Chapter 7 Commissioning Existing Buildings

7.1 Introduction

Commissioning of existing buildings is quickly becoming one of the most important topics in the building management arena. In the Federal Sector, commissioning has taken on new importance with the enactment of EISA 2007, whereby Federal facilities are required to be assessed for commissioning measures. In general, commissioning is the process of ensuring that a building performs according to its design intent and the needs of its owners and occupants (Anderson 1997). While additional research is needed to further pinpoint the costs and resulting benefits of commissioning new and existing buildings, numerous case studies have demonstrated resulting O&M-related energy efficiency improvements on the order of 5% to 30% covering a wide range of building uses. The resulting simple payback periods are typically less than 2 years and often less than 0.5 year.

Ideally, the building commissioning process begins during the planning stages of a new building design or new equipment installation. The fact is that the vast majority of buildings have never been commissioned. Even today, with mounting evidence of resulting expected benefits, very few new buildings undergo a complete commissioning process. Instead, new buildings are typically turned over to the building operating staff with operating problems in place, incomplete documentation, and minimal operator training for building-specific equipment. These same problems occur with major equipment installations. Then, during building and equipment operations phases, the overall efficiency of mechanical systems degrades as sensors drift, short-term adjustments are made, tenant needs change, and so on. Even after adjustments are made, perhaps through a one-time recommissioning effort, performance degradation is continuous.

Commissioning of existing buildings (and more specifically the energy-consuming mechanical/electrical systems within them and control systems that monitor them) is critical to ensure energy-efficient operation. Additional benefits include extended equipment life, increased tenant satisfaction through improved space comfort, improved indoor air quality, and fewer O&M emergency calls.

Table 7.1.1 below (adapted from FEMP 2006) provides guidance on commissioning types and their suitability for different facility situations.

Table 7.1.1. Commissioning type consideration by facility condition

What Type of Commissioning Should I Choose?	
My Building is…	***Consider…***
…new or going to be undergoing major renovation.	**Commissioning** – ideal for new construction or major renovation, and best implemented through all phases of the construction project.
…old and expensive to operate and experiencing a lot of equipment failures.	**Retro-commissioning** – ideal for older facilities that have never been through a commissioning process.
…relatively new and was commissioned during construction, but energy use has been increasing.	**Re-commissioning** – ideal to "tune-up" buildings that have already been commissioned, bring them back to their original design intent and operational efficiency.
…large and complex, has a metering system and a preventive maintenance program, but still has high energy use and tenant complaints.	**Continuous Commissioning** – ideal for facilities with building automation system (BAS), advanced metering systems, and well-run O&M organizations.

7.2 Definitions

There are a number of commissioning approaches that can be applied to building mechanical/electrical equipment and systems.

New Building Commissioning: New building commissioning (Cx) is a means to ensuring through design reviews, functional testing, system documentation, and operator training that systems and equipment in new buildings are operating properly.

Recommissioning: Recommissioning (RCx), which is sometimes referred to as "retrocommissioning," is the practice of commissioning existing buildings – testing and adjusting the building systems to meet the original design intent and/or optimize the systems to satisfy current operational needs. RCx relies on building and equipment documentation, along with functional testing to optimize performance.

Continuous Commissioning™: Continuous commissioning™ refers to a commissioning approach that is integrated into a facility's standard O&M program. As such, activities in support of the continuous commissioning™ effort are completed on a regular basis, compared to recommissioning approaches that tend to be distinct events. The continuous commissioning™ (CC) approach developed by the Energy Sciences Laboratory at Texas A&M University is a formalized continuous commissioning™ approach and is defined as "an ongoing process to resolve operating problems, improve comfort, optimize energy use and to identify retrofits for existing commercial and institutional buildings and central plant facilities" (Texas A&M 2002). Continuous commissioning™ is the most costly existing building commissioning approach due to necessary allocations of staff and equipment; however, the higher costs can work to identify equipment inefficiencies as they occur, allowing for quick remediation, greater energy and cost savings, and better building services. By definition, continuous commissioning™ works to ensure more stable building operations over time than the recommissioning approaches.

Value Recommissioning: Value recommissioning (VCx) is the lowest cost option that focuses on the most common opportunities, ideally incorporating them into daily operating procedures. VCx is the least comprehensive and requires the least specialized skill set. VCx concentrates on the most common opportunities that typically carry the shortest payback periods. Therefore, VCx is best applied in buildings where resources for structured recommissioning or continuous commissioning™ programs are not available. In addition to realizing highly cost-effective energy savings, tracking benefits (i.e., energy savings, cost savings, and reduced occupant complaints) of VCx activities can be helpful in developing justifications for funding requests of the more robust commissioning approaches.

Summary of Commissioning Approaches				
Commissioning Approach	**Primary Objectives**	**Relative Costs**	**Benefits**	**Best Applications**
New building or new equipment commissioning	Ensure new equipment is correctly installed and operating correctly.	Costs vary by size of building and complexity of systems: $0.50 to $3.00 per square foot (Welker 2003).	Owners know equipment operates correctly and as intended at acceptance. Resulting documentation and training helps establish correct building operations and are useful to future recommissioning activities.	The commissioning process should be applied to new buildings and equipment at the beginning of the project-planning phase.
Recommissioning (RCx)	Adjust equipment to provide services within equipment specifications while also meeting current mission/tenant operating requirements.	$0.05 to $0.40 per square foot. Additional data are needed to help pinpoint costs based on specific building features and the scope of the RCx effort.	Verifies and restores equipment operation in accordance with original accordance with original design intent and/or to meet current operating requirements.	Since RCx is a point-in-time event, best applications are for buildings/systems that have not been adequately maintained (recommissioned) for some period of time, especially those systems that have not been adapted to accommodate changing space/tenant needs.
Continuous Commissioning™	Integrate comprehensive commissioning approach into on-going facility O&M program.	Highest cost option for existing buildings and systems.	Identifies and addresses problems as they occur. Energy savings persist. Should generate greatest energy savings.	Continuous commissioning™ is the preferred approach when resources (staffing and equipment) are available.
Value Recommissioning (VCx)	Focus on the most frequently available-recommissioning/ retrocommissioning opportunities with highest payback as part of daily O&M.	Lowest cost option for existing buildings and systems.	Can be completed by in-house staff. Minimal up-front or on-going investment required.	VCx can be applied in virtually any building. Can be used to demonstrate benefits of larger, more aggressive existing building commissioning program.

7.3 Typical Findings from Existing Building Commissioning

Many case studies of existing building commissioning efforts have been published over the years. A review of case studies for multiple buildings published by Portland Energy Conservation, Inc. (PECI), Texas A&M University, proceedings from National Building Commissioning Conferences, and FEMP Assessments of Load and Energy Reduction Techniques (ALERT) is useful in identifying measures most typically available in commercial building spaces. The most frequently cited measures/ opportunities are:

- Adjust reset and set-back temperatures and temperature settings – Settings are often adjusted over time based on personal preferences, to compensate for inadequate system operation, or to achieve energy savings. In addition, sensors require periodic recalibration.
- Staging/sequencing of boilers, chillers, and air handling units – Equipment should be operated in the most efficient combination of chillers, boilers, and fans at varying load conditions.
- Adjust and repair dampers and economizers – Malfunctioning or poorly tuned dampers (including seals, actuators, and linkages) and economizers result in (1) increased supply air fan energy in the closed position or require additional air heating and cooling when open too much, (2) undesired building operating conditions due to lack of outside air, and (3) premature equipment degradation and replacement.
- Modify control strategies for standard hours of operation – Motors, pumps, fans, and air handlers often operate on a 24/7 schedule even though not required by either the building tenants or the building operating plan.
- Eliminate simultaneous heating and cooling – Heating and cooling systems for the same space can compete against each other due to improper setpoints.
- Air and water distribution balancing and adjustments – Systems require rebalancing due to drift and changing building/workspace mission and/or tenant requirements.
- Verify controls and control sequencing including enabling and re-enabling automatic controls for setpoints, weekends, and holidays. Verify that overrides are released.

7.4 Costs and Benefits

While there are many case studies available on various building commissioning approaches, these case studies do not present costs and measured savings in a uniform way. In addition, there are very few assessments of existing building commissioning efforts containing a "large" building sample from which generalized cost and benefit conclusions can be drawn. This prevents us from being able to pinpoint costs for the various commissioning approaches, especially in 2004 dollars. We are, however, able to draw from the case studies trends in the costs and, in the case of existing building commissioning, the realized energy and/or cost savings.

7.4.1 New Building Commissioning Costs and Benefits

(Welker 2003)

While O&M is typically thought of as being limited to existing buildings, it is important for building planners, designers, and O&M managers to consider O&M throughout the new building process. One important action is ensuring adequate resources are lined up for the building once it

is operating. Another highly important action is commissioning the new building. New building commissioning begins during the planning process and runs through final acceptance. The primary goals of new building commissioning efforts are to

- ensure design intent criteria and the owner's requirements are documented and met
- ensure systems and equipment are fully functional and operate in an integrated manner
- provide documentation on systems and equipment that will be
- verify O&M staff training needs are met.

The cost of new building commissioning varies based on several factors including the building's use, which determines complexity of mechanical systems and size. Typical new building commissioning provider's fees range from \$0.50 per square foot (/ft^2) for "simple" buildings (such as some spaces and classrooms) to \$3.00/ft^2 for complex buildings such as hospitals and laboratories. Economies-of-scale do apply. These cost ranges are summarized in Figure 7.4.1.

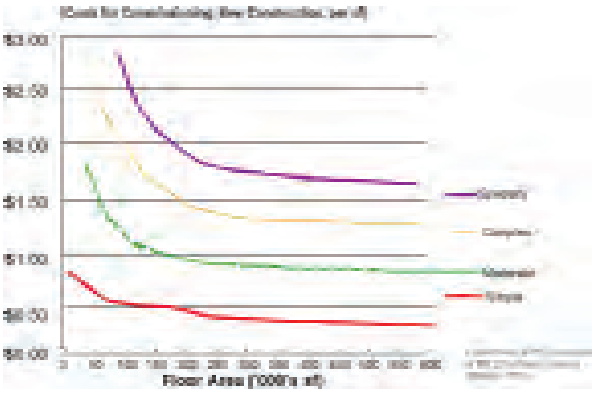

Figure 7.4.1. Construction Phase CX costs

7.4.2 Existing Building Commissioning Costs and Benefits

Of the numerous publications reporting or assessing existing building commissioning efforts, three contain significant building samples (see "Summary of Recommissioning Case Study Publications"). These publications, all of which rely on recommissioning efforts from the 1990s, show a range of resulting costs and savings. The reported average cost to recommission is usually in the range of \$0.05/ft^2 to \$0.40/ft^2. The simple payback period on these efforts is usually less than 2 years and quite frequently less than 0.5 year. Additional reported benefits include reports of improved office comfort, reduced occupant complaints, improved indoor air quality, extended equipment life, reductions in equipment failure, and improved building documentation.

The Cost Effectiveness of Commercial Building Commissioning: A Meta-Analysis of Energy and Non-Energy Impacts in Existing Buildings and New Construction in the United States

A comprehensive study completed in late 2004 (LBNL 2004) was designed as a "meta-analysis" to compile and synthesize extensive published and unpublished data from buildings commissioning projects undertaken across the United States over the past two decades, establishing the largest available collection of standardized information on commissioning experience. Data were analyzed from 224 buildings across 21 states, representing 30.4 million square feet of commissioned floor area (73 percent in existing buildings and 27 percent in new construction). The goal of this program was to develop a detailed and uniform methodology for characterizing, analyzing, and synthesizing the results. For existing buildings, the analysis found median commissioning costs of \$0.27/ft^2, whole-building energy savings of 15 percent, and payback times of 0.7 years. For new construction, median commissioning costs were \$1.00/ft^2 (0.6 percent of total construction costs), yielding a median payback time of 4.8 years (excluding quantified non-energy impacts). with an average simple payback period of 0.7 year. Average savings varied significantly for the building use types – \$1.26/ft^2/yr for medical research buildings down to \$0.17 ft^2/yr for school buildings.

7.5 Tracking Commissioning Benefits

As with any investment, it is important to develop metrics for tracking and persistence. In the case of building commissioning, these metrics need to be implemented and tracked on a regular basis for assurance of performance savings. Below is a compilation of commissioning metrics (LBNL 2004) useful for persistence tracking.

Building Characteristics and Demographics

- Building type (using DOE/CBECS definitions), vintage, location
- Year building commissioned
- Reasons for commissioning, deficiencies identified, measures recommended

Energy utilization intensity (use or savings)

- *Electricity:* kWh/building-year,12 kWh/ft^2-year
- *Peak electrical power:* kW/building; W/ft^2
- *Fuel:* MMBtu/building; kBtu/ft^2-year
- *Purchased thermal energy:* MMBtu/building-year; kBtu/ft^2-year
- *Total energy:* MMBtu/building-year; kBtu/ft^2-year13
- *Energy cost:* $/building-year; $/$ft^2$-year (based on local or standardized energy prices; nominal [not corrected for inflation] and inflation-corrected to a uniform year's currency)
- Percent energy use savings (total and by fuel)
- Percent total energy cost savings
- *Persistence index:* Post-commissioning energy use in a given year/pre-commissioning energy use (unit-less ratio)

Commissioning cost

- $/building; $/ ft^2 (based on nominal costs or, preferably, inflation-corrected to a uniform year's currency levels. Can be gross value or net, adjusting for the quantified value of non-energy impacts)
- Commissioning cost ratio, for new construction (commissioning cost/total building or renovation construction cost, %)
- Costs are tabulated separately for the commissioning agent and other parties
- Allocation of costs by source of funds (building owner, utility, research grant, other)
- Total building construction cost (denominator for commissioning cost ratio)

Cost effectiveness

- Undiscounted payback time (commissioning cost/annualized energy bill savings). This indicator is preferably normalized to standard energy prices; costs and benefits are inflation corrected to a uniform year's currency levels

Deficiencies and measures

- Deficiencies/building; Deficiencies/100 kft^2
- Measures/building; Measures/100 kft^2
- Unique codes to identify combinations of deficiencies and measures (described in more depth below) [see Measures Matrix]

Commissioning scope

- Presence of pre-defined "steps" (yes/no), with different criteria for existing buildings and new construction

Non-energy impacts

- Type
- Quantified (when possible), \$/building-year; $\$/ft^2$-year [can be positive or negative] – one time or recurring

7.6 The Commissioning Process

A four-step process for existing building commissioning is often recommended (Haasl and Sharp 1999).

Step 1: Planning. The planning step includes developing and agreeing upon the overall commissioning objectives and strategies, assembling the project team, and compiling and perusing building and equipment documentation. Examples of objectives could be a desire to optimize building operations to reduce operating costs, address complaints from occupants regarding air quality or comforts, create a model facility, and improve facility O&M including reducing emergency trouble calls. Regarding the commissioning team formation, considerations in forming the team could include contracted or in-house staff, level of effort required, desired and necessary qualifications, availability and use of resident knowledge, and available funding resources.

Step 2: Investigation. During this step the site assessment is completed, monitoring and functional test plans are developed and executed, test results are analyzed, a master list of deficiencies is compiled, and recommendations for improvements, including estimates of energy and cost savings, are generated and presented for consideration.

Step 3: Implementation. Accepted recommendations from the investigation step are put into place in the implementation step. Actions include making repairs and improvements, retesting and re-monitoring for results, fine-tuning improvements as needed, and revising estimates energy and cost savings.

Step 4: Hand-off and Integration. Final documentation of the commissioning effort describing the process, individuals, systems information, and actions taken is developed in this step. Also developed is a plan for future commissioning efforts. Items addressed by the commissioning plan should include recommended procedures for specific building equipment, frequency of testing, analysis of results, periodic reporting, identification of key players, and budget requirements.

7.7 Commissioning Provider Qualifications

The question of who should complete the recommissioning effort can be addressed once the recommissioning objectives and budget have been established. Some facilities have the in-house capability to successfully recommission their own equipment, but most do not. Here are some qualifications to consider when selecting a commissioning provider:

- Experience in recommissioning similar types of buildings by use and/or by design
- Experience in recommissioning similar types of building systems
- Experience in providing O&M training
- Specialized skills to consider include
  - Air/water testing and balancing
  - Design, installation, and/or troubleshooting of DDCs, pneumatic, and EMCSs
  - Demonstrated skills in working with metering and testing equipment/instrumentation.
- Relevant professional licenses and certifications (e.g., professional engineer)

7.8 The Future of Building Commissioning

The building commissioning field has grown markedly in the last five years. The data to date have shown tremendous benefits across the board when commissioning has been performed. While much more data are needed in order to fully verify and promote the energy and cost benefits, commissioning intuitively makes great business sense. As the awareness to the energy, cost and operational benefits is raised, we should expect to see the way commissioning is completed to become more effective and reliable and working toward becoming a regular part of the building operations process. Expect some of the following to help move the commissioning process forward.

- Chronicled experiences will lead to better estimates of costs and potential savings.
- Statements of work will become more standardized.
- New functional testing protocols will be developed and made widely available.
- New automated diagnostic technologies will become critical components in establishing continuous commissioning™ programs.
- Certified commissioning providers.

7.9 Case Studies

7.9.1 System Shutdown During Unoccupied Periods

(Texas A&M 2002)

The Figure 7.9.1 presents the measured building electricity consumption, excluding chiller consumption, before and after implementation of air-handling units (AHUs) and office equipment turn-off on nights and weekends in the Stephen F. Austin Building in Austin, Texas.

The Stephen F. Austin Building has 470,000 square feet of floor area with 22 dual duct AHUs. During the first phase of implementation, 16 AHUs were turned off from midnight to 4 a.m. weekdays and weekends. During the second phase, 22 AHUs were turned off from 11:00 p.m. to 5 a.m. during weekdays and weekends. During the second phase, all occupants were asked to turn off office equipment when they leave their office. The measured results show that the nighttime whole building electricity use decreased from 1,250 kW to 900 kW during the first phase. During the second phase, the nighttime minimum electricity decreased to 800 kW. It was observed that the daily peak electricity consumption after night shutdowns began is significantly lower than the base peak. For example, the lowest peak during the second phase is 1,833 kW, which is 8% lower than the base peak. The lower electricity peak indicates that some office equipment remained off during the daytime or employees were more conscientious in turning off lights and equipment when they left the office. The annual energy cost saving, including electricity, heating and cooling, was determined to be $100,000/yr using measured hourly data.

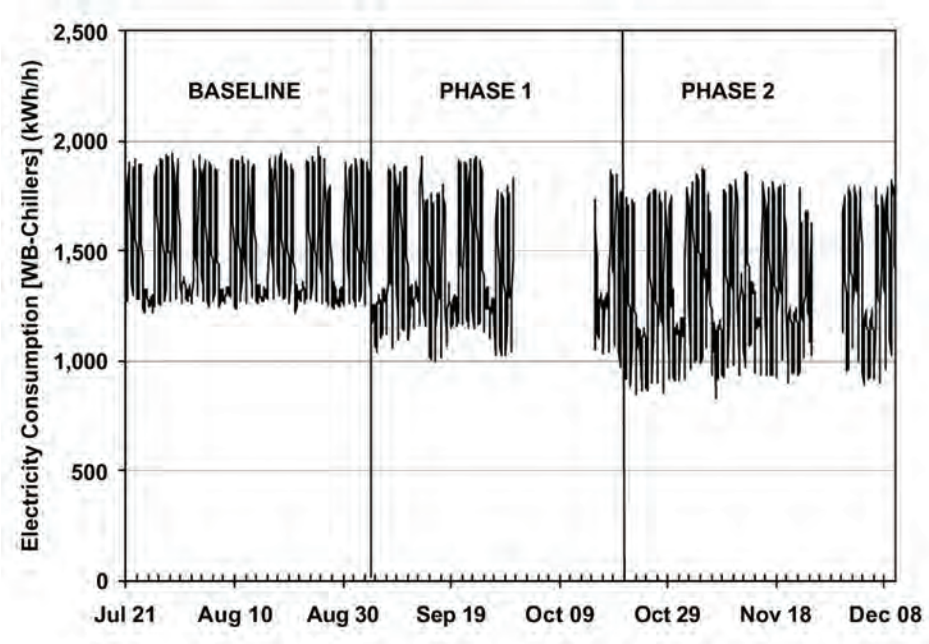

Figure 7.9.1. Whole-building electricity use before and after night shutdown program. Data gaps were periods when data were not available. Average nightime savings is 350 kW (1,250 kW – 900 kW).

7.9.2 In-House Recommissioning at a DOE National Laboratory

The William R. Wiley Environmental Molecular Sciences Laboratory (EMSL) at the Pacific Northwest National Laboratory (PNNL) in Richland, Washington, is a 200,000-square-foot national scientific user facility. In fiscal year (FY) 2000, the energy management team at PNNL recognized an opportunity to improve the performance of the laboratory and reduce energy use and costs through recommissioning. Results: In FY 2002, the estimated resulting annual energy savings of 27% and annual energy cost savings (avoidance) of 35%, or $173,735, versus expected consumption and cost. With a total investment of approximately $125,000, this retrocommissioning effort had a simple payback of well less than 1 year.

The energy performance for PNNL's EMSL building is shown in Figure 7.9.2.

The PNNL team followed the basic four-step commissioning approach. During the planning step, the team of in-house staff with experience in equipment operation, energy management, and engineering was assembled and overall objectives and strategies were agreed upon.

In the investigation step, a list of potential energy efficiency measures (EEMs) for the building was developed, the building systems were evaluated, cost estimates for corrective actions were generated, and opportunities prioritized. In developing the list of potential EEMs, the DOE Industrial Assessment Center (**www.iac.rutgers.edu/database**) served as a starting point.

During the implementation step, the implementation budget was finalized and occupant approvals obtained before changes were put into effect. EEMs deemed easy to complete, measure, and most likely to succeed were the first to be addressed. Results of these initial actions were then used to build-up credibility for the recommissioning approach and gain support to accomplish the full range of EEMs. Completed EEMs were monitored for results with readjustments made as necessary.

For the hand-off and integration step, PNNL has continued the recommissioning effort with activities such as monitoring building energy data, periodic review of operational changes, occupant and operator feedback, and monthly update reports. On-going monitoring of building performance helps to ensure that retrocommissioned building systems continue to operate in their optimized state and energy savings continue to be realized.

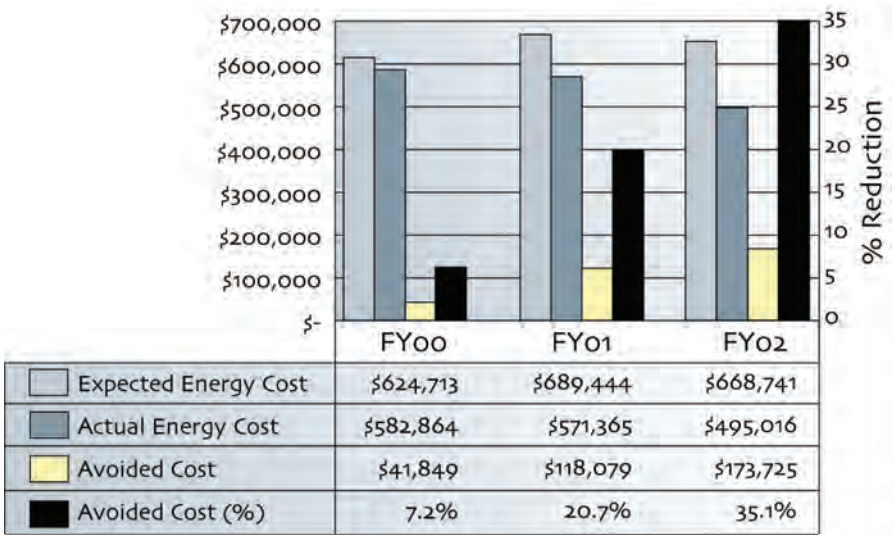

Figure 7.9.2. PNNL EMSL building energy performance by fiscal year (FY)

Roughly 200 low- and no-cost EEMs were put into place at EMSL. Examples of completed EEMs include

- HVAC systems tuning including modifying chilled water temperature setpoints, ensuring correct operation of heating and cooling valves, optimizing chiller operations, checking and correcting supply fan return dampers, optimizing selected fan heating/cooling strategies, reducing dead band limits on digital controls, and resetting building air flows as appropriate.
- Adjusting temperatures by modifying heat recovery system operational temperatures, modifying supply fan air discharge temperatures, resetting zonal thermostats to better match the conditions of the space (occupied or unoccupied), and applying additional night setbacks.
- Adding holiday schedules to building controls.
- Designating staff members to review operational strategies for facility systems for operational efficiency improvement opportunities.

While the energy and cost savings of the EMSL recommissioning effort are on the high-end, reported benefits of retrocommissioning efforts at other buildings are also impressive. Commissioning of existing buildings is an option that needs to be considered for inclusion in any O&M program.

Summary of Recommissioning Case Study Publications

"What Can Commissioning Do for Your Building" (PECI 1997) compiled a database of 175 buildings commissioned between 1993 and 1997. Commissioned buildings were located in the United States and Canada, ranged in size from 12,500 to 2.2 million square feet, ranged in age from 1 (new) to 74 years with a median age of 6 years, and covered a range of end uses including office buildings, retail facilities, hospitals, schools, and laboratories. Data in the case study are compiled by building use and provide the following general findings: costs to commission ranged from $0.02 to $2.88 per square foot with a median cost per square foot ranging from $0.09 to $0.31 per square foot. Reported benefits include energy use and energy cost savings, extended equipment life, improved documentation, reduced equipment failure, increased staff training, improved temperature control, improved relative humidity control, reduced occupant complaints, air balancing, and improved indoor air quality (i.e., contaminant control, improved ventilation, and reduced carbon dioxide).

"Commissioning Existing Buildings" (Gregerson 1997) looks at the recommissioning of 44 existing buildings. Commissioning efforts occurred primarily between 1993 and 1996 ran from $0.05 to $0.40 per square foot with energy savings usually ranging from 5% to 15% and paybacks of less than 2 years. This analysis also reports that significant opportunities are often found in buildings with large deferred maintenance, energy intensive buildings, and medical and research facilities.

The "FEMP Continuous Commissioning Guidebook for Federal Energy Managers" (Texas A&M 2002) provides a summary of results at 28 buildings continuously commissioned as part of the Texas LoanSTAR program. Building uses included hospitals, offices, and dual-use buildings with laboratories and offices or classrooms and offices. Measured annual energy savings averaged $0.64 per square foot per year (/ft^2/yr) with an average simple payback period of 0.7 year. Average savings varied significantly for the building use types – $1.26/ft^2/yr for medical research buildings down to $0.17 ft^2/yr for school buildings.

7.10 Additional Resources

In addition to the references listed at the end of this chapter, there are many sources of information on existing and new building commissioning via the Internet.

The Portland Energy Conservation, Inc. website (**http://www.peci.org**) should be your first stop when searching for additional information on existing and new building commissioning. This website offers a wide variety of materials including guidance on the commissioning process, case studies, functional testing guides, links to other websites supporting commissioning activities, and more.

Other potential sources include your state energy office (some offer additional guidance, case studies, and possibly even funding/grants) and your servicing utilities as recommissioning is an excellent way to help meet demand side management initiative goals.

7.11 References

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