] See the US-EPA Guide related case study "Marriott Marquis" in Appendix G.

INDIRECT BENEFITS (NON ENERGY IMPACTS)

The benefits of recommissioning go beyond reduced energy costs. While more difficult to quantify, non-financial benefits should not be overlooked. Even though these benefits may not yield direct monetary paybacks, they can generate associated cost savings. The dollar value of non-energy benefits alone can offset the cost of a project by up to 50%.[15]

INCREASED ASSET VALUE

Building owners may benefit from higher appraised building values if the property is properly appraised for its operating performance, since equipment that is well-maintained and operates efficiently increases the asset value of the property. The U.S. Environmental Protection Agency (US-EPA) has estimated that every dollar invested in energy upgrades yields $2 to $3 in increased asset value of a building.[16]

LOWERING OPERATING AND TENANCY COSTS

The benefits of recommissioning can translate into increased profitability for building owners by reducing operating expenses that lead to an increased net operating income and quicker returns on investment. Recommissioning lease properties can also be made more competitive by reducing the operating cost per square meter ($/m^2) and lowering tenancy cost.

IMPROVED EQUIPMENT PERFORMANCE

The recommissioning team assesses whether each piece of equipment is functioning properly, and then investigates the cause of any problem and recommends a solution. For example, if the recommissioning team finds multiple chillers operating unnecessarily at low loads, team members will collect and analyse chilled water system data and recommend changes that ensure chillers cycle on only when needed. The result? Equipment that lasts longer, works more reliably, needs fewer repairs, and uses less energy. Equipment that operates properly also demands less "crisis maintenance" from onsite staff and outside contractors, allowing staff to concentrate on their primary duties.

[15] Ibid 13

[16] Thorne, Jennifer and Steven Nadel. "Retrocommissioning: Program Strategies to Capture Energy Savings in Existing Buildings," American Council for an Energy-Efficient Economy (ACEEE), Report Number A035 (June 2003), p. 4.

INCREASED O&M STAFF CAPABILITIES AND EXPERTISE

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

IMPROVED INDOOR ENVIRONMENTAL QUALITY (IEQ)

The quality of a building's indoor environment affects the health, comfort and productivity of its occupants. The consequences of a poor indoor environment range from mildly inconvenient to very serious. Building system deficiencies that result in poor temperature control or light quality and level issues can cause an uncomfortable work environment that hinders learning and lowers an organization's productivity. In more severe cases, poor air quality causes headaches, fatigue, or severe allergic reactions. Poor air quality can have many causes, such as moisture and mold in the building envelope, inadequate outside air or poor air circulation, inappropriate control of ventilation air, and poor initial installation or tenant revisions that impact the air distribution system.

IMPROVED BUILDING DOCUMENTATION

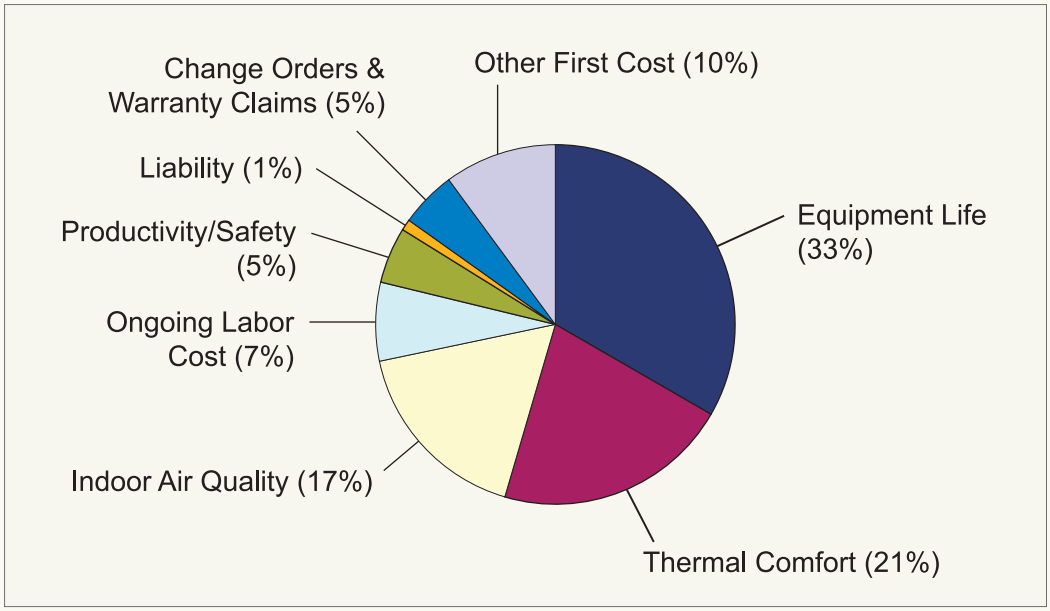
Up-to-date building documentation, including operation and maintenance (O&M) manuals, sequences of operation, and system diagrams, is produced through the recommissioning process and is essential to maintaining and troubleshooting equipment. The preventive maintenance plan and a recommissioning plan should describe in detail the human and financial resources that are necessary to maintain the benefits of the recommissioning process for many years.

PERCENTAGE BREAKDOWN OF NON-ENERGY IMPACTS

In an analysis of 36 commissioning project results, more than half of building owners reported benefits that went beyond energy savings. Extended equipment life and improved indoor thermal comfort were the most prevalent. Other recommissioning benefits (in order of decreasing incidence) included improved indoor air quality, first-cost reductions, labour savings, improved productivity/safety, fewer change orders and warranty claims, and liability reduction.

Figure 3 below displays the percentage breakdown of these non-energy impacts. More than a third of the projects reported that RCx had a positive impact on the equipment life. Where the economic value of these non-energy impacts was quantified, the value of the savings ranged from[17] $1.00 - $4.75/yr/m^2 with a median value of[18] $1.95/yr/m^2 ($17,000 of savings per project).[19]

Figure 3: Reported non-energy impacts (NEIs) for 36 projects in existing buildings.



Source: Lawrence Berkeley National Laboratory, "The Cost Effectiveness of Commercial-Buildings Commissioning," December 2004.

[17] $0.10 to $0.45/ft^2

[18] $0.18/ft^2

[19] See the US-EPA Guide related case studies "Symphony Towers" and "Office Buildings" in Appendix G.

COSTS OF RECOMMISSIONING

While recommissioning is cost effective for most buildings, it is important to understand its costs, as well as the strategies for reducing them, to ensure the greatest return. This section summarizes typical expected costs for a project and highlights cost-saving strategies.

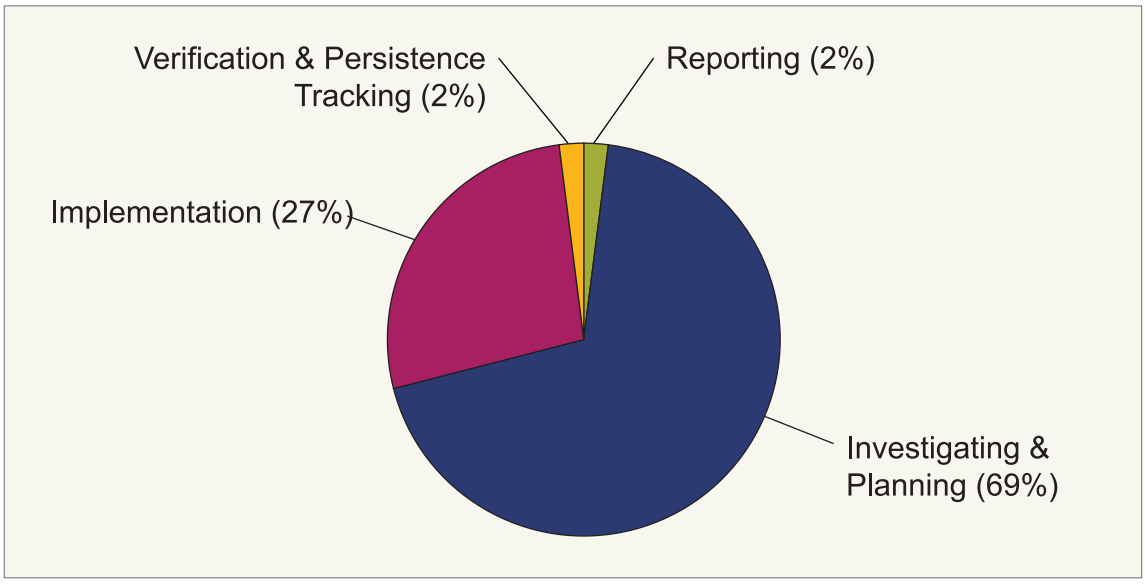
It is important to bear in mind that recommissioning costs, like the process itself, are unique to each project. Variables affecting both include:

- Scope of the project
- Number and complexity of systems
- Size of the facility
- Equipment age and condition
- Commissioning service provider costs
- Level of on-site staff knowledge interfacing with the project
- Presence of an extensive O&M program and documentation

The recommissioning provider's fee is the most obvious cost. Additional costs include other team members (internal staff and/or outside contractors) participating in the process and the cost of correcting the identified problems. Lawrence Berkeley National Laboratory's study of 100 existing buildings[20] (varying in type and size) found that recommissioning provider fees ranged from 35% to 71% of the total recommissioning costs, with a median value of 67%. As shown in ***Figure 4***, the largest percentage of costs for a project was for the investigation and planning phase activities (69%), followed by the actual implementation of measures (27%).

[20] Ibid 13

Figure 4: *Recommissioning cost allocation (represents $5.2 million for 55 existing buildings sample (2003 dollar)).*



Source: Lawrence Berkeley National Laboratory, "The Cost Effectiveness of Commercial-Buildings Commissioning," December 2004.

BUDGETING FOR RECOMMISSIONING

Often, recommissioning will identify quick fixes that can be implemented without significant additional investment. For example, energy savings are commonly found by identifying equipment that is running when it is not needed. A simple change in the control system is all that it takes to capture these savings. The provider, however, may also identify measures that cannot be paid for in the current operations and maintenance budget. In these cases, the recommissioning provider can assist in prioritizing improvements, and owners can actively plan in their upcoming budget cycles to accommodate the opportunity.

While it is possible to stage implementation of measures, it is most cost effective to conduct a recommissioning investigation that continues on to implementation. It is therefore advisable, where possible, to plan for the costs of larger measures from the start of the project, so that recommissioning services can be most effectively utilized and the greatest savings realized. There may be financial incentives available from utilities in your area, which may cover part of the cost of recommissioning. These incentives should be a factor in any analysis of the overall cost of the project and recoverable and non-recoverable expenses.[21]

STRATEGIES TO REDUCE COSTS OF RECOMMISSIONING[22]

There are strategies that owners can use to reduce the costs of recommissioning and increase the effectiveness of the project. These include sharing costs with tenants and reducing recommissioning costs by involving building staff in the projects.

Recommissioning as a Capital Expense

When recommissioning is undertaken in the context of an energy-saving capital improvement project, the cost of recommissioning may be rolled into the cost of the project itself, and therefore be treated as a capital expense. In an income-producing property, it may be possible to pass capital expenses through to tenants, depending on the lease structure in place.

Recommissioning as an Operating Expense

The cost of recommissioning can also be considered an operating expense, since it focuses on improving the operation of energy-using systems. Where the purpose of recommissioning is to address tenant complaints about comfort or respond to abnormally high energy costs, the owner may choose to pay the full cost of recommissioning. If investing in recommissioning and any related capital improvements would likely produce significant savings for all tenants, an owner might choose to claim a portion of the recommissioning expense, and then pass the rest through to the tenants (along with the cost of any recommended capital improvements) to the fullest extent permitted by the lease.[23]

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[21] See the US-EPA Guide related case study "Retrocommissioning at Marriott" in Appendix G.

[22] See the US-EPA Guide related case study "The Hatfield Courthouse" in Appendix G.

[23] Information summarized in part from the following publication: Jewell, Mark. RealWinWin, Inc. *"Understanding the Value of Commissioning in Income-Producing Office Buildings, "Proceedings of the National Conference on Building Commissioning,* Palm Springs, CA, May 20 – 22, 2003.

INVOLVING FACILITY STAFF TO SAVE TIME AND MONEY

Leveraging facility staff's first-hand knowledge of the building can reduce the time needed by the recommissioning provider to uncover building inefficiencies. There are many tasks that skilled staff can undertake to help streamline the process and increase the effectiveness of the recommissioning provider's time.

Provide a List of Opportunities

Building operators know their buildings best and are often aware of the problem systems as well as opportunities that exist for improving performance. During the initial phase of the project, the facility staff should develop a list of existing potential improvements and known problems to share with the recommissioning provider. This can help focus the investigation activities and reduce the time required by the RCx provider. It is beneficial for the operators to be involved with the process so that they can have greater understanding and involvement in the ongoing commissioning process.

Gather Documentation

One of the first steps in recommissioning is to compile an up-to-date building documentation package including any written sequences of operation. Facility staff can assist with gathering available documentation. The more complete the documentation, the less time the recommissioning provider needs to fill in the gaps. Often, documentation may not be available or the documentation that is available may not accurately reflect the current operating condition of the building or its equipment. If documentation is not up-to-date, building staff should, if possible, revise it prior to the initiation of the project or be prepared to discuss the undocumented changes with the recommissioning provider. The provider should be given available documentation prior to the site visit in order to learn as much as possible about the building ahead of time. At a minimum, all building documentation should be made available on-site for the recommissioning provider during the site visit.

Perform Scheduled Preventative Maintenance

Facility staff or an outside maintenance service contractor should complete scheduled preventive maintenance before the recommissioning Investigation Phase begins so simple maintenance issues don't delay the process. Delays in the recommissioning process because of dirty filters, loose belts, broken dampers, or loose electrical connections can increase costs.

Assist with Diagnostic Monitoring, Trend Logging, and Functional Testing

It may be useful to have facility staff members assist with the short-term diagnostic monitoring, trend logging, and functional testing that occurs during the investigation phase of the project. This can reduce project costs, as well as provide the building staff with experience that they can apply later. If building staff are trained to initiate trend logs using the building's energy management control system (EMCS), a recommissioning provider can reduce time spent on the task, and the owner will not need to hire a controls contractor for this task when the project is finished. Depending on availability, knowledge, and capabilities, facility staff also may be trained to assist with the installation and removal of portable data loggers used for short-term diagnostics and carrying out functional test plans. In addition to reducing costs, this exposes staff to different approaches for troubleshooting problems and investigating and verifying equipment performance. Observing diagnostic trending and testing will improve staff understanding of equipment and control strategies and enable them to retest or recommission systems periodically as part of the facility's ongoing O&M program.

Perform Repairs and Improvements

Recommissioning costs also can be reduced by using facility staff to perform repairs and improvements that would otherwise require outside contractors. The success of this approach hinges on staff training, knowledge, and time availability to carry out the work. Facility staff workloads should be assessed to determine how schedules and workloads might accommodate any additional work brought on by recommissioning.

SELLING RECOMMISSIONING FROM WITHIN

Facility managers or directors will need to sell recommissioning to the building owner, property managers, or other senior level decision makers to get approval or "buy in" for the project. Managers faced with this challenge have a much better chance of generating support and obtaining the desired approvals if they present decision makers with a proposal that provides a solid business case for recommissioning.

An effective case for a recommissioning project clearly demonstrates how the benefits of recommissioning outweigh the costs. Thus, it is important that proposals for recommissioning present information that clearly lays out the project's estimated costs and benefits. A strong proposal also identifies cost reduction strategies when outlining the associated costs, and highlights how the energy savings and other benefits can offer the owner a short payback period on the investment.

Keep the following points in mind when making the case for a recommissioning project:

Typical Benefits of Recommissioning:

- Identifies and addresses system inefficiencies that can cause the building owner and/or tenants to incur high operating and maintenance costs, as well as premature replacement costs.
- Improves the building's overall performance by optimizing energy-efficient design features and directly addressing issues like equipment performance and system integration.
- Helps drive down building operating expenses – generating a higher Net Operating Income (NOI) and an increased asset value for the property.
- Reduces comfort complaints that lead to tenant turnover.
- Identifies potential indoor environmental quality issues and helps alleviate occupant complaints.
- Ensures that building operations meet owner expectations.
- Provides benefits beyond energy cost savings that can generate associated revenue. These benefits include extended equipment life, improved thermal comfort and indoor air quality, labour savings, increased productivity/safety, and liability reduction.
- Verifies that building staff are well trained and have the documentation they need to effectively and efficiently operate and maintain the building.
- Provides indirect cost savings and improvements – owners and building managers benefit from improved equipment performance and system operations, and building staff receive training and improved documentation.

Associated Costs of Recommissioning:

- Recommissioning provider's fee for planning, investigating, implementing and closing RCx project.
- Facility staff time and cost of including other professionals in the recommissioning process.
- Cost of correcting the problems identified by recommissioning.
- While costs vary depending on the complexity of the systems and project goals, recent studies show typical recommissioning project costs to be about[24] $\$2.90/m^2$.
- Restorative maintenance costs to return equipment or systems to proper operation.
- Control system software upgrades, printers and sometimes PCs.

Cost Reduction Strategies:

- Using facility staff to undertake tasks to help streamline the process and increase the effectiveness of the commissioning provider's time.
- Sharing costs with building tenants where possible under lease terms.

Demonstrating Cost-Effectiveness:

- Recommissioning costs are most often offset by energy cost savings. Energy-saving improvements can yield simple paybacks typically ranging from two months to two years.
- It has been estimated that the dollar value of recommissioning non-energy benefits can offset the cost of a project by 50%.[25]

[24] Ibid 13; recommissioning costs include investigation and implementation.

[25] Ibid 13; data on non-energy benefits are from 10 buildings.

CHAPTER 3

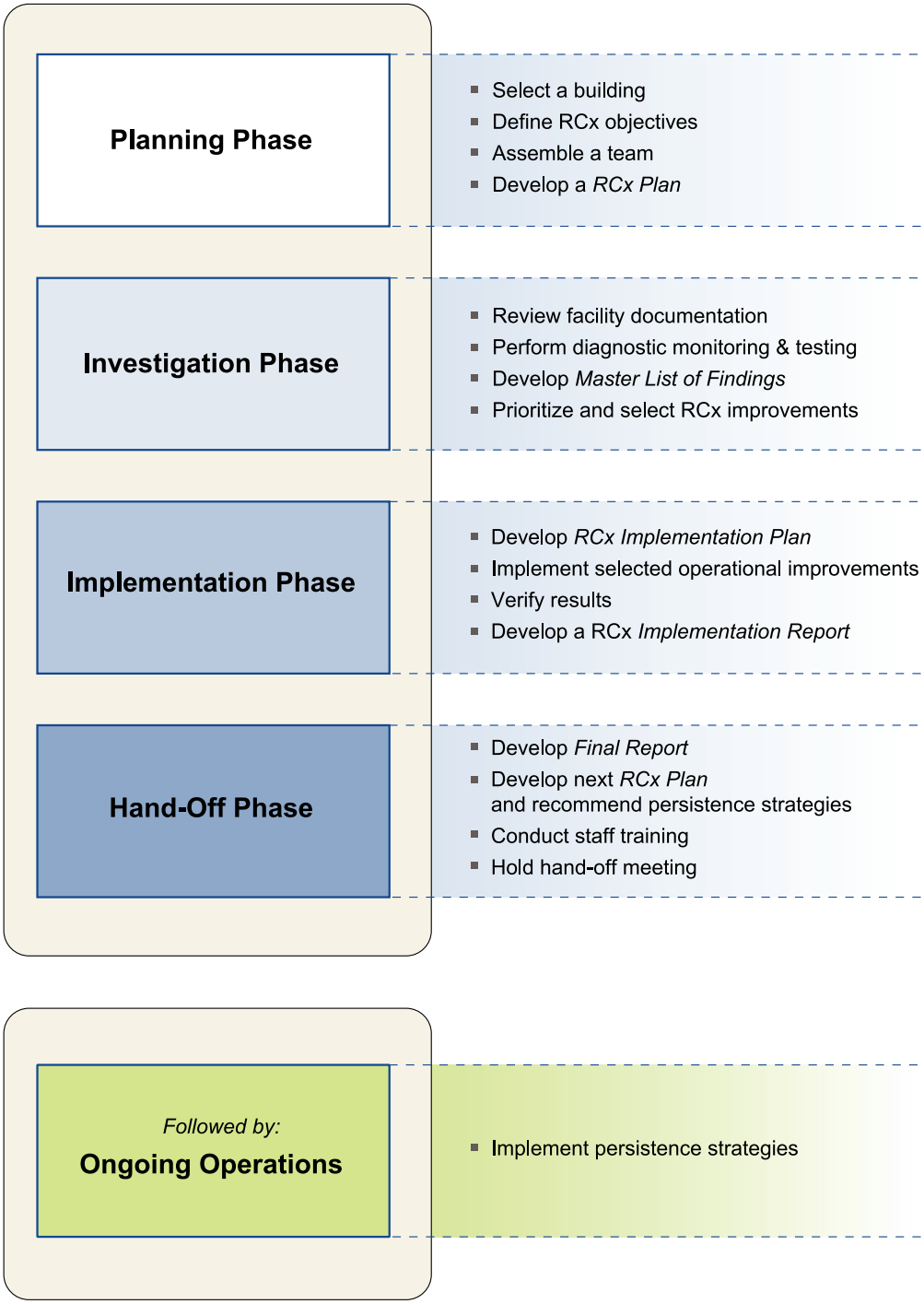
PROJECT BASICS

This chapter summarizes the steps in a recommissioning project, explains the various roles and responsibilities of the team members and concludes with a checklist of "Key Strategies for Success." The purpose of this chapter is to summarize the more detailed information that follows in order to give a quick understanding of the process and what key elements lead to a successful project with lasting benefits.

Highlights:

- Overview of the recommissioning process
- Roles and responsibilities of recommissioning team members
- Key areas for owner involvement
- Use of other outside contractors
- Key strategies for success

Figure 5: Recommissioning (RCx) Process Overview



RECOMMISSIONING PROCESS OVERVIEW

A well-planned and executed recommissioning project generally occurs in four Phases: **Planning, Investigation, Implementation, and Hand-off** (as shown in ***Figure 5***). These are followed by ongoing activities to ensure that the benefits continue, often referred to as "persistence strategies." The more detailed flow chart shown in ***Figure 6*** outlines a typical recommissioning process and highlights the major work products (deliverables) coming out of the process. There is, however, no one-size-fits-all approach to recommissioning. Several factors affect how recommissioning may be executed, including the condition of the facility, scope and budget of the project, size and complexity of the facility and availability of in-house resources and expertise. These differences do not commonly cause a project to divert significantly from the basic process.

WHO IS THE "OWNER"?

During the recommissioning process, the "owner" can be represented by any upper level manager with a vested interest in the project, a director or chief of engineering, or the property or facilities manager. In all cases, the owner's representative should be an active "champion," who is involved throughout the project and can secure the necessary senior management support to ensure that the project moves forward successfully. The owner should be a strong advocate for the recommissioning project, since his or her support allows the project to progress smoothly, correct more building problems, and produce greater benefits.

BREAKING DOWN THE PROCESS

PHASE 1: PLANNING

The primary tasks for the Planning Phase are to:

- Screen potential candidate buildings for suitability, including analysing the energy use per square meter and generating an initial energy performance rating (e.g. benchmarking);
- Select a candidate building;
- Define goals and objectives for the project;
- Select and hire a recommissioning service provider and assemble the RCx team that will see the project through to completion; and
- Develop a recommissioning plan, including projected costs and savings associated with the project.

While the majority of buildings can benefit from recommissioning, this guide provides tips on identifying those projects that will be the most cost effective. Owners and property management firms with building portfolios can look across their holdings to identify promising candidates for recommissioning. Determining factors include:

- The age and condition of a building and its equipment
- Use of building Automation System (BAS)
- Existing known comfort problems
- Utility costs
- Lease agreements
- Potential for Return On Investment (ROI) to owner
- Availability of utility, federal and provincial incentive programs
- Availability of building information including as-built drawings, specifications, air balance reports, building condition reports, previous energy audits, tenant fit up records and owner's requirements.

Projects are usually led by a third-party recommissioning provider with varying degrees of involvement by the building owner and staff. Some building owners and managers handle their own recommissioning projects, bringing in a recommissioning expert only for certain tasks. ***Chapter 4*** discusses how to determine the most appropriate approach.

To develop a recommissioning plan, the recommissioning provider conducts an on-site visit, talks with O&M staff, and reviews current operating conditions at the facility. After gaining a clear understanding of project goals, the recommissioning provider identifies opportunities for operational improvements in the building. The recommissioning plan is a scope of work negotiated between the recommissioning provider and the owner that provides an outline of the processes and procedures to be undertaken; a schedule of activities; roles of team members; and sample forms and templates that the recommissioning provider will use to document the recommissioning activities.

PHASE 2: INVESTIGATION

The primary tasks of the Investigation Phase are to:

- Understand how and why building systems are currently operated and maintained to identify issues and potential improvements; and
- Select the most cost-effective improvements for implementation.

The focus of Investigation activities depends on the scope and objectives of the recommissioning project indicated in the *RCx Plan* developed during the previous planning phase. Often, the recommissioning provider looks at all aspects of the current operations and maintenance (O&M) program in the building, as well as the management structure, policies, and user requirements that influence them. Investigation tasks typically include:

- Interviewing management and building personnel
- Reviewing building documentation and service contracts
- Evaluating trend data and equipment sequence of controls
- Inspecting the building and its sub-systems and equipment components
- Spot testing equipment and controls
- Gathering and analysing Heating, Ventilation, and Air Conditioning (HVAC) and lighting data

- Developing a *RCx Investigation Report* that lists recommended system improvements and associated estimated costs and savings

The recommissioning provider will produce a *RCx Investigation Report* for the owner at the end of this phase, describing the specific findings and identifying potential costs and savings. The owner should discuss these findings with the provider and understand not only the payback period, but also associated non-energy benefits such as increased comfort. At this time, the owner selects which "recommissioning measures" from the investigation report to implement in the next phase.

PHASE 3: IMPLEMENTATION

The primary tasks of the Implementation Phase are:

- Implement selected measures;
- Update energy savings calculations as necessary;
- Verify that measures have been implemented correctly; and
- Monitor results through metering, utility bills and trend log review.

In this Phase, the selected recommissioning measures and recommendations from the investigation report are implemented. Implementation can be carried out by the recommissioning provider, building staff, or individual subcontractors. Most commonly, however, there is a mix of individuals involved, depending on staff availability and expertise, existing equipment warranties, existing maintenance contracts, the scope of work, and the budget.

Once the selected measures are implemented, the team needs to verify that they are performing as expected. The verification process should set a baseline for each improvement so that performance can be tracked to ensure the benefits persist.

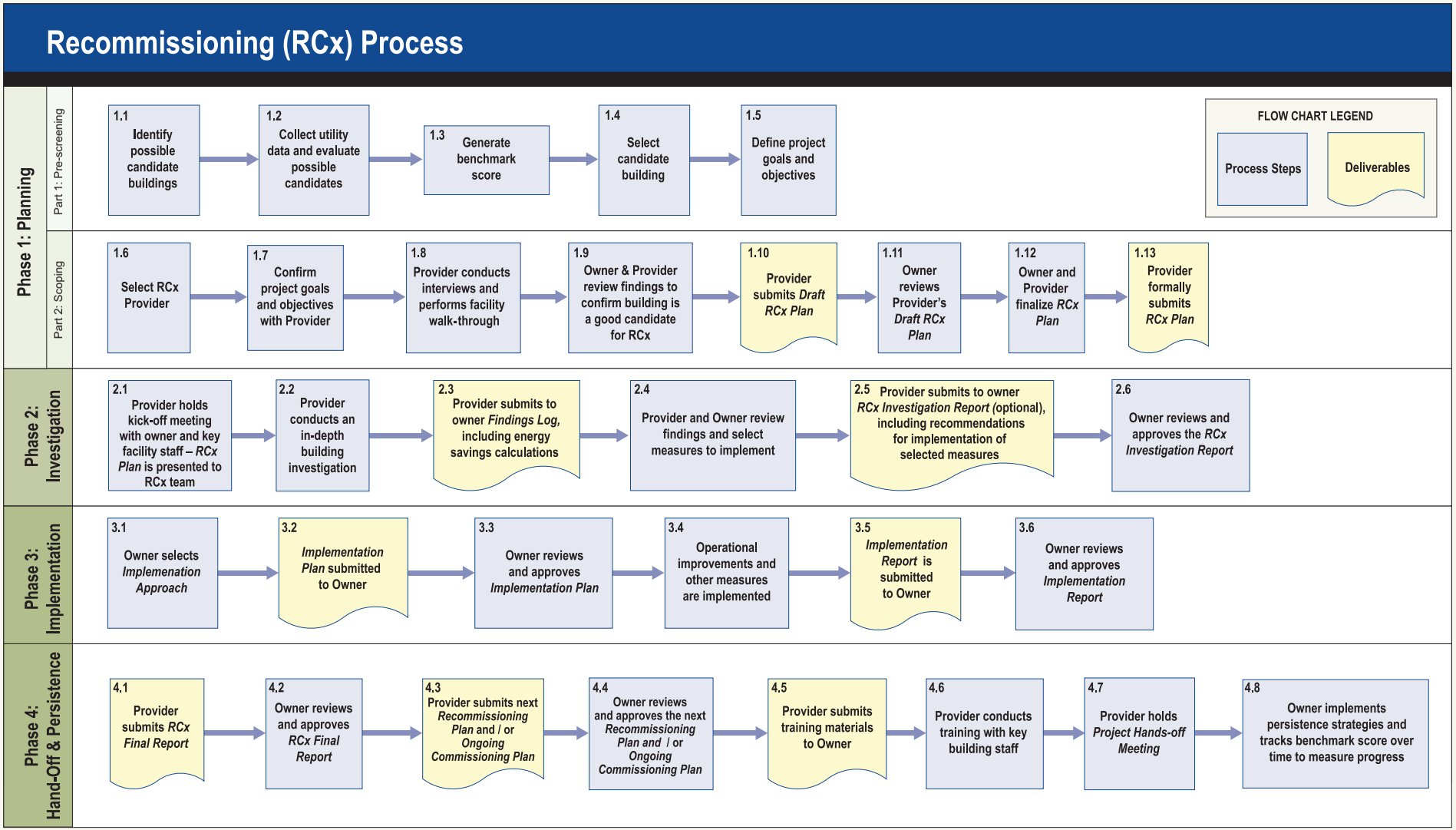


Figure 6: Recommissioning (RCx) Process Flow Chart.

PHASE 4: HAND-OFF AND PERSISTENCE STRATEGIES

The primary tasks of the Hand-Off Phase are:

- Complete a final report summarizing each improvement, findings and recommendations, including sequence of operation and operating intent as developed from the previous phase of the project;
- Conduct facility staff training;
- Hold a project hand-off meeting;
- Generate a post-recommissioning energy performance rating (e.g. re-benchmark); and
- Develop persistence strategies including the next recommissioning plan or an ongoing commissioning plan.

The Hand-Off Phase completes the initial recommissioning process. During Hand-Off, the recommissioning provider produces a final report documenting the process and its findings, conducts facility staff training, and holds a project hand-off meeting with the owner and facility staff. Persistence strategies should be put in place at this time to ensure the improvements last. Many owners choose to have the RCx provider visit the site periodically to assist the operators with the ongoing commissioning process.

RECOMMISSIONING TEAM

The first responsibility of the owner's representative is to put together the recommissioning team (see ***Table 4***). A team approach fosters the collaboration necessary to get the greatest impact from recommissioning. A team also facilitates open communication.

This is essential to a successful project for the following reasons:

- Building staff often know which upgrades and O&M activities can improve building performance, but do not have the time to evaluate what it would take to make improvements or pitch a proposal to financial decision makers. Building staff can provide valuable information to the recommissioning provider if recommissioning is approached as a collaborative process in which everyone brings skills and knowledge to the table.

- Involvement of the owner is critical to keep the project moving, achieve the greatest benefit, and ensure benefits last over time. Engaging with the team, clearly expressing project goals, and encouraging collaboration between the recommissioning provider and building staff will all contribute to the successful implementation of the process.

In structuring the team, key decision makers should be clearly identified. This process is essential to implementing the improvements recommended as part of the recommissioning process.

Table 4: Typical Recommissioning Team Member Roles and Responsibilities.

Participant	Roles and Responsibilities
Building Owner or Owner's Representative	Create and support team, provide information and resources needed for the project, clearly communicate goals and expectations.
Facility Staff	Provide existing documentation to RCx provider. Prepare a list of known problems and opportunities. Ensure system maintenance is performed (e.g. belts are tight, equipment has been serviced, and sensors are calibrated) before systems are tested. Work with recommissioning provider to perform tests and verify system operation.
Recommissioning provider[26]	Assist in developing a scope of work. Identify measures and develop report detailing opportunities. Work with facility staff to perform tests and verify system operation. Assist the owner's team in developing scopes of work for the contractors implementing the measures.
Contractor or Manufacturer Representatives as needed	Perform work as outlined in existing service contracts that cover O&M of the building's HVAC, controls, and electrical systems. Test equipment and/or implement measures that pertain to the equipment they installed.
	Controls Contractor: Assist in setting up trends and modifying the sequence of operations to meet test conditions if recommissioning provider (or facility staff) is not familiar with this function of the control system. Assist with implementation of controls-related fixes and improvements.
	Design Professionals: Provide additional expertise regarding design issues uncovered during the investigation. Assist in coordinating recommissioning with a retrofit project if timing permits.
	Testing Specialists: Assist the recommissioning provider with complicated testing or with equipment that requires special expertise.

[26] Natural Resources Canada's CanmetENERGY offers an Advanced Recommissioning Course targeted at recommissioning service providers and based on the RCx methodology described in this RCx Guide. Additional information is available on the Web: www.canmetenergy.nrcan.gc.ca.

DETERMINING ROLES

While ***Table 4*** recommends general roles and responsibilities for team members, specific roles may shift as a result of budget limitations, unique building requirements, and facility staff expertise and availability. Finding the right balance between responsibilities for facility staff and the outside recommissioning provider can be tricky and requires a good understanding of the capabilities of the individuals involved.

A third-party recommissioning consultant[27] is usually hired to lead the recommissioning effort. A building or facility manager, however, can manage the project and bring in a commissioning expert to assist with certain tasks. While it may be advantageous for the building staff to play a central role in a recommissioning project, having a recommissioning expert provide consultation is recommended, especially for large or complex projects and buildings with highly-integrated, sophisticated systems.

Four approaches for using a third-party recommissioning provider include:

1. Recommissioning provider oversees and implements the recommissioning process through all phases. This "turn-key" approach works well for owners who have one or more buildings with no on-site staff, or minimal staff with little time or training. The provider leads the project, manages any necessary subcontracts, and is solely responsible for ensuring that the owner's goals and expectations are being met through each phase of the process. This process is recommended for first-time projects even when the owner has a skilled team.
2. Recommissioning provider leads the process, but divides assessment work with facility staff. This arrangement works particularly well when facility staff has previous experience in recommissioning, or has expert-level knowledge of building systems. Arrangements such as these should be considered an active partnership between the facility staff and the recommissioning provider, leveraging in-house expertise as much as possible through all phases of the process to reduce consulting costs.
3. Recommissioning provider works closely with facility staff on initial projects, and in-house staff proceed independently with future projects. Owners with multiple buildings and well-trained and available staff may want to hire a recommissioning provider to work with the building staff for the first one or two buildings that undergo recommissioning. After the building staff is trained in the process, they can proceed with recommissioning the rest of the buildings.

[27] Ibid 26.

4. Recommissioning provider works closely with facility staff on initial project and is retained as a consultant to perform advanced tasks on future projects. This is similar to the third approach in that the in-house staff works to take on the role of the recommissioning provider. In this approach, however, the third-party commissioning consultant is retained for future projects to oversee critical parts of the assessment or advanced tasks such as functional testing, data analysis, and savings estimates and calculations.

CAUTION: While it may be tempting to have existing facility staff shoulder the majority of the recommissioning work, the key is to strike the right balance. If owners expect too much from staff, the process may stall or stop altogether. It may be helpful to think of the first recommissioning project as a capacity building opportunity for everyone, and to increasingly rely on in-house expertise with each successive project.

Good reasons to have a third-party recommissioning provider lead the recommissioning process include:

- The owner or manager may not have the time or staff resources to participate in the process or the in-house skills to perform the in-depth assessment that is required during the recommissioning process.
- Consultants specializing in recommissioning and O&M services have significant experience to draw upon, enabling them to offer a fresh perspective on a building. A third-party provider has no preconceived notions about how the building should perform, and has no vested interest in maintaining the status quo.
- Recommissioning providers are "tooled" for performing the work since they generally use data loggers, functional test forms, power monitors, and other specialized tools on a regular basis. Most have proven assessment and testing procedures that can be customized to fit a specific building.
- Engineering analysis is the specialty of the recommissioning provider, who has the analytic skills and resources needed to diagnose hidden problems and determine the cost-effectiveness of selected improvements.

The following ***Table 5*** shows the way roles were split for a large corporation with a highly experienced facility staff dedicated to the project. In this case, the energy manager developed an in-house recommissioning program to be used across all their facilities. The recommissioning provider served as a consultant for testing systems, analysing data, and training building staff throughout the process.[28]

Table 5: Sample Breakdown of Roles and Responsibilities between In-House Facility Staff and Third Parties.[29]

In-House Team	Third Parties (Recommissioning Provider and Subcontractors)
Design program	Act as resource
Conduct energy performance rating (e.g. benchmarking)	Review – assist as needed
Utility bill analysis	Review – assist as needed
Gather building documentation	Review
Create maintenance checklists (scheduled preventive maintenance)	Focus and train staff on operational improvements
Assist provider in data gathering	Conduct functional tests and data analysis (look at the root cause)
Implement easy to fix improvements	Assist with resolving design and complex implementation issues
Provide ongoing tracking and preventive maintenance	Provide ongoing support as needed
Obtain approval to implement improvements	Assist staff in developing the implementation proposal to upper management

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

[29] Ibid 28.

INVOLVING FACILITY STAFF

While some building owners or managers may be tempted to undertake recommissioning in-house, others may find it just as enticing to bring in an outside provider to carry the entire burden of the project. If the facility staff is excluded from the process, however, owners may miss an opportunity that can lower the project budget, increase in-house expertise and job satisfaction, and extend the impact of the improvements.

Facility staff can complete many supporting tasks without specialized training in this process. Gathering and analysing utility bills, benchmarking the building's performance, and performing a maintenance tune-up are generally straightforward and can be addressed with guidance from a recommissioning provider. Implementing improvements may also be accomplished by in-house staff, depending on their expertise. As indicated in ***Chapter 2 (page 20)***, owners can use in-house staff as a cost-saving strategy.

Participating in the recommissioning process can provide facility staff with a better understanding of the building's systems and their interactions. To capture this benefit, building owners need to allocate adequate staff time and budget for recommissioning work in addition to regular job duties.

OUTSOURCED O&M SERVICES

Some owners do not have full- or part-time building operators, while others may employ building operators with minimal skills or time. These owners often use service contracts to cover the O&M of HVAC, controls, and electrical systems. In these cases, the service contractor may take on recommissioning tasks that building operators would usually perform. The contractor may be asked to perform certain scheduled preventive maintenance tasks to prepare a building for recommissioning, as well as to assist in data gathering, performing hands-on testing, and adjusting and calibrating equipment.

ADDITIONAL TEAM MEMBERS/CONTRACTORS

In some recommissioning projects it is important to involve additional outside contractors (installing contractors, maintenance service contractors, controls contractors, and manufacturers' representatives). This usually occurs if equipment is still under warranty or under contract for service, as is often the case for control systems and large plant equipment such as

chillers and boilers. Where equipment is under warranty, the contractor should be involved *early* in the recommissioning process to prevent the voiding of warranties that could occur if an outside party manipulates the equipment. Installing contractors and manufacturer representatives may need to be brought in for equipment testing and/or implementation of measures on the equipment they installed.

Controls Contractor

Frequently, the person most familiar with the building's control sequences and programming is an outside controls contractor. A significant percentage of recommissioning findings are likely to address opportunities to reduce costs by improving the building's control strategies. Although it can be expensive, the expertise in trend logging and programming a control technician offers is essential and, in most cases, well worth the expense.

Design Engineers

If recommissioning is undertaken in conjunction with new equipment installation, then the engineers responsible for designing the equipment and systems should also be involved in the recommissioning process. Design engineers should be involved when the recommissioning provider needs additional expertise regarding design issues that are uncovered during investigation. Ideally, the engineer who designed the original installation should be brought in as a consultant to help resolve issues. The original design engineer may also have system documentation that is missing from the building's files.

Testing Specialists

Some recommissioning providers are also test engineers fully-equipped to perform tests most required. This, however, is not always the case. Many providers are skilled at performing HVAC functional tests and calibration exercises, but rely on other professionals or test experts for equipment that requires special expertise, such as variable-volume fume hoods. It may be particularly necessary to bring in specialized HVAC and testing and balancing experts in order to document air and water flow rates. The provider should be able to help identify qualified specialists. The recommissioning provider also typically writes the test procedures or goals for the testing exercise and then the testing is completed by the appropriate specialist.

LEED® Accredited Professional (AP)

If a recommissioning project is part of a LEED-EB™ project, then the provider and project team will need to work closely with the LEED Accredited Professional (AP).[30] The

[30] At the time of completing the Canadian adaptation of this guide, a Canadian Green Building Council (CaGBC) taskforce was developing terms of reference and timeline for the potential adaptation of LEED-EB for the Canadian market. More information can be found at www.cagbc.com.

LEED AP is responsible for compiling documentation needed to support achievement of credits required for the LEED certification. The recommissioning team needs to provide information related to the recommissioning process, and confirm that the recommissioning project is complete, or that the facility has a plan in place to complete it.

KEY STRATEGIES FOR SUCCESS

The following section summarizes strategies described in detail later in the Guide. These are areas that a building owner or owner's representative should pay particular attention to while designing and carrying out a recommissioning project. Each Key Strategy contains a link/reference to the corresponding detailed sections on each strategy. In addition, the Key Strategies section summarizes the deliverables that owners will want to obtain from their recommissioning provider.

IDENTIFY THE BEST BUILDING CANDIDATES

Owners of multiple buildings can consider a portfolio approach to selecting the best candidate(s) for recommissioning. Evaluating potential for energy improvements across a portfolio of buildings and selecting those with the most potential for success in the recommissioning process can assist with long-term planning and enable the owner to strategically capitalize on short-term paybacks. When budgets are tight, it may be wise to start with buildings in areas where utility incentives are available. Read more about Good Candidates for Recommissioning ***(Chapter 4, page 48)***. See also an example in Appendix A – List of Preferred Building Characteristics for Recommissioning.

✓*Checklist Items for the To Do List*

Analyse the building portfolio to identify the best recommissioning candidates. Bear in mind that the worst performing buildings in a portfolio may not always be the most cost effective choices.

DEVELOP WELL-DEFINED OBJECTIVES

The owner's project objectives determine the overall vision, scope, and direction of the project. They should be written and clearly articulated to the recommissioning provider to guide the project from start to finish. Understanding the objectives helps to ensure that adequate time and funds are allocated to complete the project. Read more about Defining Objectives and Project Scope ***(Chapter 4, page 52)***.

✓*Checklist Item for the To Do List*

For each building selected, write a set of objectives that can be incorporated into the *Recommissioning Plan* and the recommissioning provider's scope of work.

SELECT A RECOMMISSIONING PROVIDER WELL-SUITED TO THE PROJECT

When hiring a provider, check general qualifications, such as years in the field but, most importantly, understand what experience each candidate has with your specific building type. Ask to see sample reports to understand the type of information you can expect during the project. Read more about Selecting a Recommissioning Provider ***(Chapter 5, page 56)***.

✓*Checklist Item for the To Do List*

Develop a Request for Proposal (RFP) or a Request for Qualifications (RFQ) for recommissioning the selected building or buildings. The RFP should clearly define the project and its objectives.

DESIGNATE AN IN-HOUSE CHAMPION

Owner commitment is critical to project success. From the beginning, engaging with the team to clearly express project goals and support collaboration between the recommissioning provider and building staff helps ensure a successful recommissioning project. If the owner cannot be directly involved, the next best strategy is to assign an owner's representative to be an active "champion" for the project. This person will need to rally the facility staff to action and secure the necessary senior management support to keep the project moving forward. Read Owner's Operating Requirement ***(Appendix B)*** and Determining Roles ***(Chapter 3, page 34)***.

✓*Checklist Item for the To Do List*

Assign the appropriate in-house staff person to shepherd the project. This individual will need to be a good communicator and motivator in order to maintain adequate focus throughout the project. Also ensure that assigned staff have adequate time to oversee the provider and carry out some recommissioning tasks where necessary.

ASSIGN KEY FACILITY STAFF

Assign key facility staff to work with the recommissioning provider throughout the recommissioning project. When facility staff are brought in and consulted from the beginning, potential conflicts are avoided. A recommissioning process involving experienced, knowledgeable, interested, and available building staff is more likely to be cost-effective and have lasting results. There a several points in the recommissioning process where facility staff involvement can reduce costs and increase benefits. Read more about Involving Facility Staff to Save Time and Money ***(Chapter 2, page 20)*** and Involving Facility Staff ***(Chapter 3, page 37)***.

✓Checklist Item for the To Do List

Assign one or two experienced building operators (especially those who have the most controls experience) to work with the recommissioning provider. Request that the recommissioning provider provide estimates for the timeframe and necessary level of staff involvement for each task.

DEFINE PROJECT DELIVERABLES

As part of the recommissioning provider's contractual scope of work, include a well-defined list of deliverables or outcomes for each phase of the project. The detailed Recommissioning Flow Chart ***(Figure 6)*** shows where each deliverable typically occurs during the process. These documents may include:

Planning Phase

- Recommissioning Plan
- Read The Recommissioning Plan in ***Chapter 5 (page 61)*** [31]

Investigation Phase

- Owner's Operating Requirements
  - Read Owner's Operating Requirements in ***Chapter 6 (page 65)***
  - See an example in Appendix B – Owner's Operating Requirements

- Diagnostic Monitoring and Functional Test Protocols
  - Read Diagnostic Monitoring and Functional Testing in ***Chapter 6 (page 66)***

[31] See on-line example from the California Commissioning Collaborative Website: www.cacx.org.

[32] Ibid 31.

- Findings Log
  - Read Develop a Findings Log in ***Chapter 6 (page 70)*** [32]

- List of improvements selected for immediate implementation
  - Read Prioritize and Select Operational Improvements in ***Chapter 6 (page 70)***
  - Read Develop The Investigation Report in ***Chapter 6 (page 71)***

Implementation Phase

- Implementation Plan
  - Read The Implementation Plan in ***Chapter 7 (page 76)***
  - See an example in Appendix C – Recommissioning Implementation Plan

- Implementation Report
  - Read Implementation Verification and Reporting in ***Chapter 7 (page 77)***
  - See an example in Appendix D – Recommissioning Implementation Report

Hand-Off Phase[33]

- Final Report
  - Read The Recommissioning Final Report in ***Chapter 8 (page 80)***

- Systems Manual
  - Read Building Documentation in ***Chapter 9 (page 84)***

Strategies for Ensuring Persistence

- Recommissioning or Ongoing Commissioning Plan
- Read Periodic Recommissioning or Ongoing Commissioning Plan in ***Chapter 9 (pages 94-95)***

✓Checklist Item for the To Do List

Include a list of detailed deliverables in the recommissioning provider's scope of work.

[33] Ibid 31.

HOLD A PROJECT KICK-OFF MEETING

The recommissioning kick-off meeting is typically scheduled prior to the Investigation Phase. In this meeting, it is critical to clearly outline the benefits of participating in the recommissioning project to get buy-in from each team member. A formal project kick-off meeting creates an opportunity to bring the project team together to review the *Recommissioning Plan* and discuss the objectives, process, and team roles. Read Project Kick-Off Meeting ***(Chapter 6, page 64)***.

✓*Checklist Item for the To Do List*

Schedule time to attend the Project Kick-off Meeting. Review the agenda with the recommissioning provider prior to the meeting.

DEFINE THE OWNER'S OPERATING REQUIREMENTS

Providing detailed operating requirements for the facility enables the recommissioning provider to be sensitive when performing diagnostic activities to ensure that the critical operating requirements of the building are not disturbed. These requirements are also useful to the provider in assessing the feasibility of recommissioning measures. The owner's operating requirements inform the recommissioning provider of building schedules, functions, and processes, and differentiate between areas of the building that have different uses ***(Chapter 6)***.

✓*Checklist Item for the To Do List*

Develop a written list of operating requirements for the building as early in the project as possible. Review lease agreements for tenant operating needs and owner obligations and commitments to ensure that they are taken into consideration during the investigation process.

ACCOMPLISH STRATEGIC O&M TASKS PRIOR TO THE INVESTIGATION PHASE

Prior to the Investigation Phase, direct the building staff to gather the most up-to-date building documentation such as mechanical and electrical drawings, equipment lists, O&M manuals, and sequences of operation. Tenant improvement drawings, balancing reports and lists of changes to systems and in use of the building are also helpful. This will expedite the project by saving the recommissioning provider time. Also, direct the building staff to complete all scheduled maintenance prior to the Investigation Phase. Normal equipment maintenance should be completed before assessing equipment and system performance.

Because this does not require a recommissioning provider's expertise, it is more cost effective to have in-house staff or an outside service contractor address these tasks early to prevent delays to the project. Read Performing Scheduled Preventative Maintenance ***(Chapter 2, page 20)***.

✓*Checklist Item for the To Do List*

Make a list and assign strategic O&M tasks to the building operations staff and service contractors to help expedite the recommissioning work.

REVIEW THE FINDINGS LOG WITH THE RECOMMISSIONING PROVIDER

The Findings Log and Investigation Report are the most significant deliverables coming out of the Investigation Phase of the project. The Findings Log can be thought of as a decision-making tool for the owner. The owner and recommissioning provider use the Findings Log to select and prioritize the operational improvements for the most cost-effective results. Read Develop a Findings Log ***(Chapter 6, page 70)***.

✓*Checklist Item for the To Do List*

Schedule a meeting with the recommissioning provider to review and select the improvements for implementation based on information in the Findings Log. This meeting should include any building staff members who were intimately involved in the investigation process.

SELECT AN IMPLEMENTATION APPROACH

Depending on the building and circumstances of the project, there are different approaches to consider for implementing the recommissioning measures. The approaches range from "turn-key," where the recommissioning provider is hired to manage the entire process from start to finish, to using in-house staff to manage the entire implementation phase. Choosing an implementation approach will largely hinge on the in-house staff's availability and skills. Read Selecting an Implementation Approach ***(Chapter 7, page 74)***.

✓*Checklist Item for the To Do List*

Assess the in-house building staff's abilities and time constraints prior to determining the implementation approach. If appropriate, implementation can be staged to take advantage of utility incentives, lease changes, budget cycles and planned renovation projects.

REQUIRE OR DEVELOP AN IMPLEMENTATION PLAN

This document is critical for helping the implementation proceed smoothly and should reflect the management approach selected for the Implementation Phase. It should include scopes of work for addressing all the selected measures, as well as the methods required for evaluating the results after implementation. Read The Implementation Plan ***(Chapter 7, page 76)***.

✓*Checklist Item for the To Do List*

Review the Implementation Plan for each of the selected recommissioning improvements. Confirm that verification requirements are included to prove that each of the improvements is functioning as expected.

REQUIRE AN IMPLEMENTATION REPORT

The Implementation Report, and the data it contains that verify the impact of measures, is a key document. This is used for staff training, maintaining continuous building performance, and project evaluation. Read the Implementation Verification and Reporting ***(Chapter 7, page 77)***.

✓*Checklist Item for the To Do List*

Review the Implementation Report to make sure it is clear as to what was implemented and that it was verified to be implemented correctly. The approved report should be made available to those building staff members who are responsible for maintaining the improvements.

REQUIRE A FINAL REPORT AND HOLD A PROJECT HAND-OFF MEETING

Developing the Final Report is a key responsibility of the provider. It is the comprehensive record of the recommissioning project and should be kept as part of the on-site resources for facility staff. The owner should request that the provider present the Final Report at a Project Hand-Off Meeting, in order to address questions from staff and management about the project process, findings, and deliverables ***(Chapter 8)***.

✓*Checklist Item for the To Do List*

Schedule the Project Hand-Off Meeting to reiterate the project accomplishments and go over next steps for ensuring that the benefits last. The Final RCx Report can also be used to inform management and staff not directly involved in the recommissioning process of the achievements and results obtained.

DEVELOP PERSISTENCE STRATEGIES

During the recommissioning Hand-off Phase the owner and recommissioning provider determine effective persistence strategies for ensuring the recommissioning benefits are long lasting. Without these strategies the new, more efficient measures and improvements may degrade quickly. The recommissioning provider can recommend which strategies are most appropriate for the building and help develop a plan to carry them out ***(Chapter 9)***.

✓*Checklist Item for the To Do List*

Determine methods for incorporating persistence strategies into the building's O&M plan. These methods should include, at a minimum, periodic O&M reviews for those improvements most at risk for degradation. Constant monitoring of energy consumption will trigger an immediate look at any significant deviation and maintain rigour in the quest of persistence.

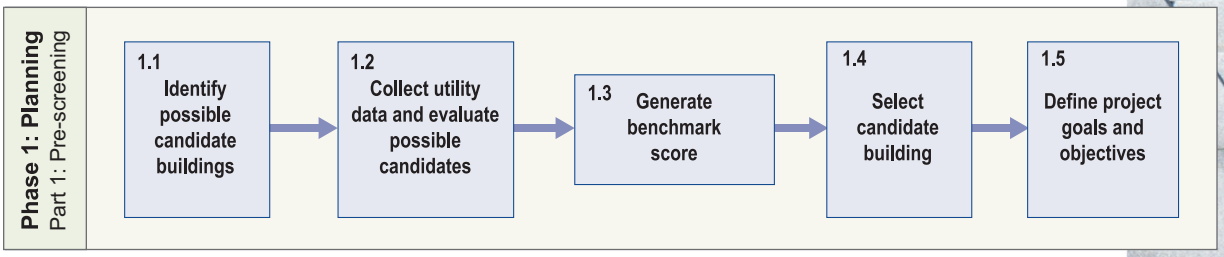
CHAPTER 4

PROJECT PLANNING – PART 1: BUILDING(S) PRE-SCREENING SELECTION

Initial planning activities are critical to the success of any recommissioning project as they set the objectives and lay the foundation for the project team's efforts. This chapter helps the owner's representative determine which buildings are good candidates for recommissioning and provides guidance for defining an appropriate scope for a project. A recommissioning provider can be hired to assist with building selection and formation of project objectives, or can be selected after the project is defined internally. The next chapter, ***Project Planning - Part 2: Selected Building Scoping,*** provides guidance on selecting a recommissioning provider and initiating the recommissioning project.

Highlights:

- Selecting a building for recommissioning
- Coordinating with retrofits
- Setting project objectives and obtaining support



GOOD CANDIDATES FOR RECOMMISSIONING

There is usually room to improve a building's performance regardless of its age, purpose, or size. Not every building, however, is appropriate for recommissioning. The first task is to determine which building or buildings are the best candidates. Newer buildings that were never commissioned often provide the most energy savings and non-energy benefits at the lowest cost. A good recommissioning provider can help determine which buildings in an owner's portfolio have the greatest potential to yield benefits.

WHAT MAKES A GOOD CANDIDATE FOR RECOMMISSIONING?

Obvious indicators of a good recommissioning candidate include:

- Unjustified high energy use index (kWh/m^2) or unexplained increases in energy consumption.
- Persistent or premature failure of building equipment, control systems, or both.
- Excessive occupant complaints about temperature, air flow, and comfort.

Note: Because buildings are complex and energy waste is often hidden, many buildings that exhibit none of the above characteristics may still prove to be good candidates for recommissioning. Experienced recommissioning providers understand how to uncover hidden energy waste that can lead to significant cost savings.

WHEN IS RECOMMISSIONING NOT THE FIRST STEP?

Recommissioning may not be appropriate for buildings where:

- Most of the equipment and systems are either outdated or at the end of their useful life and need to be replaced. In this case, "end of their useful life" means that equipment will need replacing in three years or less and recommissioning will not improve these odds.
- Major system design problems exist. Note: Care should be taken in determining this as controls malfunctions may initially be diagnosed as design flaws.

CAUTION: Owners often want to recommission their worst performing buildings first, but these facilities are not necessarily cost-effective choices.

OTHER PRE-SCREENING CHARACTERISTICS TO CONSIDER

There are several other building characteristics that may predict a project's chance of success and increase its cost-effectiveness. These characteristics include:

- Size: Though larger buildings are often thought to be better recommissioning candidates, a building of any size with complex mechanical systems and controls would be a good choice for a recommissioning project.
- Building controls: Although buildings with fully pneumatic controls have good recommissioning opportunities, buildings with computerized energy management control systems (EMCS) or hybrid systems (part pneumatic and part computerized) are typically more cost-effective. Pneumatic controls easily drift and need constant attention and calibration for benefits to last. Also, because of its trending capabilities, an EMCS can be used as a diagnostic tool during the recommissioning process to capture data, reducing the number of data loggers needed.
- In-house staff: Recommissioning performed in buildings with experienced, knowledgeable, interested, and available building staff is more likely to be cost-effective and have lasting results.
- Building documentation: While having missing or out-of-date building documentation should not eliminate a building from consideration, in the interest of cost-effectiveness, owners may wish to conduct recommissioning first in those buildings with better documentation. Complete, well-organized documentation can expedite the investigation process.

Appendix A provides a detailed sample list of preferred building characteristics.

PORTFOLIO APPROACH TO BUILDING SELECTION[34]

Owners of multiple buildings (private building owners, investment trusts, and property management firms) can consider a portfolio approach to selecting the best candidate(s) for recommissioning. Evaluating energy improvement potential across a portfolio of buildings and selecting those with the greatest likelihood for success can assist owners with long-term planning and enable them to capitalize on short-term paybacks. To begin with, an owner can look at energy records to determine how energy costs per square meter have increased over

[34] The US-EPA Guide references the *EPA Energy Performance Rating* and the *Portfolio Manager* online tool that are not adapted for Canada. However, additional information can be found at: http://www.energystar.gov/index.cfm?c=evaluate_performance.bus_portfoliomanager

the years and compare it with other properties of similar age and use. Owners may choose to have a recommissioning provider conduct a study of all their facilities to support development of a multi-year recommissioning plan. At a minimum, owners should develop a system to understand, compare, and prioritize their building stock to determine which sites present the best opportunity for recommissioning.

WORKING WITH A RECOMMISSIONING PROVIDER TO SELECT A BUILDING

A recommissioning provider can be brought in early in the decision-making process to assist in identifying a building well-suited for recommissioning. A provider can evaluate buildings in more detail than is possible using only a benchmarking score and can estimate the opportunity for reducing costs.

The information a recommissioning provider uses to analyse sites includes:

General information:

- Building type
- Number of occupants
- Size (gross square meter)
- Annual hours of operation
- Year of construction
- Year of last renovation
- Mechanical, lighting and control systems (types and sizes)

Energy data (ideally, three years' worth):

- Annual electricity use (kWh/year)
- Peak demand
- Annual natural gas use
- Annual district heating or cooling
- Average annual energy use index (EUI) for region/city for similar type building (GJ/m^2)

Operations overview:

- HVAC schedules relative to operating hours
- Set points
- Minimum outside air ventilation rates
- Extent of variable flow systems
- Preliminary discussions with facility staff members

Simulation of building optimal energy consumption:

- Optimal monthly electrical demand and energy consumption
- Differences between optimal and real data

A recommissioning provider can also review energy contracts and offer recommendations about how the owner might be able to negotiate these costs with an energy provider.

Once documentation is gathered, the recommissioning provider generally conducts a preliminary "walk through evaluation" of the top building candidates to make the final recommendation on which buildings are the best candidates for recommissioning.

COORDINATING RECOMMISSIONING AND RETROFITS

As mentioned above, a building is not a good recommissioning candidate if most or all of its equipment has aged to a point where recommissioning cannot produce improvements that would avoid equipment replacement. If only some equipment needs to be replaced, however, this can be coordinated with recommissioning to maximize benefits. Incorporating recommissioning with the replacement process improves system performance by ensuring that new equipment is properly integrated with other building systems. This assumes that the new installation is commissioned as part of the recommissioning project. In the interest of cost and continuity, the same recommissioning provider can be hired to do both the new-installation commissioning and the recommissioning processes.

Information on recommissioning and energy saving performance contracts can be found in ***Appendix F***.

DEFINING OBJECTIVES AND PROJECT SCOPE

Once a building is identified as a candidate for recommissioning, the building owner needs to define objectives for the project. A good provider can help an owner define these objectives. Owners may therefore want to take advantage of provider expertise early in the Planning Phase.

The following list provides some example objectives:

- Work with building operators to identify and recommend improvements to operational strategies and maintenance procedures, focusing on those measures that sustain optimal energy performance and reduce operating costs.
- Identify problems that could compromise the building's indoor environmental quality such as air quality and comfort.
- Train building staff during the process on how to best gather and analyse data to help troubleshoot and identify problems and improvements to operating procedures.
- Develop recommendations for improving building documentation.
- Identify possible capital projects for further investigation that can lead to energy cost savings.
- Assist management with developing language for lease agreements that prevents tenants from overriding sustainability and energy-efficiency measures.

Once the objectives are defined, it is important for the owner to actively garner the support of upper management and facility staff in accomplishing these tasks. Internal commitment to project objectives is a critical component of a successful recommissioning project. This support helps to ensure that the process is completed on time and that savings and improvement opportunities are pursued.

The project scope can be developed with the assistance of a recommissioning provider, as explained above, or can be developed in preparation for hiring a recommissioning provider. Once developed, the project scope helps define the provider's Scope of Work as described in the Proposal for Services.

The project scope should include the following:

- Project objectives
- Buildings, building systems and equipment that will be part of the assessment
- Anticipated level of involvement from in-house staff in the process
- Timeframe for investigation completion
- Number and type of expected deliverables or work products resulting from the process

Once the scope of the project is defined, the owner can decide more precisely how to involve facility staff in the project. It is important that the owner consider in-house staff expertise and availability, given the project's scope and complexity. If facility operators are new to recommissioning, the first project can be used as a capacity-building opportunity for everyone. Successive projects can potentially rely more and more on in-house expertise.

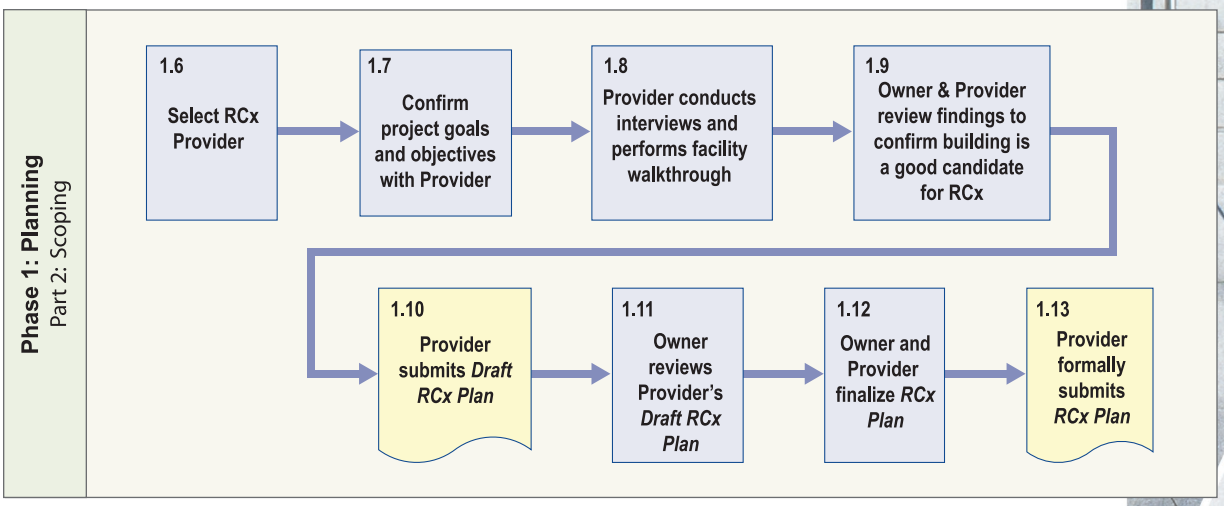
CHAPTER 5

PROJECT PLANNING – PART 2: SELECTED BUILDING SCOPING

This section describes how to select an appropriate recommissioning provider and explains the primary activities that occur during the beginning phase of a project. Once on board, the recommissioning provider conducts a preliminary walk-through evaluation. Based on initial findings in the building and a clear understanding of project goals, the recommissioning provider develops the Recommissioning (RCx) Plan. The RCx Plan serves as a guideline for team members to follow.

Highlights:

- Selecting a recommissioning provider
- Qualities to look for in a recommissioning provider
- Preparing for a building walk-through
- What to expect in a Recommissioning Plan



SELECTING A RECOMMISSIONING PROVIDER

In most cases, the recommissioning provider leads the process, works closely with the building staff, and ensures that the owner's expectations are being met at each stage of the project. The recommissioning provider has many responsibilities and must be skilled in fostering communication and promoting a positive, team-based approach to problem solving. A well-qualified recommissioning provider has a depth of troubleshooting experience, as well as the diagnostic monitoring, testing, and analysis expertise needed to uncover potential problems and select the most cost-effective solutions.

RECOMMISSIONING TASKS

While roles and responsibilities vary, the recommissioning provider's tasks typically include the following:

- Perform an initial site walk-through and gather general information about the building.
- Assist owner in developing a scope of work based on information from the site visit.
- Develop the Recommissioning Plan based on owner's goals for the project and findings from the initial site visit and information gathering.
- Review existing building documentation.
- Perform a detailed on-site assessment of the current operation and maintenance (O&M) practices.
- Develop monitoring and testing plans.
- Perform short-term diagnostic monitoring, using energy management control system (EMCS) trend logging where appropriate.
- Develop, perform, document, and oversee functional test procedures, as needed.
- Calculate energy savings and assist the owner with prioritizing the most cost-effective improvements for implementation.
- Develop Recommissioning Investigation Report that summarizes findings and provides recommendations for implementation of selected measures.
- Prepare the Implementation Plan.
- Assist with or oversee implementation of the selected improvements.
- Compile verification data by performing post-implementation monitoring and testing activities to verify proper operation.

- Recalculate energy savings based on before and after short-term energy measurements.
- Submit the *Recommissioning Final Report* (a summary of the entire project and O&M guidelines for each measure).
- Provide building operator training on the implemented measures and how to ensure improvements persist over time.
- Develop the *Next Recommissioning* or *Ongoing Commissioning Plan* for the owner.

PROVIDER QUALIFICATIONS[35]

When reviewing a recommissioning provider's qualifications, it is important to consider his or her technical knowledge, relevant experience, availability, and communication skills.

Appropriate Experience and Technical Knowledge

It is critical that the provider have the right experience and technical knowledge for the owner's project. Owners should consider how many years of experience a recommissioning provider has in designing, operating, troubleshooting, and testing building systems, including HVAC, direct digital controls (DDC), electrical power, lighting, and life safety. Owners should also look for providers with the ability to provide operation and maintenance training. The significant role that HVAC systems play in recommissioning means that a provider must have adequate HVAC and controls experience in order to ensure a successful outcome. Provision of documented references is essential as a proof of experience.

Because every project is unique, it is important to select a provider whose expertise and experience closely aligns with the project's objectives, scope, and complexity. For example, if improving indoor environmental quality (IEQ) is the primary objective for recommissioning, then the individual or firm hired for the job must be skilled at investigating and solving IEQ problems. If recommissioning is being implemented to reduce risk, owners should determine where their buildings are most at risk and if they do not perform as expected. An owner should then select a recommissioning provider who brings technical knowledge specific to that particular building function to the project. For example, an owner

[35] Natural Resources Canada's CanmetENERGY offers an Advanced Recommissioning Course targeted at recommissioning providers, and based on the RCx methodology described in this RCx Guide. Additional information is available on the Web: www.canmetenergy.nrcan.gc.ca.

of a laboratory may need a recommissioning provider with experience verifying biological containment systems.

Availability and Communication Skills

Look for a recommissioning provider that will be available when needed. Consider physical distance from or convenient travel to the facility site; however, for critical facility types it is more important to have the right technical skills than to select a provider who is physically nearby. Also, since the provider must interact with a wide range of people (owners, building operators, contractors, and manufacturer representatives), it is essential that the provider has strong communication skills. When hiring services from a consulting firm, ensure the individual assigned to your project has the required skills. The contract should specify that the selected staff stay on the project throughout.

THE SELECTION PROCESS

Two primary methods used for selecting a recommissioning provider are the *Request for Proposals (RFP)* and *Request for Qualifications (RFQ)* processes. Most government entities and many corporate owners may be required to use one of these processes.

Selection by Proposal

In a competitive selection process, the owner issues a Request for Proposals (RFP). This process solicits qualifications and a detailed scope of work from potential recommissioning providers and requires the owner to carefully evaluate each submission. Using an RFP process may be the most appropriate method to select the provider if the project is large or fairly complex. Many public agencies are required to go with the lowest qualified price proposal and should, if using an RFP process, carefully define the minimum qualifications and requirements.

Selection by Qualification

A provider can also be selected by evaluating qualifications and rate schedules, without first developing a detailed scope of work and price proposal. Using a Request for Qualifications (RFQ) is often simpler than the RFP process, but it does require the owner to carefully evaluate the providers' qualifications and interview past clients and references.

Appendix E presents a checklist of items to consider when developing a request for recommissioning services.

Most projects require providers to prepare their proposals in two phases. It will be difficult for the recommissioning provider to assess the time required for tasks in the Implementation and Hand-off Phases without first completing the Planning and Investigation Phases. Similarly, owners may not know how they want to handle the implementation without first receiving the investigation findings. Recommissioning providers may request to initially offer a specific proposal only on the planning and investigation phases of the project. Negotiations for the implementation and hand off phases would then occur when more is known about the specific needs of the project. This approach helps the recommissioning provider offer a more comprehensive and accurate cost estimate and a realistic scope of work.

THE BUILDING WALK-THROUGH

A recommissioning provider will conduct a walk-through of the facility, with the opportunity to talk to building staff, before developing a scope of work and *Recommissioning Plan*. A building walk-through allows the provider to become familiar with the building, its equipment, and main energy-consuming systems, as well as identify opportunities for further investigation. The building walk-through may be conducted as part of the proposal process, since the information gained will assist the provider in developing a Proposal for Services. A provider can learn a lot about the building by observing the overall condition and operation of the equipment, and the positions of valves and dampers. As part of the walk-through, building operators should be available to answer questions about the operating conditions, current preventive maintenance actions, and any known performance problems. Since the building operating staff knows the most about their building, prior to the walk through the building staff should put together a prioritized list of known problems and needed improvements to share with the recommissioning provider.

The owner should provide basic building information, including utility data from the previous three years, as well as preventative maintenance records and current service contracts, for the provider's review. This information allows the provider to analyse energy use and further understand current O&M practices at the facility. The goal of the walk-through is to confirm that the building is a good candidate for recommissioning and to look for indications of problem areas and opportunities that energy bill analysis and phone conversations with building staff cannot provide.

The following items are indicators of recommissioning opportunities found during the building walk through; their presence represents potential problems that can be identified and fixed through a recommissioning project:

- Systems that simultaneously and excessively heat and cool
- Indication of ineffective use of outside air for free cooling
- Pumps with throttled discharge valves
- Equipment or lighting that is on when it is not needed, especially air handling units that operate for extended periods when the building is unoccupied
- Improper building pressurization - either negative or positive (i.e., doors that are difficult to open or close)
- Equipment or piping that is hot or cold when it shouldn't be
- Unusual noises at valves or other mechanical equipment
- Spaces that are over-illuminated

As part of the walk-through, the building owner should inform the recommissioning provider of any equipment warranties that are still active. A warranty may become void if the installing contractors and/or manufacturer representatives are not called in to test the equipment and/or implement measures that pertain to the equipment they installed.

RECOMMISSIONING SCOPING STUDY – WHEN IS IT NEEDED?

A formal scoping study is often unnecessary if the building is carefully selected as a good candidate; however, for owners who want further assurance before beginning the full recommissioning process, a "Scoping Study" may be a good option.

A Recommissioning Scoping Study is a brief stand-alone report that describes the possible energy-saving opportunities in a building and recommends an approach for capturing those savings. This report is a low-cost investment to determine if recommissioning is appropriate for a particular facility. It also creates a planning mechanism that helps define the objectives, scope, and budget for the in-depth recommissioning effort. A scoping study is accomplished in a short time frame (one to three days) and at a minimum consists of a utility bill analysis and a building walk-through. A scoping study helps an owner feel confident that the building is likely to have adequate low-cost energy-saving opportunities to warrant investing in a full recommissioning effort. Some organizations use the scoping study to justify the RCx project and get buy-in from upper management or outside funding sources. Also, utilities may require a scoping study or preliminary report for buildings to qualify for energy savings incentives.

THE RECOMMISSIONING PLAN

If a Scoping Study ***(see previous textbox)*** is not requested, the recommissioning provider moves straight into developing a Recommissioning (RCx) Plan. The RCx Plan is a document that defines the project's objectives, scope, schedule, and documentation requirements. The plan serves as a guideline for team members to follow throughout the process by providing an outline of the processes and procedures that will be undertaken, a schedule of activities, defined roles and responsibilities of team members, and forms and templates that will be used to document the recommissioning activities. The RCx Plan should be viewed as a flexible document that is revisited at certain milestones in the project.

A good Recommissioning Plan should include the following elements:

- General building information and owner contact information
- Goals and scope of the project
- Brief building and system descriptions, including a list of systems that will be investigated
- List of team members, their roles, responsibilities, and expected deliverables
- Description of the communication, reporting, and management protocols
- Schedule (for primary tasks)
- Description of provider deliverables
- Documentation requests
- Investigation scope and methods
- Implementation Phase requirements
- Project hand-off

The owner's representative should provide input to the provider as the Recommissioning Plan is developed. Providing a list of deliverables that the owner expects to result from the recommissioning process assists the provider in developing the plan. Possible deliverables include:

- Scoping document
- Findings Log and energy savings calculations
- Recommissioning Investigation Report
- Progress reports and meeting minutes
- List of recommended capital improvements for further investigation
- Implementation Plan
- Recommissioning Final Report
- Building staff training materials
- Recommissioning Plan or Ongoing Commissioning Plan

The number and type of deliverables will depend on the scope of the project. The Recommissioning Process Flowchart ***(Figure 6)*** identifies typical provider deliverables required by an owner throughout the recommissioning process.

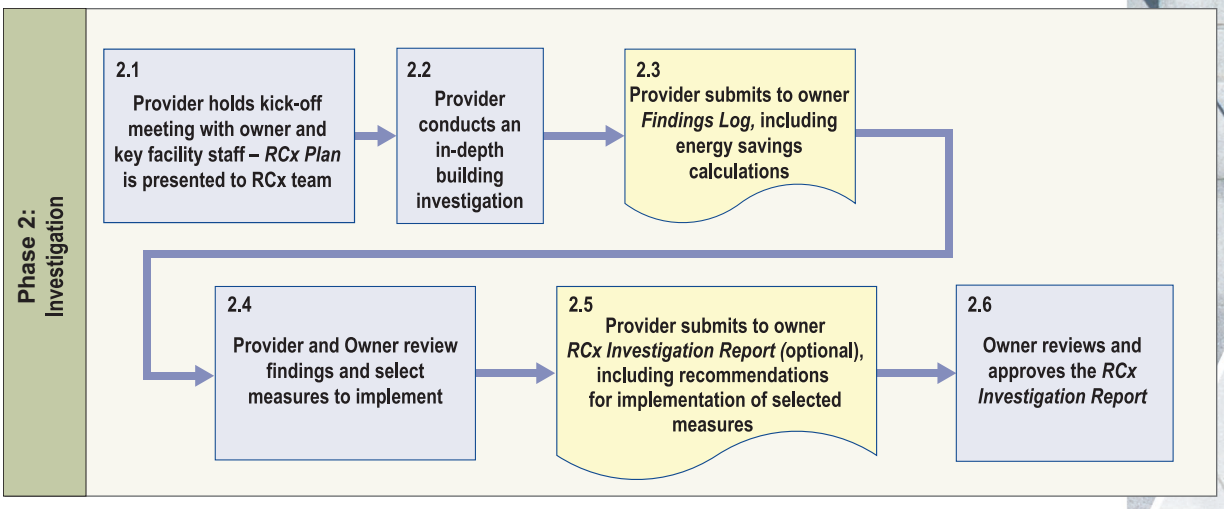
CHAPTER 6

INVESTIGATION

The primary goals of the Investigation Phase are to understand how building systems are currently operated and maintained, identify issues and opportunities for improvement, and select the most cost-effective measures for implementation. During investigation, the recommissioning provider performs a thorough review of building documents and conducts a methodical analysis of building operations by trending and testing the building systems. The recommissioning provider summarizes the results of the investigation analysis in a Findings Log, sometimes called a Master List of Findings. The recommissioning provider then presents the results to the owner and helps select measures for implementation.

Highlights:

- Holding the project kick-off meeting
- Information that the provider will need during the Investigation Phase
- Working with incomplete or missing building documentation
- Using diagnostic monitoring and functional testing to uncover the root cause of problems
- Prioritizing and selecting the most cost-effective improvements



PROJECT KICK-OFF MEETING

The Investigation Phase typically begins with a project kick-off meeting. A formal project kick-off meeting creates an opportunity to bring critical project team members together to review the Recommissioning Plan and discuss the objectives, process, and team roles. Meeting participants may include the owner or owner's representative, facility staff, and any contractors or other professionals who may be important to the process, such as controls contractors, maintenance service contractors, or consulting engineers who are familiar with the building and the owner's operating requirements.

The recommissioning provider and owner should co-lead the kick off meeting. This will demonstrate support from the owner and, at the same time, provide an opportunity for the recommissioning provider to establish a collaborative role with other team members. At the kick-off meeting, the owner and provider identify each team member's responsibilities and communicate the owner's expectations for the project. It is important that roles and expectations for each team member are established from the onset. Minutes of this meeting are generally prepared by the provider both to capture the original intent and mission of the RCx project and to document the process for those not directly involved. Staff interviews give the recommissioning provider an indication of their understanding of the proper operation of their systems. This is a good first marker of the training needs of the operators for optimum system operation.

BUILDING INVESTIGATION

The core of the Investigation Phase is a systematic analysis of the building's performance through direct observation, review of building documents and O&M practices, and monitoring and testing of building systems.

DOCUMENTATION REVIEW

One of the first actions a provider must undertake during Investigation is a thorough review of building documents. To reduce expenses and maximize the benefit of a recommissioning project, in-house facility staff can be assigned to answer questions and help gather necessary building documentation for the provider.

Owner's Operating Requirements

The Owner's Operating Requirements is one of the important documents for the provider to review. If it is incomplete or unavailable, the owner may want to ask the recommissioning provider to update or create one. This document addresses the owner's comfort requirements such as space temperature, humidity and outside air fractions, and building schedules. The objective of any recommissioning project is to ensure that the building is operating as needed by the owner. Having these requirements clearly documented enables the recommissioning provider to be sensitive to building schedules, functions, and processes during the diagnostic activities to avoid disrupting the occupants (*Appendix B* provides a sample Owner's Operating Requirements form, as well as a filled-out example.)

Other Critical Documentation

To the extent possible, the owner should gather the following additional documents for the recommissioning provider's review:

- Original design documentation;
- Equipment lists, with nameplate information (including age and energy efficiency rating where appropriate);
- Drawings for the building's main energy-consuming systems and equipment, including controls, mechanical, and electrical. (A small schematic diagram of the building's systems and floor plans can prove useful in a complex building, enabling the provider to move around more quickly and gather notes on findings more efficiently);
- Control system documentation, including point lists, control diagrams and narratives on the sequences of operation;
- Operation and maintenance manuals;
- Testing, adjusting, and balancing (TAB) reports;
- Previous commissioning reports; and
- Previous energy studies.

If the building documentation is out-of-date or incomplete, the owner may want to take advantage of the recommissioning project to remedy this. In some cases, the recommissioning provider's activities will generate new and useful documentation. The owner can also increase the recommissioning provider's scope of work to include improving or developing building documents that ensure the benefits from recommissioning last. The owner should, however, bear in mind that preparation of building documentation can be time-consuming and may add significantly to the cost of the recommissioning project. ***Chapter 9*** of this guide, "Making Recommissioning Benefits Last," contains additional details on building documentation.

How to Proceed if Documentation is Missing

The success of a recommissioning project does not hinge on the quality of the building documentation. If, however, building documentation is poor or incomplete, especially for the mechanical and control systems, it can drive up the costs of recommissioning. Without essential documentation, the provider will need to spend time gathering and recreating critical information in order to assess system operations.

FACILITY STAFF INTERVIEWS

No one knows a building better than the facility staff. After the recommissioning provider reviews the building documents, the next step is for the facility staff to help the recommissioning provider understand known problems and areas of improvement. Facility staff should consider preparing for discussions with the provider by developing a list of problems and improvements that they want addressed.

DIAGNOSTIC MONITORING AND FUNCTIONAL TESTING

Because recommissioning is a method for identifying the root cause of problems and determining the most cost effective solutions, data gathering, testing, and analysis is an integral part of the process. The owner can expect the recommissioning provider to perform diagnostic monitoring and functional testing to help uncover the root cause of problems and look for ways to improve existing operating strategies.

DIAGNOSTIC MONITORING

Diagnostic monitoring uses the building's energy management control system (EMCS), where these systems exist. For those buildings without an EMCS or adequate points for diagnostics, portable data loggers can be used to gather the data. ***(See textbox below for a more detailed explanation of the two methods.)*** Monitoring involves collecting data over time at intervals ranging from one minute to one hour depending on the problem. Variables typically trended include:

- Whole building and end-use energy consumption (such as electrical consumption or demand, gas, steam, or chilled water);
- Operating parameters (such as temperatures, actuator positions, flow rates, and pressures);
- Outdoor temperature, humidity and CO_2 indoor sensors;
- Equipment status and runtimes; and
- Setpoints that change (reset schedules).

Collecting data this way allows the recommissioning provider and facility staff to observe system performance under various modes and operating conditions over time. The next step in the diagnostic monitoring process is to analyse the data. The provider will analyse data and create charts showing hourly, daily, weekly, or monthly trends. Charts can also be used to document how one parameter varies with changes in another. Analysing this information allows the recommissioning provider to characterize system performance and verify whether each system is operating correctly. This information should be shared with the facility staff so they can see how the systems are actually performing. Seeing the data can often lay to rest any guess-work or debates about how a system is or should be operating.

[36] Also known as Building Automation System (BAS) or Direct Device Control (DDC).

DIAGNOSTIC MONITORING METHODS FOR COLLECTING DATA

EMCS TREND LOGGING

Energy management control systems (EMCS)36 will have different capabilities to do trend logging (trending). These capabilities have a considerable effect on the extent to which trending can be used for diagnostics. Many facilities do a considerable amount of trending, but rarely include in-depth analysis by the building operator.

PORTABLE DATA LOGGING

Portable data loggers are stand-alone electronic data-gathering devices. Data loggers utilize sensors to collect equipment information at intervals set by the provider for as long as they are left in place. Because data loggers are battery-powered, small, light, and easily installed and removed without disrupting building occupants, they can be extremely useful diagnostic tools. This is true especially if the EMCS has any limitations on collecting, storing, or presenting data. Many data loggers come with software packages so that data can be downloaded and easily graphed.

FUNCTIONAL TESTING

In most cases, it is not possible or cost-effective for the recommissioning provider to directly observe all the building's different operating regimes; therefore, the provider performs diagnostic monitoring, coupled with specific functional performance tests. When trend analysis is not enough to determine why a particular problem exists, performing functional tests can help pinpoint the actual cause. Functional tests take the system or piece of equipment through its paces: observing, measuring, and recording its performance in all key operating modes. Functional testing also may be used to help verify whether a particular improvement is needed and cost-effective.

Test Protocol

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

- Preparing for tests;
- Manipulating the systems to assist the provider in conducting tests; and
- Putting the systems back to normal following testing.

A rigorous test protocol describes exactly how a test will be carried out and includes:

- Purpose of the test;
- Prerequisites for testing;
- Instructions for carrying out the test, including safety precautions;
- Detailed procedural steps for testing and documentation;
- Procedure for returning to normal;
- Equipment required for the test;
- Analysis required;
- Acceptance criteria and quality control procedures; and
- Required sign-offs.

Prior to performing the most complex functional test, the recommissioning provider develops a test protocol. The test protocol clearly describes how the test will be carried out. The owner and provider need to schedule the testing so facility staff are available to handle any necessary preparations, as well as participate in the test. The provider and staff carry out the tests and record all findings on a pre-defined data sheet.

Completing Simple Repairs as the Project Progresses

During the process of Investigation, the need for simple or immediate repairs is often uncovered. While these can be tracked for later action, fixing items as they are discovered is usually the most effective strategy. These adjustments increase the effectiveness of the diagnostic monitoring and testing. Often, a strategic fix (such as a sensor calibration) will support the process of understanding the root causes of operational issues. Planning ahead for this during Investigation allows the owner to set aside a small budget and provides facility staff time to accommodate repair opportunities. Although these repairs may be quick and easy to do, they can sometimes lead to significant energy cost savings and should therefore be recorded as part of the Findings Log.

Investigation Strategies for Short Time Frames

Many recommissioning projects are done within a limited time frame; therefore, the diagnostics and testing may only occur during one season. In such cases, the following strategies should be considered:

- Plan to do the investigation during the season where the most problems occur or where the most opportunities lie for saving energy and improving operations. A rigorous utility bill analysis along with building operator recommendations will help determine when the Investigation Phase should occur. This could actually be during the "swing" or "shoulder" season, which occurs in spring or fall when there is low demand for heating or cooling.
- Conduct in-depth interviews with the building operation staff regarding the opposite season from when the investigation occurs. Along with a rigorous review of the building documentation, sequences of operation and energy bills, this may suffice for recommending improvements during the opposite season.
- Consider deferring some testing if there are significant problems in both the cooling and heating season. This can help identify the root cause of a complicated problem occuring in the opposite season from when the investigation takes place. Budget should be allotted for deferred testing in such instances.

PRIORITIZE AND SELECT OPERATIONAL IMPROVEMENTS

The process of prioritizing and selecting operational improvements depends on the budget and goals of the owner and is therefore unique to each building. The Investigation Phase results in a list of findings, which are recorded in a Findings Log (or Master List of Findings). In a meeting with the owner, the recommissioning provider presents the Findings Log along with recommendations to implement those findings that hold the largest opportunities for improvement and meet the owner's project objectives. Together, the owner and provider select and prioritize the group of findings for implementation and agree on an implementation plan and budget.

DEVELOP A FINDINGS LOG

The Findings Log is one of the most significant deliverables from the recommissioning process and ultimately becomes an important decision-making tool for the building owner. It summarizes every finding from the Investigation Phase, including the "field fixes" made during the course of investigation. At a minimum, the Findings Log should provide a rec-

ord of measure descriptions, estimated energy savings, cost estimates, simple payback, recommendations for implementation, and status of implementation. A unique identification number should be assigned to each finding, to be used as a reference number throughout every recommissioning report and document to avoid confusion, especially during implementation.

The owner should participate in the design of the Findings Log to ensure that the necessary information is included. The owner may wish to have an estimated simple payback or return on investment (ROI) for each measure or group of measures reflected in the Findings Log. The Findings Log might also include the following:

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

The owner should request that the savings calculations be provided with the Findings Log. This is especially important for measures that may not be implemented for several months or years. Knowing the original assumptions and calculations saves time and money in updating the costs and paybacks at a later date.

DEVELOP THE INVESTIGATION REPORT

For many owners, the Findings Log will provide sufficient documentation of the Investigation Phase and be an adequate tool to use in making decisions regarding what actions to take during the Implementation Phase. Some owners, however, prefer to have the Findings Log information incorporated into an Investigation Report. In this report, the investigation team provides detailed findings from the site assessment, building documentation review, utility bill analysis, and diagnostic trending and testing. Based on a review of recommendations included in the Findings Log, the owner and provider can reach an agreement on how to proceed with those recommendations. These decisions can be recorded as part of the Investigation Report.

The Findings Log and associated Investigation Report are tools that help owners determine which measures to implement, based on their projected value in terms of energy savings or occupant safety and comfort. The next chapter – Implementation – discusses the planning process for getting the selected solutions and improvements implemented in the building.

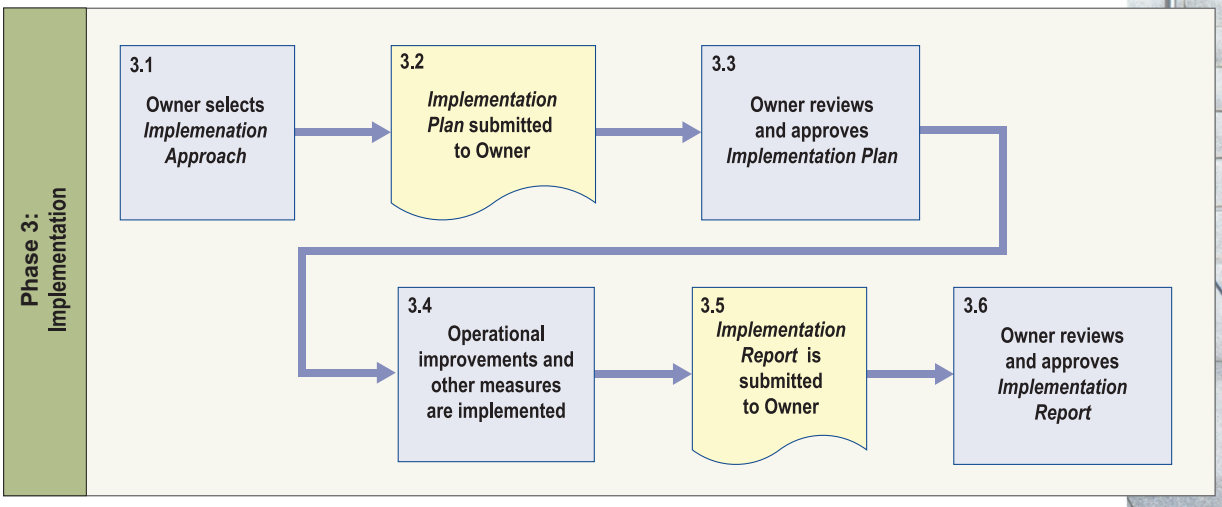
CHAPTER 7

IMPLEMENTATION

During Implementation, the operational improvements selected at the end of the Investigation Phase are completed and verified. Depending on the type of project and the resources available to the owner, there are several models for Implementation. This chapter describes these different approaches and the situations where each is appropriate. It also discusses the Implementation Plan and Report, important documents which the owner should request to ensure this phase proceeds effectively.

Highlights:

- Selecting the right implementation approach
- Establishing a reasonable timeline for implementation of chosen measures
- What to expect in the Implementation Plan and Report



SELECTING AN IMPLEMENTATION APPROACH

Once the Investigation Phase is complete, the owner will need to choose an approach for moving forward with Implementation. Implementation usually involves a combination of facility staff, outside contractors, and the recommissioning provider, with each doing some portion of the work as appropriate to the building conditions, existing warranties, staff expertise and availability, and budget.

During Implementation, the role of the recommissioning provider can be reduced if most of the work is contracted out or undertaken by in-house staff. Retaining the recommissioning provider to oversee this phase of the project, however, has a number of advantages. The provider's intimate knowledge of the building systems and needed improvements may ultimately save time and reduce costs, as well as ensure that projected cost-effectiveness is achieved. If the recommissioning provider stays with the project, it may also be possible to pursue additional recommissioning measures that are uncovered during Implementation. In determining the most appropriate strategy, it is helpful to review the following three most common approaches to implementing a recommissioning project:

- Turn-key implementation
- Recommissioning provider-assisted implementation (consulting option)
- Owner-led implementation

TURN-KEY IMPLEMENTATION

In many instances, the recommissioning provider can complete the project for the owner by leading implementation activities.

- **Appropriate Projects.** Turn-key implementation is usually applied to projects where the provider is capable of providing the service, and the in-house staff is either not available to implement any of the measures or does not have the necessary skills.
- **Advantages.** Only one contract is held by the owner. Any subcontracts are held and managed by the recommissioning provider. This is often the easiest option for the owner, as it reduces the need to coordinate, contract and manage Implementation activities. Also, since the recommissioning provider has insight into the building and its system operations, he or she is well-qualified to thoroughly address implementation issues. The provider's contract could also include performance obligations in terms of guaranteed savings or offer shared savings options.

RECOMMISSIONING PROVIDER-ASSISTED IMPLEMENTATION (CONSULTING OPTION)

Under this approach, the recommissioning provider is retained to provide assistance and oversight through implementation, but does not directly complete the majority of the work. The owner holds the contracts with the various firms that will be implementing the recommissioning fixes.

- **Appropriate Projects.** This approach is ideal when highly skilled, in-house staff are available and can carry out much of the work, as well as when the owner has the time and expertise to manage Implementation.
- **Advantages.** This arrangement takes advantage of in-house capabilities while simultaneously leveraging the expertise of the recommissioning provider to oversee the coordination and outcome of the work. Working with a recommissioning provider in Implementation also can build in-house skills among facility staff, so that they are better able to maintain performance of systems over time. In this role, the recommissioning provider can help the owner define the scope of work for in-house staff and contractors, coordinate scheduled work, and verify that the results meet expectations.

OWNER-LED IMPLEMENTATION

The owner also can choose to take the results and recommendations from the Investigation Phase and proceed to the Implementation Phase without further assistance from the recommissioning provider.

- **Appropriate Projects.** This option may be attractive to owners who have strong, established relationships with a service contractor or a highly capable in-house engineer who can implement and verify the recommissioning measures. Note that, even in this case, the recommissioning provider should still conduct the tasks outlined in the Hand-Off Phase chapter that follows.
- **Advantages.** This approach takes advantage of existing in-house facility staff expertise and established service contractor relationships. In some cases, this is the goal of owners who adopt recommissioning as a "business-as-usual" practice. They may start projects with very little recommissioning expertise among their facility staff and, over the course of several recommissioning projects, seek to build the ability and expertise in-house to manage their own projects. This approach does, however, require significant commitment on the part of the owner.

SETTING A TIMETABLE

Some owners adopt a staged implementation plan to accommodate budgeting constraints, but other owners may implement all measures in one project. While each situation is unique, following up on all or most of the measures immediately after the Investigation Phase has several compelling advantages. Project momentum, consistent staff involvement, and maximum cost savings are all substantial reasons to keep the project going right into Implementation.

THE IMPLEMENTATION PLAN

Once the owner has selected measures in consultation with the recommissioning provider and has determined the most appropriate approach to managing the Implementation Phase, the provider develops an Implementation Plan. The Implementation Plan organizes and defines the work needed to implement the measures selected by the owner. It also describes the required results, how to get them, and how to verify that the objectives have been met. The Implementation Plan can include a scope of work for addressing each issue that the owner has selected, along with requirements for verification. Depending on what post-implementation data the owner needs – either for internal purposes or for receiving incentives from an outside program – the plan may also recommend methods for verifying the performance of the measures after implementation.

The Implementation Plan takes on different forms and is used in different ways depending on the approach selected to manage the work. It can be a guideline for building staff to make the repairs and improvements, or it can be used to gather scopes of work and bids from contractors. If the recommissioning provider is providing turn-key implementation, the plan may take the shape of a proposal and scope of work for the provider to perform all implementation and verification activities (***Appendix C*** includes a sample Recommissioning Implementation Plan.)

IMPLEMENTATION VERIFICATION AND REPORTING

As measures are implemented and the project moves forward, it is critical to document and verify the results. This is an important part of the Implementation Phase and has value beyond assuring the correct completion of work, since it also establishes a new baseline for performance.

As measures are completed, it is important to retest the equipment or systems to ensure that the improvements are working as expected. Retesting can be done with the same diagnostic testing methods used in the Investigation Phase, such as EMCS trending, data logging, functional testing, simple observation, or a combination of these methods. When retesting, post-implementation data are compared to the original baseline data to confirm that the combination of improvements are integrated and have the desired effect on the building.

The recommissioning provider can use the verification data to update the energy savings estimates as needed. Verification data can also be used to establish a new baseline for the performance of each of the treated building systems. The new baseline can be used to establish criteria or parameters for tracking whether or not the improvements are performing properly throughout the life of the equipment or systems.

The Implementation Report documents each measure with a description, resolution status, resolution description, and any future recommended actions. (***Appendix D*** provides a sample Recommissioning Implementation Report.)

Once all the improvements are completed and verified, a new benchmark should be generated (e.g. building re-benchmarking). Since the score is based on the past year of utility data, recommissioning energy savings will be reflected in the energy performance rating over time. This will provide a new baseline score against which each following year's building performance can be matched.

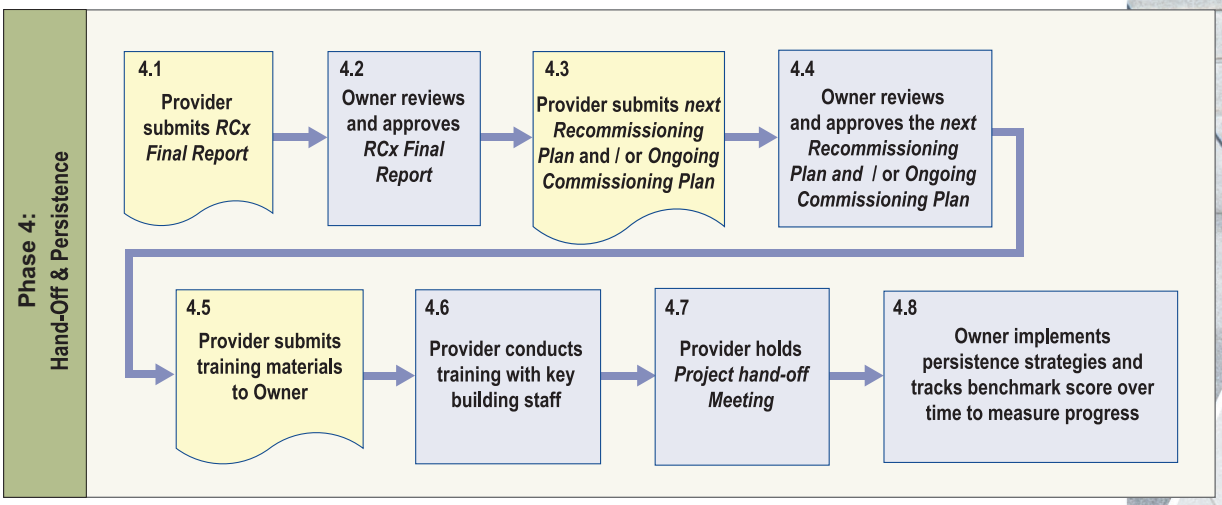
CHAPTER 8

PROJECT HAND-OFF

Project Hand-Off is the final phase of a recommissioning project. In this Phase, the recommissioning provider develops reports and other significant documents that summarize the project. These reports are useful in maintaining the results that recommissioning achieved, as well as in providing the basis for facility staff training. During this Phase, the recommissioning provider also assists the owner in determining the best strategies for keeping the new improvements functioning efficiently over time. Without these persistence strategies (discussed in ***Chapter 9***), recommissioning measures sometimes can be circumvented, changed, or ignored by facility staff. With an effective Hand-Off Phase, the measures will not only continue to deliver cost savings and contribute to the improved quality of the building, but the project can also be the foundation for continued operational improvement.

Highlights

- What to expect in the Final Report
- Importance of facility staff training
- Recommendations to ensure that recommissioning benefits last
- The project Hand-Off Meeting



THE RECOMMISSIONING FINAL REPORT

A key responsibility of the recommissioning provider during the Hand-Off Phase is to develop the Recommissioning (RCx) Final Report. The RCx Final Report brings together important information from other recommissioning deliverables into a single document. As a comprehensive record of the project, it should become a part of the on-site resources for facility staff. The specific contents of the RCx Final Report will vary according to owner needs, but may include the following:

- Executive Summary
- Owner's Operating Requirements
- The Findings Log with descriptions of the implemented measures
- Updated savings estimates and actual improvement costs
- The EMCS trending plan and data logger diagnostic/monitoring plan
- All completed functional tests and results
- Recommended frequency for recommissioning
- Complete documentation of revised or new control sequences (or where this can be found)
- Recommendations for maintaining the new improvements
- Training Summary including training materials
- A list of capital improvements recommended for further investigation
- A methodology to periodically recalculate energy and cost savings that takes the main factors affecting the energy consumption (such as climate, level of occupancy, hours of use of major equipment, and so on) into consideration

FACILITY STAFF TRAINING

To ensure that the benefits of recommissioning are maintained over the long-term, building operators and managers must have the right knowledge and skills. In addition to involving facility staff during the course of the project, it is important for the owner to request that the recommissioning provider develop and conduct additional training for facility staff at the end of the project. This training is particularly important for those staff members who were not part of the day-to-day recommissioning activities. Such training provides an opportunity to address how staff can maintain the recommissioning improvements, as well as any aspects

of the building's typical operations and maintenance practices that are of concern in maintaining a high level of system performance. A training session typically involves a classroom workshop with some hands-on demonstrations on the building equipment. Owners should consider videotaping the training session for future reference and as resource for training new facility staff.

RECOMMENDED HAND-OFF TRAINING TOPICS

- Energy usage analysis
- Energy accounting and benchmarking
- Operating schedules and owner's operating requirements
- Investigation process and methods used to identify problems and deficiencies
- Master List of Findings
- Measures that were implemented and by whom
- Expected performance improvements from these measures (showing before and after trends if applicable)
- O&M requirements to keep these improvements working
- Staff's role in helping to maintain the persistence of savings
- Re-training, as, on the operation of the more complex systems or those that have undergone important recommissioning changes

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

RECOMMENDED PERSISTENCE STRATEGIES

An owner should consider having the recommissioning provider recommend persistence strategies to help ensure that the benefits of the recommissioning project continue beyond the life of the project itself. These strategies, discussed in detail in the next chapter, include the following:

- Developing policies and procedures for updating building documentation
- Providing ongoing training for building staff

- Ensuring efficient operating performance
- Tracking energy and system performance
- Periodically recommissioning the building, paying close attention that the original recommissioning improvements are still producing benefits
- Instituting a plan of ongoing commissioning

PROJECT HAND-OFF MEETING

The owner should hold a project Hand-Off Meeting and work with the recommissioning provider to develop the agenda and lead the meeting. At the Hand-Off Meeting, the recommissioning provider presents the RCx Final Report to the owner and project staff and answers questions from the staff and management about the project process, findings, and deliverables. Any remaining issues and next steps can be included in the meeting discussion. It is helpful to structure this meeting as an opportunity to not only review the project, but also to celebrate its success and discuss the applicability of the process in regard to other buildings in the owner's portfolio.

The owner should expect the RCx Final Report to include recommendations for strategies to ensure lasting benefits from recommissioning. As part of the Hand-Off Phase, the owner and recommissioning provider should decide which of the recommended strategies to implement. The next chapter describes several persistence strategies.

CHAPTER 9

MAKING RECOMMISSIONING BENEFITS LAST – STRATEGIES FOR ENSURING PERSISTENCE

There are many things that can be done to ensure that the benefits from recommissioning persist. Particularly for controls improvements, it is important to use persistence strategies to reduce the chance that recommissioning measures are changed or modified in ways that reduce their benefits. This chapter provides information on activities that an owner might want to consider to ensure that their investment in recommissioning continues to pay off in the future.

Highlights:

- Developing building documentation
- Planning for staff training
- Maintaining efficient operating performance
- Performance tracking
- Planning for the next recommissioning and ongoing commissioning
- Feedback and success celebration

BUILDING DOCUMENTATION

For existing buildings that do not have complete or up-to-date documentation, the recommissioning project offers a useful opportunity to update or create these resources. These documents supply building operators as well as HVAC, controls, or maintenance service contractors with the information they need to operate and maintain systems and equipment, and troubleshoot problems so the recommissioning measures continue to perform as expected.

Essential documents that should be updated or created as part of the recommissioning project include:

- Equipment Lists
- O&M Manuals
- Control System Documents (points lists, sequences of operations, system diagrams)

Equipment Lists

Typically, the equipment lists contain the following information for each piece of equipment:

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

O&M Manuals

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

If a building already has good, up-to-date O&M Manuals, they may only need to be modified to include any changes to equipment or operations that are made as part of the recommissioning project. If existing O&M Manuals are not complete enough to support effective O&M of the existing equipment, the owner should consider including a task in the recommissioning scope to improve them.[37]

Recommended O&M Manual Contents

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

[37] See also ASHRAE Guideline 4: Preparation of O&M Documentation.

Control System Documents

Points Lists

Both for control and trend logging purposes, it is helpful to have a complete Points List that includes all the physical input and output points in the control system. Any changes made to the Point Lists as part of the recommissioning process should be recorded promptly. The Points List should include:

- Point name (adhering to a consistent and clear naming convention)
- Point type
- Sensor or actuator type and accuracy limits
- Name and type of the associated component
- Panel in which it is located
- Alarm limits

Sequences of Operation

Sequences of Operation inform the building staff about how the control system should operate the building. In many cases, the original sequences were programmed into the EMCS but never put in writing, or the existing written sequences lack sufficient detail to help building staff understand how the controls are integrated within and among systems.

At minimum, any changes that were made to the control sequences as a result of recommissioning should be carefully documented, along with the reasons for the changes. Improvements are more likely to persist when operators understand the rationale for the changes and agree with their implementation. Also, it may be worthwhile to consider rewriting any control sequences that were not affected by the recommissioning project but are found to be incorrectly or poorly documented.

System Diagrams

System Diagrams, which are sometimes called one-line diagrams, enable the user to see the entire process of heating, cooling, and ventilation of spaces and visualize potential interactions. They depict an entire system in schematic format.

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

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

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

Systems Manual

The Systems Manual can be thought of as an umbrella document that includes the RCx Final Report, as well as most of the building's critical O&M documentation or, at minimum, describes how O&M documents are catalogued and where they are located. Also, the Systems Manual may include new materials emphasizing how systems and equipment interface. While a Systems Manual is not a commonly produced deliverable for a recommissioning project due to cost considerations, it is a worthwhile effort, especially for complex systems or in cases where O&M staff turnover is common. An owner may specify the Systems Manual in the recommissioning provider's scope of work or request that it be developed collaboratively between the owner and the provider. The most effective scope of the Systems Manual is typically determined on a project-by-project basis.

A Systems Manual often includes.[38]

- Master list of building documentation and locations
- Owner's Operating Requirements
- RCx Plan
- RCx Final Report
- O&M Plan (including record-keeping procedures)
- Sequences of operation for all control systems
- System diagrams
- List of monitoring and control points
- List of control system alarms
- Trending capabilities

BUILDING STAFF TRAINING

As discussed in the Project Hand-Off chapter, facility staff training is critical to maintaining the benefits of recommissioning. A well-designed training plan, supported by comprehensive building documentation and videotapes of the training sessions, will help ensure that the building is operated efficiently and that the benefits associated with the recommissioning process persist for the life of the building. Videotaped trainings, developed during the Hand-Off Phase of the recommissioning process, are especially valuable for new staff.

Owners may wish to consider a broader range of training activities, in addition to those provided at the end of the recommissioning process. Perhaps the most common training opportunity lies in understanding and using the trending and alarming functions of the control system. The wide gap between the capabilities of these complex systems and the ability of building operators to fully utilize them can lead to missed opportunities in both the early identification of building problems and significant energy savings. For example, trends and alarms can be set in the control system, but unless the staff responsible for the energy management control system are trained on how to retrieve and analyse the data and review

[38] For more detailed information about the components of a Systems Manual, consult ASHRAE Guideline 0, The Commissioning Process, Informative Annex O.

alarm logs, the owner will not get the most out of the system. Many control vendors offer a range of training opportunities from introductory to advanced sessions. Training pays for itself quickly when operators know how to use all the capabilities of their system.

Through high-quality training, facility staff can increase their knowledge and expand their ability to identify and address improvement measures in their buildings. Such training courses are generally offered by utility energy centres, training organizations, and equipment manufacturers.

MAINTAINING EFFICIENT OPERATING PERFORMANCE

The biggest challenge for facility staff is to redefine their preventive maintenance program to include activities that maintain the recommissioning operational improvements. Operational activities need to be incorporated to ensure long-term energy efficiency and reliability. Owners can enhance preventive maintenance goals by incorporating procedures that promote efficient operation.

A typical preventive maintenance plan consists of a checklist of maintenance tasks and a schedule for performing them. It can be extensive and is often computerized. The checklists are kept for each piece of equipment and are updated after maintenance tasks are performed. Incorporating operations into the current maintenance plan requires similar rigour for recording setpoints, settings, and parameters for the control strategies. It also means that operators regularly review and update the owner's operating requirements as occupancy or operational changes are made. Incorporating operational activities into the preventive maintenance plan encourages building operators to continuously ask questions such as:

- Have occupancy patterns or space layouts changed?
- Has the tenant added or removed loads from the space?
- Have temporary occupancy schedules been returned to original settings?
- Have altered equipment schedules or lockouts been returned to original settings?
- Is equipment short-cycling?
- Are time-clocks checked monthly to ensure proper operation?
- Have any changes in room furniture or equipment adversely affected thermostat functions?

- Are new tenants educated in the proper use and function of thermostats and lighting controls?
- Are the building's sequences of operation performing as intended?
- Are discretionary systems, such as lighting or computers, being turned off during unoccupied periods?

To facilitate activities that address operations, the owner can require an Ongoing Commissioning Plan be developed at the end of the recommissioning project. This plan focuses on strategic operation and maintenance activities that support the recommissioning improvements. The Ongoing Commissioning Plan is discussed at the end of this section.

It may seem like expanding the preventive maintenance plan would significantly increase the workload of building staff. Performing these tasks on a regular basis, however, should save staff time in the long run as preventive operation activities help to reduce occupant comfort complaints and equipment malfunction. More time spent on preventive operations generally means that less time is spent "fighting fires" and troubleshooting problems. Also, the efficiency of the systems that was achieved during recommissioning may decline unless explicit strategies are put into place to maintain and monitor the improvements.

PERFORMANCE TRACKING

Performance tracking helps building operators detect and diagnose problems early, before they lead to tenant comfort complaints, high energy costs, and unexpected equipment failure.

Lighting and HVAC systems have become so complex that continuous performance tracking (using trend logs and utility bills) is vital for building operators to know when systems aren't functioning properly. Unfortunately, a formal process for data gathering and analysis is not typically established at a facility.

There are five important strategies for tracking building performance:

- Benchmarking
- Utility billing analysis
- Trend analysis
- Automated diagnostic tools
- Energy Information Systems

These activities and tools are commonly included as part of the Planning and Investigation Phases of a recommissioning project. This is an opportunity for the building staff to learn and determine ways to incorporate them into their preventive maintenance plan. In this way, these strategies actively help ensure that the recommissioning benefits last.

BENCHMARKING

Benchmarking a building allows an owner to compare the building's current performance to past baseline levels of performance, as well as to the performance of similar buildings. This is a way for owners to assess how their building is doing and determine whether there is potential for improvement. In the case of recommissioning, benchmarking should be done before the start of the project to set a baseline. When the project is complete and about six to 12 months of utility bills are available, the building can be benchmarked again to see the effects of the recommissioning process.

UTILITY BILL ANALYSIS

Utility tracking records a building's energy use over time and helps staff understand the building's energy consumption patterns. By tracking energy data over time, facility managers and building operators can detect and investigate high energy use.

TREND ANALYSIS

Trend logging through the energy management control system (EMCS) is important for observing the performance of systems under various modes and operating conditions over time. Trending is typically the central strategy for ensuring that the implemented recommissioning measures persist. Data collection, however, is just the first step. Facility staff also should be trained to analyse and interpret the data. To support this, important metrics should be defined during recommissioning along with evaluation methods.

The recommissioning provider's scope of work can include setting up "smart alarms" in the direct digital control (DDC) system – alarms that flag problems by looking at several variables at one time, or comparing variables to limits that depend on the operating mode. Facility staff should be trained to recognize what alarm conditions signify, how to respond to these alarms when they are triggered, and how to set up their own alarms.

The DDC system does not, however, provide the whole story. Building operators should check each piece of equipment regularly and note any changes that may not be picked up by trend logging. This information can then be combined with DDC system data for a more complete picture.

AUTOMATED DIAGNOSTIC TOOLS

Another form of performance tracking uses more advanced software tools called automated diagnostics or Fault Detection and Diagnostics (FDD). These tools are often used in conjunction with an existing EMCS. Using automated diagnostic tools can reduce the time required for problem detection and the associated costs as compared to manual diagnosis.[39] Other benefits include improvement in the long-term persistence of energy savings and commissioning efforts, resulting in increased efficiency and performance of building systems.

Some diagnostic tools automate the process of collecting data, predicting energy use, detecting faults with physical systems and helping to diagnose their causes. They are typically installed on the front end of the building's EMCS to help the building operators not only monitor but also diagnose operations within their buildings. Automated diagnostic tools generally use the sensors from the EMCS to assess operational parameters such as air and water flow rates, temperatures and power measurements, to determine whether the system is working properly. If a

[39] Friedman, Hannah, and Mary Ann Piette, 2001. "Comparative Guide to Emerging Diagnostic Tools for Large Commercial HVAC Systems." Lawrence Berkeley National Laboratory.

problem is detected, the FDD tool then sends a report or alarm that notifies the building operator. Some diagnostic tools report when the problem occurred, at which piece of equipment, and for how long, and provide suggested remedies. A few of the tools quantify the energy waste related to specific problems, allowing prioritization of maintenance tasks. Examples of problems that can be detected through automated diagnostic tools include the following:

- Simultaneous heating and cooling
- Excessive equipment runtime
- Lack of economizer cooling
- Leaking cooling and heating coil valves
- Unstable or oscillating control
- Chiller efficiency degradation

Automated diagnostic tools are relatively new to the commercial buildings market. Continued development will increase and fine-tune their detection and diagnosis abilities.

ENERGY INFORMATION SYSTEMS

Energy Information Systems (EIS) can also be used for advanced monitoring of system performance. EIS may be used with EMCS data or with a dedicated data acquisition system. EIS refer to software, data acquisition hardware and communication protocols to provide energy information to commercial building energy managers, recommissioning providers and electric utilities.[40] An EIS may include numerous classes of information such as energy use, peak demand, building characteristics, HVAC or other building system data, and weather data. A typical EIS communicates with interval meters to collect energy use data from remote sites. Users can access archived energy data using a web browser. Depending on the features of the EIS and points included, this tool can enable the RCx provider or building operator to establish a baseline for comparison over time, be notified and react to energy use changes within the building, and track energy use and utility bill data.

[40] Motegi, Naoya, and Mary Ann Piette, 2002. "Web-based Energy Information Systems for Large Commercial Buildings." Lawrence Berkeley National Laboratory.

A growing number of EIS, sometimes referred to as Enterprise Energy Management (EEM) systems, have advanced data analysis and benchmarking features. Simple EIS benchmarking may include comparison of monthly and annual energy usage over time for multiple facilities. More advanced benchmarking techniques often include data correction for weather and detection of deviations from the energy use predicted by a baseline energy use model. Further, when these tools are used with web-based EMCS to retrieve and track building operational data, they allow users to perform system-level diagnostics. Users should be aware that some EIS, especially those in the EEM and web-based EMCS categories, have a variety of visualization and analysis features which may require additional expertise.

PERIODIC RECOMMISSIONING

The need for the next recommissioning process depends on several things: changes in the facility's use, quality and schedule of preventive maintenance activities, and the frequency of operational problems. In terms of both cost and process, it is most effective to develop the next recommissioning timeline as a part of the recommissioning project's scope of work and to factor estimated recommissioning costs into future budget cycles.

The next recommissioning process is generally less expensive since it builds on the information gathered and produced as part of the first recommissioning project. As in recommissioning, systems are monitored, tested, and inspected and any issues are recorded in a new Findings Log for potential implementation. If a *Recommissioning Plan* was drafted by the recommissioning provider during *Hand-Off*, this process should be straightforward. At completion, the building documents are updated to reflect any changes in building systems and functions.

TIME TO RECOMMISSION?

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

- Is there an unjustified increase in energy use? Is energy use more than 10% higher than previous years?
- Have comfort complaints increased compared to previous months or years?
- Has night time energy or weekend/holiday use increased?
- Is the building staff aware of problems but unable to find the time or in-house expertise to fix them?

- Has control programming been modified or overridden to provide a quick fix to a problem?
- Are there frequent equipment or component failures?
- Have there been significant tenant improvement projects (build-outs)?
- Have there been significant changes in building use or the proportion of used to unused space?
- Have there been major upgrades on main energy consuming equipment (boilers, chilled water plant, large HVAC systems)?
- Has the operations staff changed since the last recommissioning process?

ONGOING COMMISSIONING PLAN

An Ongoing Commissioning Plan can be developed by the recommissioning provider after the Implementation Phase and can be a primary deliverable for the Hand-off Phase. This is a more comprehensive plan than the RCx Plan in that it provides building staff with detailed instructions on performing strategic operation and maintenance (O&M) tasks that help retain the recommissioning benefits. While recommissioning is often performed every three to five years and provides a "snapshot" of how the building is operating at a given time, ongoing commissioning is more continuous and dynamic by nature in that it encompasses all of the performance tracking strategies discussed above.

FEEDBACK AND SUCCESS CELEBRATION

Maintaining a high level of motivation within the building staff is an important aspect to consider in retaining the benefits of recommissioning. Ongoing commissioning increases the complexity of building operation, requires more attention in routine work and often imposes closer supervision of building performance. In order to maintain focus and staff motivation over the long term, it is important to regularly solicit feedbacks and celebrate successes.

ENERGY CONVERSION TABLES[41]

The following conversion tables of commonly used units are provided for the convenience of people who may be more familiar with the Imperial System.

Common Units

Crude Oil and Natural Gas Liquids

Abbreviation	Description
b/d	barrels per day
bbl	barrels
m^3	cubic metre
m^3/d	cubic metres per day
Mb/d	thousand barrels per day
MMb	million barrels
MMb/d	million barrels per day

Natural Gas

Abbreviation	Description
Bcf	billion cubic feet
Bcf/d	billion cubic feet per day
Btu/cf	British thermal units per cubic feet
cf	cubic feet
m^3	cubic metre
m^3/d	cubic metres per day
Mcf	thousand cubic feet
MMBtu	million British thermal units
MMcf	million cubic feet
MMcf/d	million cubic feet per day
Tcf	trillion cubic feet

[41] National Energy Board Website: www.neb.gc.ca/clf-nsi/rnrgynfmtn/sttstc/nrgycnvrsntbl/nrgycnvrsntbl-eng.html#a_s_04_ss_04

Electricity

Abbreviation	Description
MW	megawatt
kWh	kilowatt hour
MWh	megawatt hour
GWh	gigawatt hour
TWh	terawatt hour

Common Conversions

From	To	Multiply By
metres (m)	feet	3.2808
kilometres (km)	miles	0.621
hectares (ha)	acres	2.471
kilograms (kg)	pounds	2.205
cubic metres (m^3)	barrels (oil or natural gas liquids)	6.292
cubic metres (m^3)	cubic feet of natural gas (@ 14.73 psia and 60°F)	35.301
litres (L)	US gallons	0.265
litres (L)	imperial gallons	0.220
imperial gallons	US gallons	1.201
barrels (bbl)	US gallons	42.0
barrels (bbl)	imperial gallons	34.972
metric tonnes (t)	pounds	2204.6
kilometers/litre	miles/gallon	2.825
gigajoules (GJ)	million British thermal units	0.95

Prefixes and Equivalents

From		Equivalent
k	(kilo)	10^3
M	(mega)	10^6
G	(giga)	10^9
T	(tera)	10^{12}
P	(peta)	10^{15}
E	(exa)	10^{18}

Energy Content

The energy content of a 30-litre tank of gasoline is approximately one gigajoule or 0.95 million Btu of energy. A petajoule is one million gigajoules. On average, Canada consumes about one petajoule of energy every 50 minutes for all uses (heat, light and transportation) for both commercial and residential use.

Energy

Unit	Equivalent to
gigajoule (GJ)	10^9 joules 0.95 million Btu 0.95 thousand cubic feet of natural gas at 1000 Btu/cf 0.165 barrels of oil 0.28 megawatt hour of electricity

Crude Oil

Unit	Equivalent to
1 cubic metre (m^3) (pentanes plus)	35.17 GJ
1 cubic metre (m^3) (light)	38.51 GJ
1 cubic metre (m^3) (heavy)	40.90 GJ

Natural Gas

Unit	Equivalent to
1 cubic metre (m^3)	35.301 cubic feet @ 14.73 psia and 60°F
thousand cubic feet (Mcf)	1.05 GJ
million cubic feet (MMcf)	1.05 TJ
billion cubic feet (Bcf)	1.05 PJ
trillion cubic feet (Tcf)	1.05 EJ

Natural Gas Liquids

Unit	Equivalent to
1 cubic metre (m^3) (ethane)	18.36 GJ
1 cubic metre (m^3) (propane)	25.53 GJ
1 cubic metre (m^3) (butane)	28.62 GJ

Electricity

Unit	Equivalent to
gigawatt hour (GWh)	10^6 kWh 3 600 GJ 0.0036 PJ
kilowatt hour (kWh)	0.0036 GJ
megawatt hour (MWh)	3.6 GJ
terawatt hour (TWh)	10^9 kWh or 3.6 PJ

Coal

Unit	Equivalent to
1 tonne (t) (anthracite)	27.70 GJ
1 tonne (t) (bituminous)	27.60 GJ
1 tonne (t) (lignite)	14.40 GJ
1 tonne (t) (subbituminous)	18.80 GJ
trillion cubic feet (Tcf)	1.05 EJ

Petroleum Products

Unit	Equivalent to
1 cubic metre (m^3) (asphalt)	44.46 GJ
1 cubic metre (m^3) (aviation gasoline)	33.52 GJ
1 cubic metre (m^3) (aviation turbo fuel)	35.93 GJ
1 cubic metre (m^3) (diesel)	38.68 GJ
1 cubic metre (m^3) (heavy fuel oil)	41.73 GJ
1 cubic metre (m^3) (kerosene)	37.68 GJ
1 cubic metre (m^3) (light fuel oil)	38.68 GJ
1 cubic metre (m^3) (lubes and greases)	39.16 GJ
1 cubic metre (m^3) (motor gasoline)	34.66 GJ
1 cubic metre (m^3) (naphtha specialties)	35.17 GJ
1 cubic metre (m^3) (petrochemical feedstock)	34.17 GJ
1 cubic metre (m^3) (petroleum coke)	42.38 GJ
1 cubic metre (m^3) (still gas)	41.73 GJ
1 cubic metre (m^3) (other products)	39.82 GJ

Other Fuels

Unit	Equivalent to
1 cubic metre (m^3) (ethanol)	23.60 GJ
1 cubic metre (m^3) (hydrogen)	0.12 GJ
1 cubic metre (m^3) (methanol)	15.60 GJ

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APPENDIX

The following documents provide examples of tools and templates that can be used to facilitate the recommissioning process, from preliminary planning through implementation.

APPENDIX A - List of Preferred Building Characteristics for Recommissioning

APPENDIX B - Owner's Operating Requirements

APPENDIX C - Recommissioning Implementation Plan

APPENDIX D - Recommissioning Implementation Report

APPENDIX E - Request for Proposal Checklist

APPENDIX F - Linking Energy Savings Performance Contracts and Recommissioning

APPENDIX G - US-EPA Guide related case studies

APPENDIX A - LIST OF PREFERRED BUILDING CHARACTERISTICS FOR RECOMMISSIONING

The following briefly discusses some important building characteristics that should be considered during the planning phase of a recommissioning project when a building owner and recommissioning provider are determining whether a building is an appropriate recommissioning candidate. Most existing buildings are candidates for recommissioning. However, some buildings are better candidates because they have characteristics that can help reduce project costs. Using the following preferred characteristics list as a screen during the planning phase can help to determine what may bolster or create barriers to the cost effectiveness of a project. A checklist that summarizes the characteristics is also included. Using the checklist can assist in identifying these important characteristics during the scoping and budgeting process.

Note: For the purpose of this document, recommissioning is a process that primarily seeks to find operational improvements that can improve the energy and comfort performance of medium to large buildings with relatively up-to-date equipment and systems. Recommissioning for small buildings or buildings in need of major equipment upgrades is beyond the scope of this document, although some of these characteristics may also apply.

1. Mechanical equipment age and condition

When a recommissioning project is defined as a set of activities to improve building performance through mainly operational improvements, the cost-effectiveness of a project partly depends on the age of the energy-using equipment, systems, and controls. Buildings with equipment that is broken or in need of major upgrades generally do not make good candidates for this type of recommissioning. Equipment and systems that are less than 12 years old or are several years from the end of their useful life and are well maintained are ideal. However, the age of equipment is less of a problem as long as the equipment has been well maintained.

2. Financial considerations

The owner's financial criteria such as the required simple payback time and the cost limits that determine when to obtain funds from the capital budget vs. the operating budget should be gathered early in the planning phase of the project. These criteria, along with budget cycle information, can help the recommissioning provider and owner determine how to prioritize the work during the recommissioning process and how to develop implementation strategies that can fit with in the financial criteria. Also, if the building is located where there are tax incentives or rebates available

(some utilities give incentives for recommissioning and retrofits) these can help off-set some of the costs and help reduce payback times, allowing more expensive improvements to fit into the owner's financial requirements.

3. Building staff participation

The cost-effectiveness of a project may be greatly increased when the building staff is given the time and is skilled enough to perform some of the recommissioning tasks throughout the project. Recommissioning costs may be reduced when an owner is willing to engage the facility team in getting the maintenance items and simple repairs (coil cleaning, filter changes, belt tightening, broken linkages and damper blades) completed before the recommissioning investigation. These activities allow the recommissioning provider to proceed efficiently through the system investigation without the process getting bogged down with simple maintenance and repairs issues. Also, building staff can minimize costs by helping set up the trend logs, setting and removing data loggers and implementing some of the less complicated measures. Staff involvement on this level reduces the need to hire outside contractors. It is ideal if the building owner or manager assigns a senior level building technician to work with the recommissioning provider. At a minimum, it is important for building staff to be available to provide the recommissioning provider with as much information about the building's operating strategies, maintenance procedures, and perceived problems as possible.

4. Buildings with energy management control systems (EMCS)

Buildings with computerized energy management control systems (EMCS) are preferable candidates to those with purely pneumatic systems. This is due to two main factors: an EMCS can be used as a data acquisition tool during recommissioning whereas a purely pneumatic system cannot, and pneumatic controls tend to drift out of calibration much more frequently than electronic based controls, so that energy saving may not be long lasting in buildings without EMCS. However, the owner and/or provider should carefully examine level of robustness of the EMCS in order to understand what it can and can't do. More robust systems are able to trend and store large amounts of data at short frequencies (2 minutes or less) for long periods of time without slowing down the normal control functions of the system. Some of the most robust systems are also web-based. A web-based system allows the recommissioning provider to look at building data from an Internet

connection at any time. Without adequate trending and data storage capability, the recommissioning provider will need to use more portable data loggers and hand-held test equipment than is typically used, which can add time and expense to the project.

5. Available and up-to-date building documentation

When scoping a project, it is important to understand what building documentation is available. Clear, complete, up-to-date documentation expedites the investigation phase of a project. Buildings that lack good documentation, especially in regards to the mechanical and control systems, can drive costs up if the recommissioning provider has to spend time gathering and recreating critical information in order to assess system operation. An example list of important building documentation is included in the Preferred Building Characteristics Checklist below.

6. Owner support and the in-house champion

There is probably not a more important combination that will lead to a project's success than to have an involved, supportive owner along with a technically savvy in-house champion. However, owners are often absent or distracted by other important tasks, making it difficult to gauge their level of interest in a recommissioning project. Furthermore, the building staff may lack the preferred technical training needed to be an active hands-on partner in the recommissioning process. Therefore, a critical ingredient for a project's success is an in-house champion such as an energy manager, facility manager or property manager, who is willing to work as a facilitator to get what needs to be done accomplished in a timely manner. In any case, looking at an owner's investment history in energy efficiency and sound O&M practices as an indicator of a progressive management philosophy and commitment to improving building operations allows the recommissioning provider to more easily judge the seriousness of the owner to support the recommissioning project.

7. Future building projects and changes

When developing a recommissioning project scope, it is wise for the building owner to explain to the recommissioning provider what the future plans are for the building. For example, if an owner is considering doing some retrofit projects or major tenant improvements in the near future (within the next year or two) it may be advantageous to wait for these activities to occur before going forward with a full recommissioning project. On the other hand, depending on what the

improvements are, the recommissioning project can be designed to have a commissioning component to ensure that new installations are specified, installed, and operated as intended, and integrated completely with the existing systems in the building. Further, it may be highly beneficial to retrocommission some of the systems before a major retrofit in cases where reducing loads may lead to downsizing equipment included in the retrofit. Another consideration is how the operations and maintenance will be accomplished in the future. How this is done can affect the persistence of the benefits realized as a result of the project. Questions about plans for outsourcing the maintenance and staff turnover can affect the training and documentation scope for the project.

PREFERRED BUILDING CHARACTERISTICS CHECKLIST

Mechanical Equipment Age and Condition

- ❑ Building does not rely on a majority of major systems or equipment that is in disrepair or in need of major upgrades.
- ❑ The majority of building equipment and systems are less than 12 years old or are several years from the end of their useful life (older equipment that is well maintained can last well beyond the typical replacement life cycle).
- ❑ Equipment and systems are well maintained.
- ❑ There is no evidence of excessive deferred electrical and mechanical maintenance issues.

Financial Considerations

- ❑ Information is available regarding owner's investment criteria such as simple pay-back requirements and use of capital budget vs. operating budget.
- ❑ The building may qualify for financial incentives through local programs or tax incentives

Building Staff Participation

- ❑ Building staff is available to provide information about the building's operating strategies, maintenance procedures, and perceived problems.

- ❑ Management is willing to direct building staff to perform scheduled maintenance items and simple repairs prior to the recommissioning investigation.
- ❑ Building staff is skilled enough to perform some of the recommissioning tasks throughout the project.
- ❑ Management is willing to allocate staff time to performing some of the recommissioning tasks throughout the project (i.e. help set up the trend logs, set and remove data loggers and implement some of the less complicated measures).

Building Controls

- ❑ Building has computerized energy management control systems (EMCS).
- ❑ EMCS is robust enough to use as a data acquisition tool during recommissioning
  - EMCS is able to trend and store large amounts of data at short frequencies (2 minutes or less) for long periods of time without slowing down the normal control functions of the system.
  - EMCS is web-based, allowing the recommissioning provider to look at building data in real time from an Internet connection at any time.
  - Trend data files are conducive to spreadsheet analysis (multiple points possible in each .csv file export, limited missing or bad data included).

Available and Up-to-Date Building Documentation

Building has clear, complete, and up-to-date documentation of the following items:

- ❑ As-built mechanical and electrical drawings including piping and riser diagrams
- ❑ An equipment list with nameplate information and dates of installation
- ❑ As-built control system documentation
  - Points list
  - Sequences of operation
  - User's manual
  - Control drawings with as-built sensor locations
- ❑ Testing, Adjusting and Balancing reports
- ❑ Operation and maintenance manuals

- ❑ Pump and fan curves
- ❑ Copy of current service contracts
- ❑ Equipment warranties still in effect

Owner Support and the In-House Champion

- ❑ Building owner is involved in and supportive of the recommissioning process.
- ❑ The recommissioning project has a technically savvy in-house champion that will facilitate the process.
- ❑ Owner has an investment history in energy efficiency and sound O&M practices that indicate a progressive management philosophy and commitment to improving building operations.

Future Building Projects and Changes

- ❑ No major retrofit projects or major tenant improvements are planned within the next 1-2 years.
- ❑ No future plans to transfer the management of operations and maintenance activities to an entirely new staff or outsourced company.

APPENDIX B - OWNER'S OPERATING REQUIREMENTS – TEMPLATE

Requirement	Typical for Building	Offices	Lobby	Conference Rooms	Computer or Data Storage	Other	Notes
Temperature requirements for cooling and heating seasons							
Humidity requirements							
Dehumidification requirements							
Pressure relationship requirements							
Filtration requirements							
Ventilation requirements							
Air change requirements							
Sound and noise level requirements							
Normal operating schedule for occupancy							
Weekend schedule							
Holiday schedule							
Process and office equipment status during evening/night time hours							
Process and office equipment status during holiday hours							
Process and office equipment status during scheduled maintenance shut-downs							
Cleaning schedules							
Other requirements							

OWNER'S OPERATING REQUIREMENTS – SAMPLE DOCUMENT OPERATING REQUIREMENTS FOR THE HIGH RISE OFFICE BUILDING

Requirement	Typical for Building	Offices	Lobby	Conference Rooms	Computer or Data Storage	Other	Notes
Temperature requirements for cooling and heating seasons	Occupied: 22°C ±1°C Unoccupied Summer: 25-27°C Unoccupied Winter: 21°C	Same	Same	Same	19.5°C degrees at all times		
Humidity requirements	No direct humidity control by building systems, possible of tenant systems				50%		
Dehumidification requirements	None				50%		
Pressure relationship requirements	(+) 0.01 kPa diff. pres. between building interior and outside environment					(-) 0.005 kPa diff. pres. between the Print Shop and surrounding areas.	
Filtration requirements	5 cm 30% pleated pre-filter – changed as needed. 50 cm 90-95% bag – changed once per year.						
Ventilation requirements	25% outdoor air	Same	Same	Same	Same	Separate MUA system	
Air change requirements	N/A						
Sound and noise level requirements	N/A	N/A	N/A	N/A	N/A		

Requirement	Typical for Building	Offices	Lobby	Conference Rooms	Computer or Data Storage	Other	Notes
Normal operating schedule for occupancy	M-F = 6am-6pm		24 hours, 7 days a week				Equipment is operating 1 hour prior to occupancy
Weekend schedule	Sat = 8am-1pm Sun = N/A						
Holiday schedule	Holiday same as Sunday	Same	Same	Same	Same		
Process and office equipment status during evening/night time hours	100-300 tons of FC units with chiller water coils serving equipment loads	Same	Same	Same	Same		
Process and office equipment status during holiday hours	Same as evening and night time hours	Same	Same	Same	Same		
Process and office equipment status during scheduled maintenance shut-downs	Same as evening and night time hours						
Cleaning schedules	M-F = 6am 2:30pm						
Other requirements	All week days and Sat: 5am to 9pm Sundays and Holidays the lights are off and the Garage is locked						

APPENDIX C - RECOMMISSIONING IMPLEMENTATION PLAN

The Recommissioning Implementation Plan (Plan) can be developed by the Recommissioning provider at the end of the recommissioning Investigation Phase. This Plan describes and prioritizes each of the recommissioning findings, identifies a solution, and outlines the owner's acceptance criteria for correct performance. The Plan can be used to develop a scope of work for the contractor(s) responsible for implementing the recommissioning improvements. One Plan can be written that covers all the improvements and repairs or a separate Plan can be developed for each type of improvement. The following presents both a template and a completed sample to assist in developing a *Recommissioning Implementation Plan.* Note that the control improvements are the focus for the sample.

RECOMMISSIONING IMPLEMENTATION PLAN – TEMPLATE

The following outlines a plan for implementing the improvements identified during the recent recommissioning project for [Building Name and Location]. Recommissioning has identified [number] issues as listed below in order of priority:

1. [Name of Issue or Finding]
2. [Name of Issue or Finding]
3. [Name of Issue or Finding]

The following describes each of the issues in detail, proposes a solution, and outlines the acceptance criteria:

1. [Name of Issue]
   Description:
   Proposed Solution
   Acceptance Criteria
2. [Name of Issue]
   Description:
   Proposed Solution
   Acceptance Criteria

3. [Name of Issue]
   Description:
   Proposed Solution
   Acceptance Criteria

RECOMMISSIONING IMPLEMENTATION PLAN – SAMPLE

Recommissioning Implementation Plan for the High Rise Office Building – Control Improvements

The following outlines a plan for implementing the control improvements identified during the recent recommissioning project for the High Rise Office Building located at 1234 Street in Toronto, Ontario, Canada.

Recommissioning has identified five significant issues as listed below in order of priority:

1. Hot water plant control
2. Night low limit control investigation
3. Economizer control modifications
4. Complete programming modifications for warm-up mode
5. Ventilation air preheat control

1. Hot Water Plant Control

Description

At the beginning of recommissioning, the hot water plant was in overflow condition, with a temperature differential between the supply and return of only a few degrees. The hot water plant flow has been reduced by lowering the remote differential pressure setpoint, which resets the differential setpoint across the hot water distribution pumps (P-6, 7, and 8). Now, instead of 3 pumps running at 95% speed, 1 pump runs at 50% speed and still meets the hot water load.

The two small (Aerco) boilers operate almost 100% of the time, along with 1 to 3 of the large boilers. See hot water plant schematic attached. Even with reduced system flow, the two small Aerco boilers only add about 1°C to the supply water temperature. With such a low TD, it is unclear why these boilers even run. Furthermore, the control sequences say that the Aerco boilers are to be enabled first when loads are low, and then used as trim for the large boilers.

Proposed Solution

1. Compare the sequence as programmed to the written sequence. It may be found that the Aerco boilers are not being controlled properly within the entire sequence of the hot water system. Or, it may be that the secondary hot water flow needs to be further reduced (by lowering the differential setpoint across the pump further) to allow the Aercos to significantly influence the hot water supply temperature. Consider turning OFF the Aerco boilers whenever boilers 3, 4, or 5 are commanded ON.

2. Remote DP setpoint has already been reduced and secondary pump speed reduced. Check remote DP setpoint and determine if setpoint value can be reduced further to optimize system operation. Program minimum VFD speed for each secondary pump to be 20 Hz (variable).

Acceptance Criteria

- The problem will be considered fixed once the programming code is clarified and the Aerco boilers are integrated properly into the hot water system sequence.
- The Control Contractor must document the source of the problem and all changes made.
- The Recommissioning provider will trend the hot water plant after any modifications to verify operation as intended.

2. Night Low Limit Control Investigation

Description

Even when the night time outside air temperatures are as high as 10°C, the hot deck air handlers are commanded ON due to the night low limit (NLL) control sequence. The written control sequence says that AHU 5 and 6 will start when "space temperature drops below 15.5°C" and stops when "the space temperature rises to 17°C."

Proposed Solution

- Compare the sequence as programmed to the written sequence. Make sure NLL setpoints are properly implemented.
- Provide a list of zones polled for the NLL control function and note the night time zone temperatures from point histories or trending.
- If one or more zone temperatures are less than 15.5°C, then the night low limit operation would appear to be warranted.
- If no zone temperatures are less than 15.5°C, then NLL should not function.
- The Recommissioning provider will work with the building staff to look for nearby opportunities for infiltration if any zones are identified as driving the night low limit.

Acceptance Criteria

- The problem will be considered fixed once the polled zones are clarified and the NLL sequence is verified to be working properly. The Maintenance Service Contractor and building staff will work to prevent NLL from occurring due to infiltration.
- The Control Contractor must document the source of the problem and any changes made.

3. Economizer Control Modifications

Description

The current economizer sequence utilizes differential enthalpy. Due to difficulties with relative humidity sensor maintenance and accuracy, the economizer is not enabled when it should be, thus requiring additional mechanical cooling.

Proposed Solution

Change the economizer control sequence for AHU 1, AHU 2, AHU 3, and AHU 4 to differential dry bulb.

Acceptance Criteria

- The problem will be considered fixed once the economizer is working to provide free cooling as expected. The Controls Contractor must document all changes made.
- The Recommissioning provider will trend all four air handlers for economizers operation after any modifications to verify that the differential dry bulb control strategy is working properly.

4. Complete control modifications for warm-up mode

Description

The Controls Contractor has been working with the Recommissioning provider to implement a corrected warm-up sequence that prevents warm-up from occurring when there is a cooling load or when the building is occupied. The corrected sequence needs to be replicated on AHU 3 and 4, and the outdoor air fan isolation dampers may need to be programmed to close when warm-up is enabled.

Proposed Solution

Make sure the isolation dampers on the outside air fans close during warm-up. Replicate the corrected programming modifications of the warm-up sequence for AHU 3 and 4.

Acceptance Criteria

- The problem will be considered fixed when the warm up sequence for all AHU works as and when expected. The Controls Contractor must document all changes made.
- The Recommissioning provider will test the control strategy using overrides as well as trend warm-up mode operation to verify implementation.

5. Ventilation air preheat control

Description

The preheat coils on the outside air handlers (AHU 7, 8, 9, and 10) are supposed to open when the outside air temperature is below 2°C and modulate to maintain the cooling AHU discharge air temperature setpoint. On many occasions, the preheat coils have been active even on relatively warm days when there is a call for cooling. The preheat does not control to the discharge air temperature of the cooling AHU, but rather, produces up to 29.5°C discharge temperature. It is not clear how the coil is being controlled.

Upon initial investigation, the Recommissioning provider and the Controls Contractor found that the temperature sensor after the preheat coil may not exist, or at least it is has not been found in the control programming.

Proposed Solution

The Control Contractor with help from the building staff will complete the investigation of the source of the control problem at the preheat coil and correct problems with the sequence on AHU 7, 8, 9, and 10.

Acceptance Criteria

- The problem will be considered fixed when the preheat coils work as expected and not during warm days. The Control Contractor must document the source of the problem and all changes made.
- The Recommissioning provider will trend or functionally test all four outside air handler's preheat operation after any modifications to verify operation as intended.

APPENDIX D - RECOMMISSIONING IMPLEMENTATION REPORT

The Recommissioning Implementation Report can be developed by the Recommissioning provider at the end of the Recommissioning Implementation Phase. This Report briefly describes each measure identified during the recommissioning process, the implementation status, the resolution, and any future recommendations to maintain and enhance system performance.

RECOMMISSIONING IMPLEMENTATION REPORT - TEMPLATE

Recommissioning Implementation Report [Insert Building Name]				[Insert Company LOGO] [Contact Name] [Company Address] [Company Phone Number]
Measure	Finding Description	Resolution Status	Resolution Description	Future Recommendations
List the name and number of the RCx measure as it appears throughout the project.	Describe the problem (deficiency) or recommended improvement that was discovered during the RCx Investigation.	Describe the resolution status: Complete, in process, or for future consideration.	Describe how the problem was resolved or what improvement was made to address the deficiency.	If applicable, describe the recommendations needed to help the benefits of the improvement persist over time or describe further work that could help increase the benefit beyond what was done as a result of the RCx project. "No further action required" is an acceptable response.

RECOMMISSIONING IMPLEMENTATION REPORT – SAMPLE

Recommissioning Implementation Report for The Great Office Building

The Recommissioning Implementation Report briefly describes each measure identified during the recommissioning process, the implementation status, and any future recommendations to maintain and enhance system performance.

Recommissioning Implementation Report The Great Office Building				Prepared by RCx Inc [Contact Name] [Company Address] [Company Phone Number]
Measure	Finding Description	Resolution Status	Resolution Description	Future Recommendations
Pump impeller trim	It was noted during the site assessment that all of the triple duty valves serving the condenser water pumps were throttled to approximately 50%. This indicates that the original pump was designed to provide more head than the system required and the valve had to be throttled back in order to achieve design flow rate. A pump test was conducted to determine the impeller size that would be necessary to achieve design flow with the throttling valves wide open.	Complete	The impellers for condenser water pumps CDP-1 through CDP-9 were trimmed to the appropriate diameter based on the pump tests. In some cases, the impellers were trimmed to the smallest diameter that could be used in the respective pump housing and the throttling valve was then used to tune the system to design flow rate. All of the pump nameplates have been modified to indicate the actual impeller diameter within the respective pump.	No further action is required for this measure unless the required flow rate for any pump change significantly in the future.

Recommissioning Implementation Report The Great Office Building				Prepared by RCx Inc [Contact Name] [Company Address] [Company Phone Number]
Measure	Finding Description	Resolution Status	Resolution Description	Future Recommendations
Chiller 3 Operational problems	Chiller 3 is rated at 115 tons of FC and should operate when building loads are 115 tons of FC or less. However the chiller's internal controller was set to prevent the unit from operating above 50% full load amps, which prevented it from satisfying chilled water temperature setpoint. As a result a second chiller would come online and contribute to the chilled water plant instabillity outlined above.	Complete	This mesure has been implented. The internal controller for Chiller 3 has been fixed and the chiller is capable of operating at 100% load without any problems..	It is imperative that Chiller 3 remain capable of operating at 100% load for the chilled water plant to remain stable. Chiller 3 is the base unit and it must carry the load during low-load situations. Any future operational issues associated with Chiller 3 must be corrected immediatly; else the chilled water plant may not achieve stable operation if one of the large chiller is required to run to serve a low load.

Recommissioning Implementation Report The Great Office Building				Prepared by RCx Inc [Contact Name] [Company Address] [Company Phone Number]
Measure	Finding Description	Resolution Status	Resolution Description	Future Recommendations
Economizer Control	Due to unreliable relative humidity sensor measurements, the differential enthalpy economizer control strategy for all cold-deck air handling units (AHU1 through AHU4) was not resulting in an effective use of outdoor air for free cooling. A "differential" control strategy means that the economizer cycle is enabled whenever the outdoor air enthalpy is less than return air enthalpy.	Complete	For this climate zone, dry-bulb air temperature is a more effective economizer control strategy than enthalpy. Hence, the control programming was modified to base economizer operation on differential dry bulb rather than differential enthalpy.	No further action is required for this measure.

APPENDIX E - REQUEST FOR PROPOSAL (RFP) CHECKLIST FOR RECOMMISSIONING SERVICES

- ❑ Include clear objectives and assign priority to each (energy, comfort, building control, etc.)
- ❑ Provide information about the building. At minimum include:
  - A brief building description
  - Square footage
  - A general HVAC description (central plant as well as distribution systems for both heating and cooling) and controls system description
  - A list of major equipment, including number and age of each type
  - A brief renovation, retrofit and equipment replacement history
  - A building use description
- ❑ Provide as much information on the trending capabilities of the EMCS as possible. Ideally, a complete points list should be provided. This increases the bidders' ability to more accurately budget the data acquisition tasks. Also, state whether the system can be accessed remotely (by modem or Internet).
- ❑ Provide a list of available up-to-date building documentation.
- ❑ Include as complete a scope of work as possible. State the type of recommissioning expected (existing-building, new equipment, or combined new and existing systems). If it is unclear what the scope of work can realistically include, allow Step One of the project to address developing a detailed scope of work. Or, hire an experienced recommissioning consultant to help develop the scope of work for inclusion in the RFP. The scope of work should include a list of equipment needing recommissioning. Also, clearly state for each phase of the project (planning, investigation, implementation, and integration) what the in-house building staff and/or service contractor responsibilities include and what the recommissioning provider responsibilities include.
- ❑ If the preferred data acquisition methods are known (data logging, trending, functional testing) state them, otherwise specifically ask that bidders detail their approach on these issues.
- ❑ Indicate what is expected for each of the recommissioning phases (planning, investigation, implementation, and hand-off). It is especially important for the bidders to know whether the contract proceeds through the implementation phase or ends with the investigation phase (detailed site assessment).

- ❑ Request the recommissioning service provider's general approach and a skeletal recommissioning plan for the project.
- ❑ List the specific support that the recommissioning service provider can expect from the facility staff and service contractors (particularly the controls vendor) and give the skill level of each of the facility staff. State how much testing and investigation can be done by facility staff.
- ❑ When requiring savings calculations/estimates, state the desired method for completing the work (qualitative ranking of measures for implementation using expert judgment, cost estimates and engineering calculations of savings, costs from actual bids and bin or computer simulations of savings).
- ❑ Cleary state any cost or energy savings calculations or estimates required of the recommissioning service provider prior to implementation and after post-verification.
- ❑ List the required qualifications of the recommissioning service provider and any subcontractors.
- ❑ Request work examples from previous projects (final report, Master List of Findings, etc.).
- ❑ List the RFQ/RFP selection criteria.
- ❑ Give a cost range for the project.
- ❑ Provide a list of required deliverables (see section titled "Selecting a Recommissioning Provider").
- ❑ Include other specific information as necessary.

APPENDIX F - LINKING ENERGY PERFORMANCE CONTRACTS (EPC) AND RECOMMISSIONING

One option for financing some energy efficiency projects is an energy performance contract (EPC) – typically offered by energy service companies (ESCOs). These contracts are set up so that the ESCO covers the project costs and is paid back through energy cost savings. This allows owners to avoid investing their own capital and lowers the risk related to the performance of the new equipment.

While an attractive option, EPCs present certain challenges when used in conjunction with recommissioning. First, because recommissioning is often a low-cost investment with high returns, it can create a revenue stream that the owner may not want to pass on to an ESCO. In addition, recommissioning may not fit well into the business model of most ESCOs due to its reliance on labour rather than on installation of equipment. As a consequence, it may be difficult to find an ESCO interested in a thorough recommissioning project.

If an owner does pursue recommissioning while working with an ESCO using an EPC, there are issues that the owner should consider. Recommissioning O&M improvements bundled with retrofits and equipment replacement may increase the overall financial appeal of the project and achieve a higher degree of improvement in building performance. In this context, when considering use of EPCs in conjunction with recommissioning, it is important that owners take steps to ensure that the process is as effective as possible. Some things to bear in mind include:

1. Complete the recommissioning process first, if appropriate. A major retrofit project is the perfect time to do recommissioning so that the new equipment is properly selected and installed to function correctly as a system. Completing recommissioning as a first step allows the owner to receive all the associated cost savings by keeping it out of the financial agreement with the ESCO. Only necessary capital measures are financed with the ESCO.
2. Where recommissioning is implemented prior to finalizing an energy savings agreement, it is critical that the owner inform the ESCO of the project and provide a copy of the Final Report. The ESCO will need to use recent utility bills, post-recommissioning, to determine an energy baseline. If not, the baseline will be inaccurate since the recommissioning savings are not included.

3. New equipment, whether installed under an EPC or paid for directly as a capital expenditure, should be commissioned. This type of commissioning, however, often stops short of the holistic perspective of recommissioning, which evaluates how new equipment interfaces with existing systems and their performance. When recommissioning is conducted as a part of an EPC, the provider ensures that the performance of new equipment is not hindered as a result of interfacing with the existing equipment, components, or systems that may be malfunctioning.

APPENDIX G - US-EPA GUIDE RELATED CASE STUDIES[42]

CASE STUDY: TARGET RETROCOMMISSIONING PROGRAM RCx GUIDE, U.S. EPA VERSION, CHAPTER 1, PAGE 3.

Thanks to recommissioning at several SuperTarget® stores, Target® identified adjustments to its refrigeration systems which resulted in a $5,000 - $10,000 annual energy savings per store. Due to the potential risks associated with food quality if refrigeration systems do not perform, Target funded this effort not only as an energy savings measure, but also as a risk minimization strategy.

Source: Williams, Scott D., PE, "Owner's Strategies for In-house Commissioning," *Proceeding of the National Conference on Building Commissioning*. (New-York, NY, May 4-5, 2005.)

CASE STUDY: MARRIOTT MARQUIS RCx GUIDE, U.S. EPA VERSION, CHAPTER 2, PAGE 9.

Marriott's flagship property, the Marriott Marquis, a 50-story structure located in Times Square in New York City includes nine floors of retail and meeting rooms, 35 floors of occupant rooms, five restaurants, and a 1,500 person theatre. In order to achieve the goal of reducing operational energy consumption, Marriott used a retrocommissioning process to determine if improved operation could result in energy savings. In contrast to the efficiency measures the hotel had implemented in the past to maximize lighting and guest room controls, significant opportunities were found in areas separate from the guest facilities, allowing the hotel to improve its bottom line without altering its functionality to its guests. Among other improvements, by optimizing the facility's chilled water plant and installing variable speed drives on the air handling system, the facility was estimated to save $775,000 per year. Through this project, Marriott was able to improve on the building's mechanical systems, maximize efficiency, and shield against ever-rising energy costs all with simple payback of less than two years.

Source: NYSERDA case study drafted by Portland Energy Conservation, Inc.

[42] All monetary units are in USD.

CASE STUDY: SYMPHONY TOWERS
RCx GUIDE, U.S. EPA VERSION, CHAPTER 2, PAGE 14.

The Chief Portfolio Engineer of the Irvine Company, Inc., a 140-year old commercial real estate firm, decided to launch a retrocommissioning project, recognizing the importance of optimizing building performance as well as the value of the whole building engineering analysis offered by retrocommissioning. Of the more than 400 commercial office spaces in its portfolio, the company identified a building in downtown San Diego that qualified for a local utility incentive as its first candidate. Built in 1980, Symphony Towers is 714,000 square feet and has 34 stories.

The retrocommissioning project identified potential annual cost savings of $65,000. The high savings opportunities identified, coupled with relatively low implementation costs and program incentives, resulted in a payback of only four months for the project. Even without the utility incentives the payback would be a reasonable 14 months.

Investigation and Implementation

Through an in-depth operational analysis and close collaboration with building staff, the retrocommissioning provider identified several significant savings opportunities, including:

- Correcting uneven flow through the cooling tower
- Improving chiller sequencing
- Adjusting chilled water temperatures and setpoints
- Reducing cooling system night operation during the summer
- Optimizing the control of air-handling units (AHUs)

In all, seven energy-saving measures were selected and implemented in less than four months.

Project Costs and Savings

- Estimated annual kWh savings: 497,000 kWh
- Estimated annual cost savings: $65,000
- Total project cost: $76,600, including investigation and implementation
- Total program incentive: $52,800
- Net Owner cost: $23,800
- Simple payback: 4 months
- Simple payback without incentive: 14 months

Non Energy Benefits

- Improved cooling tower operation and reduced maintenance costs
- Increased chiller efficiency and reduce chance of premature failure
- Quality documentation and training for building engineers
- Performance tracking of implemented measures and feedback to building engineers
- Improved tenant comfort

Source: The Irvine Company and the San Diego Gas & Electric (SDG&E®)

CASE STUDIES: OFFICE BUILDINGS
RCx GUIDE, U.S. EPA VERSION, CHAPTER 2, PAGE 15.

Crown Plaza is a 311,000 square foot office building built in 1979 and located in Portland, Oregon. In 2005, the building's owner applied to participate in the local recommissioning incentive program, which included a full recommissioning investigation of the property, as well as incentives to support implementation of measures. The recommissioning investigation identified many hidden problems and opportunities for improvement. The implemented measures included optimizing the supply fan duct static pressure set points, reducing reheat and increasing the number of hours the building is in economizer mode, trimming impellers on oversized chilled water pumps, and shutting terminal units in unoccupied floors during weekend occupancy. In addition, lighting in the parking garage, which was previously lit 24 hours a day, seven days a week, is now scheduled. The building owner implemented a total of 19 identified measures, reducing annual energy expenses by an estimated $53,967.

Project Costs & Savings:

- Total project cost (including incentives): $47,100
- Estimated Annual Cost Savings: $53,967
- Estimate Annual kWh Savings: 775,339 kWh
- Simple payback: 0.87 years
- Non-Energy Benefits: Increased equipment life, including chillers and pumps; reduced replacement costs for lighting in the parking garage; improved control of equipment such as air handlers, air terminal units, and chillers.

Source: Byron Courts, Director of Engineering Services, Melvin Mark Company, August 2007.

The Ronald V. Dellums Federal Building is a 1.2 million sq. ft. office building built in 1994. In 2001, the building's owner (U.S. General Services Administration) hired a commissioning provider to install new software for the building's control system as a way to improve energy performance. In the initial assessment, the provider discovered that air handlers were operating inefficiently and poor programming required building operators to run the central chiller plant manually. The provider recommended that the owner retrocommission the building to effectively reduce the building's energy use. Retrocommissioning identified several low-cost and relatively simple operations improvement opportunities with dramatic savings potential. The implemented measures, which included relocating sensors, optimizing the static pressure setpoint, and repairing the economizer dampers, saved the owner $66,981 in annual utility expenses – providing a payback period of less than one year.

- Project Cost: $35,000
- Size: 1.2 million sq. ft.
- Energy Benefits: $66,981 in annual utility expense savings
- Non-energy Benefits: Reduced staff time to manually operate systems, more efficient opertions, increased controls stability, extended equipment life, better facility staff understanding of systems operation and diagnostics set-up.

Source: California Commissioning Collaborative, http://www.cacx.org/resources/commissioning.php

CASE STUDY: RETROCOMMISSIONING AT MARRIOTT
RCx GUIDE, U.S. EPA VERSION, CHAPTER 2, PAGE 18.

The competitiveness of the luxury hotel industry requires hotel business owners to continuously work to increase revenue – which means aggressively pursuing lower operating costs. A retrocommissioning project at the hotel determined that reactivating the parking garage's demand controlled ventilation system could save hotel $60,000 in electricity costs per year. The full retrocommissioning project identified improvements with energy reduction potential of 8.4% in Phase 1 of the project, and another 10.6% in potential savings for future implementation. Some additional benefits of the project included improvements to chilled water capacity, reduced chiller runtime (which will increase chiller life), documented operation and maintenance procedures, and training for the hotel's O&M staff.

"At Marriott, we've found that retrocommissioning saves us time and money. At one property, we expect to save nearly $500,000 annually in energy costs from implementing retrocommissioning measures - and the project will pay for itself in less than one year. We're using the [local utility] RCx program to continue our efforts in this area." -E.J. Hilts, Regional Energy Manager for Marriott (Western Region).

Source: Portland Energy Conservation, Inc.

CASE STUDY: THE HATFIELD COURTHOUSE
RCx GUIDE, U.S. EPA VERSION, CHAPTER 2, PAGE 21.

In 2003, the U.S. General Services Administration (GSA) initiated a full retrocommissioning (RCx) study of a federal Courthouse located in Portland, Oregon. The Hatfield Courthouse, built in 1997, has a total of 21 floors and a gross square footage of 591,689 sq. ft. The GSA's RCx goals included:

- Improve occupant comfort
- Identify O&M and energy efficiency improvements
- Train the building operators on how to help improvements persist
- Review and enhance building documentation

Investigation involved reviewing the building's documentation and utility bills, inspecting building equipment, interviewing building operators, testing selected equipment and systems, and extensive trending of the heating, ventilating and air conditioning (HVAC) control system. The investigation process identified 29 findings which addressed GSA's RCx goals. The implementation process involved coordinating efforts among the commissioning provider, facility staff, and building services contractors. Twenty-three of the 29 recommendations to address these findings were implemented. This process resulted in a 10% reduction in energy use and significant improvements in building comfort and system operations.

Retrocommissioning increased the building's EPA energy performance rating from 65 to 75, allowing the building to receive an ENERGY STAR® label.
To ensure lasting benefits from retrocommissioning and achieve savings persistence, GSA is employing an "ongoing commissioning" approach.

The Numbers:

- Annual Utility Cost Savings: $56,000 (a 10% reduction of the facility's current utility expenditures) implemented, with $30,099 in energy saving improvements planned for future implementation.
- RCx Cost (investigation and implementation, including implementation project oversight costs): $172,459 - incentives and tax credits = $149,450
- Total RCx Cost: $0.25 per sq. ft.
- RCx simple payback: 2.7 years

Source: GSA and Portland Energy Conservation, Inc.

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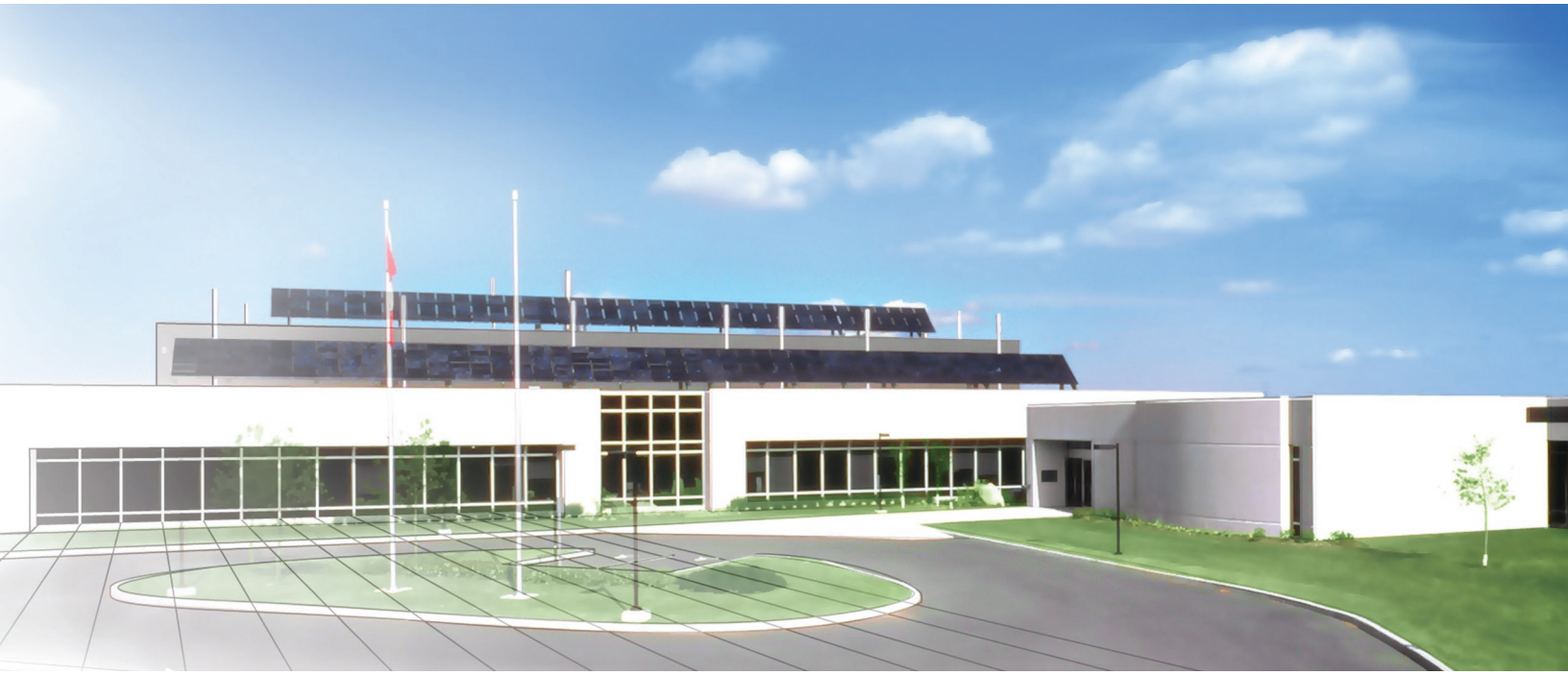
September 2008



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