1 Introduction

Building commissioning is rapidly becoming an important new field. More and more architectural and engineering firms are including commissioning services as a core business component. For the most part, *building commissioning* is a term associated with *new* construction projects as a process of ensuring that new buildings and their systems perform as designed. Commissioning is integrated into the construction process to ensure that owners and investors get good buildings for their investments.

Unfortunately, most buildings have never gone through any type of commissioning or quality assurance process and are therefore performing well below their potential. Even if building staff have been able to work out most of the "bugs" in the building systems, they are often forced to solve problems under severe time constraints and without the benefit of proper documentation. Having to address such problems too fast and without good information usually results in "quick and dirty" solutions, and such makeshift solutions lead to other building problems that often are invisible yet costly.

Commissioning of existing buildings, when appropriately applied, is going beyond quick-fix solutions to systematically optimize building systems so that they operate efficiently and effectively, often eliminating the need for costly capital improvements.

To improve buildings and capture the sizable opportunities that exist within them, commissioning principles are being applied to existing buildings more and more often. Fortunately, commissioning of existing buildings—also known as *retrocommissioning*[1]—when appropriately applied goes beyond quick-fix solutions to systematically optimize building systems so that they operate efficiently and effectively, often eliminating the need for costly capital improvements. Not only does retrocommissioning identify problems that occurred at construction just as traditional commissioning does, but it also identifies and solves problems that have developed during the building's life.

In his book *Energy-Efficient Operation of Commercial Buildings*, Peter Herzog describes the three fundamental components of an organization's energy management program as

[1] The term *retrocommissioning* is used by Rick Casault, *An Integrated Approach to Building Commissioning,* ASHRAE Professional Development Seminar, 1998–. This is one of several seminars sponsored by ASHRAE; see http://www.ashrae.org/EDUC/pdsinfo.htm.

- **efficient purchasing** — purchasing energy at the lowest available unit cost,
- **efficient operation** — operating the equipment that consumes energy as efficiently as possible, and
- **efficient equipment** — upgrading or replacing existing equipment with more energy-efficient versions whenever it is cost-effective to do so.[2]

Herzog notes that most energy management programs focus on purchasing energy and installing energy-efficient technologies, with little emphasis placed on efficient operation. Yet, efficient operation, although it is the least understood of the components, can offer the highest potential for savings with little or no capital outlay. A key goal of retrocommissioning is achieving this efficient operation. Retrocommissioning seeks to ensure the functionality of equipment and systems and also to optimize how they operate together in order to reduce energy waste and improve building operation and comfort. Thus, the goal of ensuring comfort and productivity of the building occupants accompanies the goal of cost savings.

"Do my existing buildings need commissioning?" an owner may ask. Many existing buildings are limping along in terms of performance, and unfortunately, most owners don't know it. As long as building systems maintain a reasonably comfortable environment, nothing appears to be wrong. Many problems are noticed only when a catastrophic failure or a visible consequence occurs. For example, when unnecessarily large volumes of outdoor air are drawn into a building, excessive heating and cooling energy are used. As long as the heating and cooling systems have the capacity to handle this increased air volume, however, the problem goes unnoticed. Other common problems that drive energy costs up but may or may not cause comfort or other visible problems include

- adjustable speed drives that are no longer adjusting appropriately,
- time clocks that are circumvented or set up improperly,
- equipment that is running more than necessary or running inefficiently because of improper operating strategies,
- energy management systems that were never installed or programmed to take full advantage of their capabilities or that have degraded over time, and
- controls that are out of calibration or are improperly sequencing.

[2] Peter Herzog, *Energy-Efficient Operation of Commercial Buildings: Redefining the Energy Manager's Job* (New York: McGraw-Hill, 1996).

Each of these problems can have a sizable effect on the economics of owning and operating a building. Not only can energy costs become excessive, but also capital dollars invested may cease to provide a return. These types of problems are typical in many buildings. Commissioning existing systems not only can find and correct these problems, but can optimize systems so that they operate in an integrated manner. These are just some of the reasons that retrocommissioning provides attractive returns to owners and managers.

Systems that are functioning improperly can have a sizable effect on the economics of owning and operating a building.

Retrocommissioning is widely applicable because operating and maintenance (O&M) problems are very common in buildings. Commissioning can benefit the "good, the bad, and the ugly" building. Which building type do you have and which type benefits the most from retrocommissioning? The bad building has numerous, obvious, and often complex O&M problems. It usually has attractive retrocommissioning opportunities. The ugly has these combined with needs for major capital improvements. Commissioning for both the existing equipment and new equipment is a good choice for this building type. Although "the bad and the ugly" stand to achieve the most benefit from retrocommissioning, the so-called "good" building often has lots of improvement potential as well, especially where multiple and more complex systems are used. Numerous well-designed, -constructed, and -operated buildings have major cost-saving opportunities. Often these opportunities are invisible to the owner but readily detectable through retrocommissioning. Chapter 5 discusses the many factors to consider when deciding whether an existing building is a good candidate for retrocommissioning. In most cases, energy savings alone makes retrocommissioning an attractive business investment.

How do I commission my existing buildings? is another question owners and managers often ask. Retrocommissioning is implemented as the four-part process outlined in Table 1.

Table 1. The four phases of the retrocommissioning process

Planning phase	Decide which building systems should be analyzed and assign responsibilities
Investigation phase	Determine how the selected systems are supposed to operate, measure and monitor how they operate, and prepare a prioritized list of the operating deficiencies found
Implementation phase	Correct the highest priority operating deficiencies and verify proper operation
Hand-off phase	Report improvements made and show the building owner/operator how to sustain proper operation

Retrocommissioning begins with the planning phase, which consists of identifying project objectives, targeting systems for improvements, and defining tasks and responsibilities. A plan for conducting the work results. An investigation phase follows, in which on-site assessment and testing are conducted. This phase allows deficiencies to be found and the scope of work to be refined. Once the scope is finalized, the improvements are then installed in an implementation phase, and their success is validated. Finally, the completed improvements are "handed-off" to the owner along with information and knowledge gained during the process to help ensure long-term performance for the owner.

This guide is written to educate building owners and managers about the retrocommissioning process and help them obtain the most value out of commissioning their existing buildings. It discusses commissioning terminology, how to get started, the phases and steps in the retrocommissioning process, the roles and responsibilities of the team members, retrocommissioning costs and benefits, how to increase cost effectiveness, and more. It is not a detailed how-to manual for commissioning service providers, although it can be useful for commissioning providers who are interested in understanding the owner's and manager's roles and expectations. The guide specifically targets those who are interested in obtaining cost-effective O&M improvements that do not entail a large capital investment. **O**

2 Commissioning Terminology

The following discussion of commissioning terminology provides clear definitions for use throughout this document. The definitions are based on current literature and discussions with commissioning professionals.

Building Commissioning

It is generally accepted that building commissioning is a method of risk reduction for new construction projects. Commissioning activities for new construction, summarized in Table 2, follow the construction process from pre-design through construction and acceptance. In addition, new construction commissioning may include all building systems (security, fire, life and safety, HVAC, lighting, electrical, etc.). *Commissioning* is defined in ASHRAE Guideline 1–1996 as the process of ensuring that systems are designed, installed, functionally tested, and capable of being operated and maintained to perform in conformity with the design intent. The guideline states that "commissioning begins with planning and includes design, construction, startup, acceptance and training, and can be applied throughout the life of the building."

The terms *building commissioning* and *building-systems commissioning* are often used interchangeably. If anything, building-systems commissioning is more specific in that it generally includes only the dynamic or energy-using systems in the building, whereas building commissioning may also include static systems such as the building envelope. In any case, the primary emphasis in commissioning new construction or new installations is on ensuring that building systems meet design intent and provide the owner what he or she expects.

Existing-Building Commissioning, or Retrocommissioning

Existing-building commissioning, also known as retrocommissioning, is an event in the life of a building that applies a systematic investigation process for improving and optimizing a building's O&M. As Table 2 indicates, many of its components are similar to those for new-construction commissioning. Retrocommissioning, however, occurs after construction, as an independent process, and its focus is usually on energy-using equipment such as mechanical equipment, lighting, and related controls. It may or may not emphasize bringing the building back to its original intended design. In fact, the

Table 2. New-construction commissioning vs retrocommissioning

New-construction commissioning	Retrocommissioning (existing equipment)
1. Conception or pre-design phase (a) Develop commissioning objectives (b) Hire commissioning provider (c) Develop design phase commissioning requirements (d) Choose the design team	**1. Planning phase** (a) Develop commissioning objectives (b) Hire commissioning provider (c) Review available documentation and obtain historical utility data (d) Develop retrocommissioning plan
2. Design phase (a) Commissioning review of design intent (b) Write commissioning specifications for bid documents (c) Award job to contractor (d) Develop commissioning plan	**[No design phase activities]**
3. Construction/installation phase (a) Gather and review documentation (b) Hold commissioning scoping meeting and finalize plan (c) Develop pre-test checklists (d) Start up equipment or perform pre-test checklists to ensure readiness for functional testing during acceptance	**2. Investigation phase** (a) Perform site assessment (b) Obtain or develop missing documentation (c) Develop and execute diagnostic monitoring and test plans (d) Develop and execute functional test plans (e) Analyze results (f) Develop Master List of deficiencies and improvements (g) Recommend most cost-effective improvements for implementation
4. Acceptance phase (a) Execute functional tests and diagnostics (b) Fix deficiencies (c) Retest and monitor as needed (d) Verify operator training (e) Review O&M manuals (f) Building/retrofit accepted by owner	**3. Implementation phase** (a) Implement repairs and improvements (b) Retest and remonitor for results (c) Fine-tune improvements if needed (d) Revise estimated energy savings calculations
5. Post-acceptance phase (a) Prepare and submit final report (b) Perform deferred tests (if needed) (c) Develop recommissioning plan/schedule	**4. Project hand-off and integration phase** (a) Prepare and submit final report (b) Perform deferred tests (if needed) (c) Develop recommissioning plan/schedule

original design documentation may no longer exist or may be irrelevant. Retrocommissioning is applied to buildings that have *not* previously been commissioned. Retrocommissioning ensures system functionality. It is an inclusive and systematic process intended not only to optimize how equipment and systems operate, but also to optimize how the systems *function together*. Although retrocommissioning may result in recommendations to investigate further capital improvements, O&M tune-up activities and diagnostic testing are primarily used to optimize the building systems. The goals and objectives for applying the process, as well as the level of rigor, may vary, depending on the current needs of the owner, the budget, and the condition of the equipment. The retrocommissioning process most often focuses on the dynamic energy-using systems with the goal of reducing energy waste, obtaining energy cost savings for the owner, and identifying and fixing existing problems.

Continuous Commissioning

The continuous commissioning process involves many of the same planning elements and investigation procedures as retrocommissioning. Its objectives are essentially the same. And like retrocommissioning, it is a systematic way of identifying and correcting building system problems and optimizing system performance in existing buildings. Continuous commissioning, however, more rigorously addresses the issue of persistence. A key goal is to ensure that building systems remain optimized continuously. To achieve this, continuous commissioning requires benchmarking pre- and post-energy use via metering equipment that is permanently installed. Data are then continuously gathered and compared against the post-commissioning benchmarks to ensure that the building systems function optimally throughout their lives.

Recommissioning

The term recommissioning is a confusing and often misused term. Simply put, recommissioning can occur only if a building was commissioned at some point in its life. Once a building has undergone either building commissioning as part of new construction or retrocommissioning as defined above, the periodic recommissioning ensures that the original results persist. Therefore, recommissioning is a *periodic event* that *reapplies* the original commissioning tests in order to keep the building operating according to design or current operating needs. In the best of worlds, recommissioning becomes part of a facility's ongoing O&M program. Recommissioning may need to occur only every 3 to 5 years. However, the frequency of recommissioning should be based on the complexity of the systems involved and the dynamic needs of the occupants. If there are frequent build-outs or changes in building use, recommissioning should be applied more often.

This document does not address recommissioning in any detail, but focuses entirely on retrocommissioning.

Commissioning Service Providers

The commissioning service provider, or commissioning provider, is often referred to as a commissioning agent, commissioning engineer, or commissioning expert. For projects involving the installation of new equipment or systems, the service provider is often referred to as the commissioning authority or agent. However, the use of the term *agent* is controversial because it implies having legal authority on behalf of the owner. The commissioning provider is hired or assigned by the owner. **O**

3 Benefits and Costs of Commissioning Existing Buildings

The benefits of retrocommissioning are numerous. Many of those most important to building owners and occupants are summarized in Table 3.

Table 3. Benefits of commissioning existing buildings

- Identifies system operating, control, and maintenance problems
- Aids in long-term planning and major maintenance budgeting
- Helps ensure a healthy, comfortable, and productive working environment for occupants
- Reduces energy waste and ensures that energy-using equipment operates efficiently
- Provides energy cost savings that often pay back investment
- Reduces maintenance costs; reduces premature equipment failure
- Provides complete and accurate building documentation; expedites troubleshooting
- Provides appropriate training to operating staff to increase skill levels; increases staff effectiveness in serving customers or tenants
- Reduces risk and increases the asset value of the building

A 1996 study of the cost-effectiveness of retrocommissioning in 44 existing buildings revealed attractive paybacks, even when estimates were based solely on energy costs savings. Table 4 summarizes the 44 buildings that were retrocommissioned. Retrocommissioning proved to have modest project costs of between $10,000 and $52,000, resulting in whole-building energy savings of 5–15%. Based on energy savings alone, for an investment of 5 to 43 cents per square foot, commissioning existing buildings delivered simple paybacks that rarely exceeded 4 years—and were often 2 years or less.[3] For building owners and managers these are

[3] J. Gregerson, "Cost Effectiveness of Commissioning 44 Existing Buildings," in *Proceedings of the National Conference on Building Commissioning* (Huntington Beach, Calif., April 28–30, 1997).

Table 4. Summary of recent costs and savings for recently commissioned existing buildings

Building name or location; type	Area (ft^2)	Ending date	Pre-comm. energy cost ($/$ft^2$/yr)	Commissioning cost		Energy cost savings		Simple payback (years)
				Total $	$/$ft^2$	$/yr	% of total cost	
Commissioning performed by PECI; funded by U.S. Environmental Protection Agency and Department of Energy								
Oregon; office	278,000	1995	1.25	12,745[a]	0.05	8,145	2.3	1.6
Citizen's Plaza, Tennessee; office	250,000	1995	1.81	23,967[a]	0.10	42,045	9.3	0.6
Arizona; office	80,000	1995	1.95	14,546[a]	0.18	16,194	10.4	0.9
Colorado; retail	122,000	1995	0.88	11,310[a]	0.09	13,779	12.8	0.8
Massachusetts; retail	107,000	1995	2.40	12,801[a]	0.12	8,042	3.1	1.6
Commissioning performed by Herzog/Wheeler; funded by building owner								
High-tech research facility	44,000	1984	4.35	14,000	0.32	59,840	31.3	0.2
Commissioning performed by Sieben Energy; funded by building owner								
203 N. LaSalle St.; office	623,000	1995	1.28[b]	80,000	0.13	150,000[c]	18.8	0.5
Commissioning performed by Texas A&M ESL; funded by Texas LoanSTAR								
State Capitol Complex								
Capitol Building; computer facilities/office	282,499	1996	1.63	24,000[d]	0.08	88,812	19.2	0.3
S. F. Austin Building & CP; computer facilities/office	470,000	1993	1.24	28,000[d]	0.06	30,385	5.2	0.9
John H. Reagan Building; computer facilities/office	169,756	1996	1.56	24,000[d]	0.14	50,680	19.2	0.5

Table 4 (continued)

Building name or location; type	Area (ft^2)	Ending date	Pre-comm. energy cost ($\$/ft^2/yr$)	Commissioning cost		Energy cost savings		Simple payback (years)
				Total $	$\$/ft^2$	$/yr	% of total cost	
Insurance Building; office	102,000	1996	1.28	24,000[d]	0.24	14,823	11.3	1.6
Archives Building; library	120,000	1996	0.37	24,000[d]	0.20	9,867	22.5	2.4
Starr Building; office	99,000	1995	2.16	20,000[d]	0.20	48,000[e]	22.5	0.4
Central Services Bldg; office	100,000	1996	n/a	15,000	0.15	8,000[e]	n/a	1.9
State Preservation Board								
Capitol Extension; computer facilities/office	592,781	1996	0.84	28,000[d]	0.05	89,758	18.0	0.3
UTHSC Houston								
School of Public Health; medical institution	233,738	1994	1.62	24,000[d]	0.10	63,502	16.8	0.4
Medical School Building; medical institution	887,187	1994	3.16	28,000[d]	0.03	879,101	31.4	0.0
Texas Department of Health; medical institution	298,700	1995	1.54	24,000[d]	0.08	11,550	2.5	2.1
Fort Worth ISD								
Sims Elementary School	62,400	1994	0.79	20,000[d]	0.32	14,310	29.0	1.4
Dunbar Middle School	92,884	1993	1.41	24,000[d]	0.26	11,802	9.0	2.0

Table 4 (continued)

Building name or location; type	Area (ft^2)	Ending date	Pre-comm. energy cost ($\$/ft^2/yr$)	Commissioning cost		Energy cost savings		Simple payback (years)
				Total $	$\$/ft^2$	$/yr	% of total cost	
UTMDA Cancer Center								
Boiler Room; medical institution	412,872	1994	1.72	28,000[d]	0.07	154,660	21.8	0.2
Basic Research; medical institution	120,376	1994	3.77	24,000[d]	0.20	208,857	46.1	0.1
Old Clinic & Lutheran Pavillion; medical institution	499,013	1994	2.05	28,000[d]	0.06	397,749	38.8	0.1
New Clinic; medical institution	276,466	1995	1.59	24,000[d]	0.09	209,164	47.5	0.1
UTMB Galveston								
John Sealy North; medical institution	54,494	1993	6.61	20,000[d]	0.37	177,984	49.4	0.1
Clinical Sciences; medical institution	124,870	1995	2.83	24,000[d]	0.19	23,638	6.7	1.0
Basic Sciences; medical institution	137,856	1993	4.00	24,000[d]	0.17	235,151	42.7	0.1
Moody Memorial; library	67,380	1994	2.48	20,000[d]	0.30	35,064	21.0	0.6
John Sealy South; medical institution	373,085	1994	2.48	28,000[d]	0.08	176,904	19.1	0.2

Table 4 (continued)

Building name or location; type	Area (ft^2)	Ending date	Pre-comm. energy cost ($\$/ft^2/yr$)	Commissioning cost		Energy cost savings		Simple payback (years)
				Total $	$\$/ft^2$	$/yr	% of total cost	
Commissioning performed by Texas A&M ESL; funded by Bay City								
Bay City Courthouse; office	65,000	1996	n/a	10,000	0.15	6,000[e]	n/a	1.7
Commissioning performed by Texas A&M ESL; funded by Texas A&M University								
Reed McDonald; office/classroom	77,435	1996	n/a	24,000[d]	0.36	40,000[e]	n/a	0.6
Large Animal; medical institutions	140,865	1996	n/a	24,000[d]	0.20	226,000[e]	n/a	0.1
Research Facility; office/classroom/lab	114,666	1996	n/a	24,000[d]	0.24	144,000[e]	n/a	0.2
Heep Center; office/ classroom/lab	158,979	1996	n/a	24,000[d]	0.18	65,000[e]	n/a	0.4
Richardson Petroleum; office/classroom	113,700	1996	n/a	24,000[d]	0.25	60,000[e]	n/a	0.4
Kleberg; office/classroom/lab	165,031	1996	n/a	24,000[d]	0.17	395,000[e]	n/a	0.1
Harrington Tower; office/classroom	90,000	1996	n/a	5,000	0.21	12,000[e]	n/a	0.4
Small Animal; medical institution	150,000	1996	n/a	5,000	0.17	25,000[e]	n/a	0.2

Table 4 (continued)

Building name or location; type	Area (ft^2)	Ending date	Pre-comm. energy cost ($/$ft^2$/yr)	Commissioning cost		Energy cost savings		Simple payback (years)
				Total $	$/$ft^2$	$/yr	% of total cost	
Commissioning performed by PECI; funded by Southern California Edison[f]								
Retail	146,000	1994	2.09	41,555	0.28	21,900[d]	7.4	1.9
Office	152,000	1994	1.64	45,065	0.30	12,160[d]	5.2	3.7
Nordstrom; retail	170,000	1994	2.26	52,336	0.31	42,500[d]	11.2	1.2
Office	48,000	1994	1.25	16,634	0.35	16,320[d]	27.0	1.0
Office	50,000	1994	1.82	21,713	0.43	11,000[d]	12.2	2.0
Office	120,000	1994	1.45	16,454	0.14	3,600[d]	2.4	4.6

Notes: n/a = information was not available.
Source: Adapted from Gregerson, "Cost Effectiveness of Commissioning 44 Existing Buildings."
[a]Commissioning cost included facility staff time for these buildings. This amount was not included in the costs of other projects.
[b]Energy cost excludes cost of tenant lighting and plug loads for this building.
[c]Savings were estimated from utility bills and/or simplified engineering calculations for these buildings.
[d]Commissioning cost per building is estimated for these buildings, based on known *project* cost (which included several buildings). ESL estimated the cost per building to be $20,000 for buildings under 75,000 ft^2, $24,000 for buildings from 75,000 to 300,000 ft^2, and $28,000 for buildings over 300,000 ft^2.
[e]Annual commissioning savings are projected based on measured savings for less than a full year.
[f]Energy cost, savings, and simple payback include electricity only for these six buildings.

attractive figures, demonstrating that retrocommissioning is an effective, low-cost method to improve buildings and reduce operating costs.

The study showed that retrocommissioning costs vary according to the complexity of the systems, the number of pieces of equipment, and the objectives or scope of the retrocommissioning project rather than by building type. Retrocommissioning costs for only 10 of the buildings exceeded 28 cents per square foot. Yet, 9 of these 10 had simple paybacks of 2 years or less. The buildings ranged from medical facilities and schools to office buildings. The actual project cost for these 10 buildings ranged from $14,000 to $52,000, but for the majority (8 buildings) project costs were about $24,000. The higher cost per square foot for these buildings was mostly a function of their *smaller size*. Only two of them were over 100,000 ft^2. The rest were between 44,000 and 77,000 ft^2. In comparison, the largest building in the study (623,000 ft^2) cost the most to commission—$80,000—but the cost per square foot was only 13 cents. Simple payback for this building was only 6 months.

In addition to energy savings, the benefits of retrocommissioning include extended equipment life, improved indoor air quality, and reduced O&M costs.

In most cases, it is much easier to accurately track and quantify commissioning costs than it is to track and quantify benefits. Energy savings, for example, are usually determined by calculation rather than actual measurement. Benefits such as extended equipment life, improved indoor air quality, improved worker productivity, and reduced O&M costs should not be overlooked, even though they are more difficult to quantify than energy savings. These non-energy benefits are often more important to building owners and upper management than the energy cost savings. For owners concerned about indoor air quality (IAQ) litigation, improving indoor air quality and documenting the effort may be a primary goal of retrocommissioning. An Occupational Safety and Health Administration (OSHA) report noted that 20–30% of commercial buildings suffer from IAQ problems that are not associated with temperature alone.

Although little research has been completed to document the link between comfort and productivity, common sense tells us that comfortable employees are more productive. The few studies that have been conducted on this topic agree. One estimate of productivity losses in a typical office building where occupants complained of discomfort was stated in the following terms:[4]

Payroll costs	$150/$ft^2$/year
Productivity lost to complaint time	$0.10/$ft^2$/year

[4]Presentation to National Electric Light and Power Association, 1989, by Cedric Trueman, Sr., technical advisor for British Columbia Buildings Corp.

This example assumes that this typical building has one occupant per 200 ft^2 of space and an annual payroll cost of $30,000/person or $150/$ft^2$ of office space. If one out of every five employees spends only 30 minutes a month compensating for or complaining about the lighting or the temperature or both, the employer loses $0.10/$ft^2$ in annual productivity. For a 100,000-ft^2 building, this amounts to $10,000 per year. Because uncomfortable employees probably spend more than just half an hour each month addressing building comfort issues, the actual losses may be higher.

If comfort problems are severe enough to make employees ill, business owners can sustain additional productivity losses and increased liability risks. Building operation costs also increase, as operators respond to more complaints.

These problems concern not only building owners who occupy their buildings: they affect owners who rent building space as well. Tenants who are experiencing comfort and productivity problems may not remain tenants for long. Based on the estimated costs shown in Table 5, losing a tenant in Class A office space can be expensive.

Table 5. Cost of losing a tenant

Five-year lease value	$262,500
Rent loss due to vacancy	$26,250
Improvements for new tenant	$52,500–70,000
Leasing commission	$13,125
Total cost of losing tenant	$91,875–109,375

Source: ASHRAE presentation by David Zier of Melvin Mark Company. The Melvin Mark Company owns, manages, and develops real estate. Available at www.cbs.state.or.us/external/ooe/cons/commsave.htm.

Assuming an average office size of 3,500 ft^2, rented at $15/$ft^2$ a year, a typical five-year lease has a value of $262,500. If a tenant leaves, this space will remain vacant an average of 6 months, for a total rent loss of $26,250. Improvements and build-outs to satisfy a new tenant usually run $15–$20/ft^2, or $52,500–$70,000 in this case. On top of all this, the building owner often pays a leasing commission of 5% of the 5-year lease value, or $13,125. Thus, the total cost of losing one tenant could range from $91,875 to $109,375, or 35 to 42% of the 5-year lease value. If a building develops a reputation for being uncomfortable and unproductive, the vacancy period could last longer. Word of uncomfortable building conditions is likely to spread among business peers; market research shows that dissatisfied customers—in this case, tenants—are likely to complain to 7 to 10 of their peers. **O**

4 Preparing for a Retrocommissioning Project

This section addresses key questions and activities to consider when preparing for a retrocommissioning project. Before starting a such a project, it is helpful to answer the following questions:

- Is retrocommissioning appropriate?
- What resources are available?
- Who needs to be convinced of its value?

Answering these questions help ensure that the benefits of retrocommissioning will meet the needs of both management and O&M staff.

Is Retrocommissioning Appropriate?

To some extent, it is easier to answer this question by understanding when retrocommissioning is not appropriate. Generally, retrocommissioning is not appropriate for buildings where

- most of the equipment and systems are either outdated or at the end of their life;
- major system design problems exist; and/or
- major equipment malfunctions exist such that the best remedy is an equipment replacement.

The main intent of retrocommissioning is to improve and optimize how building systems are operated. It is not a method for keeping old, inefficient equipment limping along. Although retrocommissioning should not be performed in lieu of making needed capital improvements, budgets do not always allow for buying new equipment unless existing equipment is broken beyond repair. Under these circumstances, it may be

better to invest in the retrocommissioning process than continue "firefighting" or doing nothing. This is particularly true for control systems, which sometimes become outdated but are not necessarily broken. Retrocommissioning may be a cost-effective solution to making the best use of the old system and ensuring that any needed equipment repairs or improvements are prioritized on the basis of return on investment.

Retrocommissioning may be a cost-effective solution to making the best use of the old system and ensuring that any needed equipment repairs or improvements are prioritized on the basis of return on investment.

When considering retrocommissioning, evaluate the equipment and the building systems to determine how many of them will need replacing within the next year or two. Investing in retrocommissioning when the equipment or systems involved will be replaced shortly after the process is completed is obviously not a good investment. However, for buildings with newer equipment (less than 12 years old), retrocommissioning may be the most appropriate first step for optimizing building performance and obtaining cost savings. Energy and facility managers are beginning to see retrocommissioning as an energy efficiency measure in itself, much like any other energy-efficiency retrofit. Owners can use retrocommissioning to obtain low-cost energy saving opportunities before considering more expensive capital improvements. In some cases, the savings from retrocommissioning may help pay for needed capital improvements.

Is an ESPC Being Considered?

Some level of retrocommissioning is usually appropriate if you are considering any type of energy savings agreement such as an energy savings performance contract (ESPC). There are two primary reasons for performing retrocommissioning *before* obtaining an energy-savings agreement. First, the low-cost energy savings gained from retrocommissioning remains with the building (the owner gets all of the savings) and does not become part of the financial agreement; second, retrocommissioning optimizes the existing equipment so the most appropriate capital measures are selected and financed through the agreement.

A good reason for doing retrocommissioning as *part of* an energy-savings agreement is to ensure that the performance of new equipment is not hindered because it interfaces with older equipment, components, or systems that are malfunctioning. Even when commissioning is specified for the new equipment, it often stops short of looking at the systems with which the new equipment interfaces or examining how it integrates with other systems or equipment that may affect its performance. This is especially true for energy management control systems. Because controls are an area where many difficulties and misunderstandings occur between building owners and performance contractors, it is a good idea to specify commissioning for both the new

equipment and the existing equipment that may affect the performance of the new equipment.

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

Retrocommissioning performed up front to capture the low cost savings may not be a wise choice if the savings from the retrocommissioning do not remain with the building but, instead, go into a general fund. In this case, the "low-cost/no-cost" improvements should be part of the performance contract. In this way, a portion of the savings stays with the building as part of the financial arrangement. Integrating the retrocommissioning measures into the energy savings agreement is a way to capture the savings as part of the investment repayment. The amount invested can be increased when the savings estimates are higher. Moreover, the savings gained from bundling these measures with the capital upgrades—especially if some of the upgrades are marginally cost-effective (i.e., good value but with long paybacks)—help to increase the overall viability and attractiveness of the ESPC funding.

What Resources Are Available?

Before beginning a commissioning project, it is important to understand what resources are available for getting the work accomplished. The most cost-effective projects usually have a least one in-house staff person assigned to the project. The staff person chosen should have expertise in the building's control systems, HVAC equipment, and lighting systems. It is preferable to assign a building operator who knows the building's history and why and how systems are operated and maintained. If the commissioning provider lacks in-house support, the project may still be successful but not always as cost-effective as it could be. Another benefit of allowing in-house staff to work on the project is the training they receive. Participating in the project allows them to incorporate many of the troubleshooting and testing methods learned during retrocommissioning into the facility's O&M program.

Participating in the project allows in-house staff to incorporate many of the troubleshooting and testing methods learned during retrocommissioning into the facility's O&M program.

When taking stock of the available resources, include calls to the local utility as well as state and local governments (Department of Environmental Quality or the State Energy Office) to find out if they have any services or funding available for the

retrocommissioning of existing buildings. These organizations may even offer such services directly or may have a list of qualified commissioning providers. Also, the utility may be interested in providing metering or monitoring tools for the measuring and diagnostics as part of the retrocommissioning process.

Who Needs to Be Convinced?

In order to implement a retrocommissioning program or project, obtaining buy-in from those who will be directly involved with the project work, as well as those in upper management who will reap the benefits, is usually necessary.

Obtaining upper management support

Upper management usually needs to be sold on the financial benefits of the project—managers will want to know how commissioning an existing buildings will positively affect the organization's "bottom line." It may be necessary to provide individuals in upper management, such as the chief financial officer, with a written project proposal to obtain needed financial support. It is important to understand the organization's financial process and philosophy in order to demonstrate how the project can best fit into the budget and why it is important for the company to fund the project. Because retrocommissioning does not generally require capital expenditures, funding can often come from the facility's operating budget. However, this may entail requesting a one-time increase in the budget to cover the project costs.

Managers will want to know how commissioning an existing building will positively affect the organization's "bottom line."

In making the case for a retrocommissioning project, here are some important ideas to consider:

- **Retrocommissioning as an asset management activity.** This can be the initial step that helps change the old paradigm of O&M as part of the "cost of doing business" to a new paradigm of O&M as part of sound asset management. Retrocommissioning increases the ability of the O&M department to provide quality services to its clients. Also, the facility's net operating income increases when a building is operated as energy efficiently as possible.[5]

[5] M. Chao and D. Goldstein, *Energy Efficiency and Property Valuation by Appraisers and Financial Markets: The Need for Commissioning and Credible Performance Documentation* (San Francisco: Institute for Market Transformation, September 1997, 1–6).

- **Retrocommissioning as a risk-reduction method.** Reducing the risk of tenant loss, early equipment failure, IAQ issues, and high utility bills also increases the asset value of the facility.
- **Retrocommissioning as an internal benchmarking technique.** The documentation and testing completed during the commissioning process can be used to set the internal benchmarks for building operating performance, including indoor environmental quality. This sets the pace for providing an ongoing record of quality control and increases the quality focus for the facility.
- **Retrocommissioning as part of the energy management program.** Retrocommissioning supports the *efficient operation* of the energy-using equipment in the building. This is a low-cost method for obtaining savings without capital outlay. The savings obtained may help offset the cost of needed capital improvements.

Both the energy and non-energy benefits of the proposed project must be presented clearly. Measurable objectives will aid in getting management buy-in. These objectives should be presented to upper management along with a brief description of the intended measurement and verification methods. Chapter 4 discusses this concept in more detail in the planning section entitled "Developing and Communicating Objectives."

Once the case for retrocommissioning has been presented, it is often effective to leave the decision-makers with some brief, clear informational materials. The resource booklet *What Can Commissioning Do For Your Building?* may help obtain management buy-in to the importance of retrocommissioning as well as commissioning for new equipment. This booklet, which draws from a database of 175 case studies, is geared specifically toward upper management in that it is short (13 pages) and clear about the energy and non-energy benefits of commissioning. Information about obtaining copies of this booklet can be found at the end of Appendix A.

Obtaining building operating staff support

The building operating staff also need to feel committed to the retrocommissioning effort. They need to view retrocommissioning as part of the overall O&M program that positively supports their work and not as a fault-finding, make-work exercise. Staff support can be gained by including O&M personnel in defining the results they want from the project. For example, building staff should be better trained, less taxed with nuisance problems and trouble calls, and more able to proactively pursue preventive O&M tasks, leading to better use of their time. Bringing in an outside commissioning provider can sometimes be threatening. Therefore, it is important that the building staff be assured that the commissioning process will actively address their needs and help them provide better service. **O**

5 Getting Started

This section introduces and discusses some strategies for selecting successful projects, increasing the cost-effectiveness of the projects, and determining the roles and responsibilities of the major participants. Desirable characteristics that help improve retrocommissioning value are listed in Table 6.

Table 6. Characteristics that improve retrocommissioning value

- Management support and commitment
- A motivated and available building staff
- An unjustified, high-energy-use index
- An energy management control system (EMCS)
- No major system problems
- Easily accessible and up-to-date building documentation
- Newer equipment (12 years old or less)
- Cooperative tenants or occupants

Selecting the Right Project

Some buildings or groups of buildings make better candidates for retrocommissioning than others. Owners of multiple buildings may want to develop a spreadsheet to better understand and compare their building stock, and then prioritize retrocommissioning projects according to which sites present the most opportunity for obtaining cost-effective O&M improvements. Buildings that appear to be the best or most attractive candidates (that exhibit the most opportunity for improvement) should be first in line for retrocommissioning. The most broken buildings may not be the most attractive, while fairly new buildings may offer the most savings or benefit for the least cost. Appendix B includes a list of building characteristics that may be placed in a database or spreadsheet format for comparing multiple buildings.

The following discussion provides some guidance on characteristics desirable in buildings to be retrocommissioned. Not all of the elements discussed below need to be present for the project to be successful, but the more elements that are present, the better the chance for success.

Energy management control systems

Buildings with computerized energy management control systems (EMCSs) often make some of the best candidates for retrocommissioning. A recent survey of class A and B building owners showed that although a high percentage of the buildings surveyed had computerized control systems, the systems were underutilized. The systems were capable of performing more sophisticated energy management strategies than they were actually set up to do. This situation generally offers energy-saving opportunities. Other saving opportunities stem from the fact that EMCSs, no matter how recently they were installed, are often just not functioning correctly. Most were never commissioned at installation. In addition, unless building staff members have received adequate training, they are often unaware of how to program and troubleshoot the EMCS and how to use it as a powerful tool for diagnosing the performance of HVAC and other systems. Many of these systems lack adequate documentation, such as written sequences of operation or control strategies, making it difficult for building staff to understand what the EMCS was intended to do. Not only can retrocommissioning provide a fully optimized system, but it also can document exactly what control sequences and strategies are presently incorporated into the system. The process can also provide important training for building staff.

The best building candidate for retrocommissioning will have

- *an EMCS*
- *no major system problems*
- *an in-house O&M staff*
- *building documentation*
- *newer equipment*
- *cooperative tenants*

Absence of major system problems

Buildings with known major system problems, especially design problems, are generally not good candidates for retrocommissioning because the solutions are more complex than typical retrocommissioning alone can provide. Also, buildings that have not been through an asbestos abatement process may be subject to stringent requirements for working in the building that can drive the cost of a project beyond what is acceptable. Because the cost-effectiveness of a retrocommissioning project is primarily connected with optimizing how a building is operated, buildings with broken control systems generally do not make good candidates. For example, buildings with pneumatic control systems that have oil or water throughout the pneumatic lines, or buildings where the EMCS is out of date, cannot be upgraded, or lacks documentation, would typically be considered as having a broken control system. Repairing major problems is a must before retrocommissioning.

In-house O&M staff

Retrocommissioning performed on buildings with experienced, willing, and available building staff is more likely to be cost-effective and have lasting results. Staff knowledge, especially in the area of controls, can minimize costs. Staff can perform many of the tests and implement many of the improvements without having to hire outside contractors. They can also readily provide the commissioning provider with accurate information about the building's operating strategies and maintenance procedures.

Accessible and up-to-date building documentation

The condition of building documentation is another important criterion in selecting a building for retrocommissioning. Having the commissioning provider spend numerous hours recreating and gathering critical building documentation can increase the cost of the project significantly. Unless updating building documentation is a primary objective for the retrocommissioning project, owners should choose buildings with complete and up-to-date documentation if they want to increase the cost-effectiveness of the project.

Newer equipment

Equipment age can also have a significant impact on the project. If most of the building's primary energy-using systems are at the end of their lives (especially if they have not been well-maintained), retrocommissioning is probably not the best choice for obtaining energy savings or reducing risk. Buildings containing equipment that is no more than 12 years old are usually better candidates for retrocommissioning.

If improvement strategies can be implemented and produce the desired return on investment (ROI) in less time than the remaining life of the equipment, it makes sense to implement them. Properly planned control improvements, such as those invoked by an EMCS, can be applied to existing equipment for its remaining life and then applied to new equipment as replacements occur.

If significant equipment or EMCS upgrades or replacements are already scheduled to occur within the next two years, the owner should consider combining retrocommissioning of the existing equipment and the new installations at that time.

Cooperative building tenants

Buildings with tenants who are unwilling to cooperate with the retrocommissioning process or who use areas in the building that are particularly sensitive to any

operational changes may not be good candidates for retrocommissioning, especially if these tenants occupy most of the building space. On the other hand, if the building houses tenants who have numerous complaints about comfort or environmental quality, the building may be a very good candidate for retrocommissioning.

Energy Accounting

Whether or not a project involves an energy-efficiency retrofit, obtaining energy-use data on the buildings being considered for retrocommissioning is fundamental for selecting a successful project. Buildings with excessive energy use or energy budgets are usually good candidates as long as the reason for their high energy use is not easily justified. High energy use is often justified for buildings with high occupant densities, 24-hour-per-day operation, high outdoor air requirements, or sizable computer facilities.

The building annual energy use index (EUI) is the common benchmark used to make building energy use comparisons.[6] It is expressed in energy use per square foot of floor area (Btu/ft^2 or kWh/ft^2). This normalizes for floor area, allowing buildings of different sizes and similar use to be compared. It is best to compare a building with others in the same city or region so that major climatic differences do not affect the EUIs. A higher-than-normal EUI can indicate significant opportunities for retrocommissioning. A lower EUI, however, does not necessarily mean a lack of opportunities.

An example of EUIs for various types of commercial buildings is provided in Table 7. These EUIs are based on a sample of over 6,000 buildings across the United States. They are disaggregated into low, medium, and high categories corresponding to the 25th, 50th, and 75th percentiles when all buildings in the sample are ordered by ascending EUI.[7] At the 75th percentile, 75% of all U.S. buildings would be more efficient. While these EUIs are accurate indicators for buildings nationwide, they are not necessarily good benchmarks for a building in a specific location (because all U.S. climates are represented in the table). EUIs based on this same sample and broken out into nine U.S. regional locations can be found online at Oak Ridge National Laboratory's (ORNL's) Buildings Technology Center web site.[8] These are better EUI benchmarks for individual buildings because their regional basis accounts for most of the nationwide variations in climate and fuel types.

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[6] The annual energy use index (EUI), also known as a building annual energy budget, is generally calculated in Btus per square foot of gross floor area. All fuels are taken into consideration by converting them to Btus for the calculation. The total Btus for the year are then divided by the building gross square footage.

[7] Research at Oak Ridge National Laboratory has found that comparing an individual building to a distribution of building EUIs is a better performance indicator than comparison to average EUIs (T. R. Sharp, "Energy Benchmarking in Commercial Office Buildings," pp. 321–29 in *Proceedings of the ACEEE 1996 Summer Study on Energy Efficiency in Buildings,* vol. 4, Pacific Grove, Calif., August 23–28, 1996).

[8] All of the web sites referred to in this chapter can be found in Appendix A.

Table 7. Distribution of annual total energy use intensities (EUIs) for commercial buildings

Commercial building type	Number of buildings in sample	Annual total energy consumption (kBtu/ft^2)[a]		
		Low	Medium	High
Office	1383	79	135	228
Mercantile and service	1206	56	106	198
Warehouse (non-refrigerated)	912	18	42	95
Education	718	76	113	160
Public assembly	380	39	82	149
Religious worship	372	26	47	74
Vacant	263	8	29	82
Lodging	255	100	184	325
Food service	232	219	441	766
Health care (inpatient)	126	109	164	364
Parking garage	106	59	125	169
Food sales	103	248	418	686
Public order and safety	83	93	145	225
Laboratory	68	82	254	545
Health care (outpatient)	63	80	144	236
Skilled nursing	48	143	254	321
Warehouse (refrigerated)	39	56	102	188

Source: Energy Information Administration (EIA), *Commercial Buildings Energy Consumption and Expenditures,* DOE/EIA-0318(92) (Washington, D.C.: EIA, 1995).

[a]Low, medium, and high categories correspond to 25th, 50th, and 75th percentiles of the sample, respectively. To calculate your annual total energy use for comparison to values in this table, these approximate conversion factors can be used:

fuel oil = 140 kBtu/gal;
natural gas = 100 kBtu/ccf, 100 kBtu/therm, or 1000 kBtu/mcf;
electricity = 10.3 kBtu/kWh.

A site-based electricity conversion factor (3.412 kBtu/kWh) should not be used. If used, EUI distributions for electrically dominated buildings, particularly all-electric buildings, are considerably different from those represented by this table.

There are a few software tools that allow the user to compensate for additional secondary effects when comparing buildings based on EUIs. One of these is MAISY, a commercial software product that provides the user access to U.S. Department of Energy (DOE) national building databases; product information is available at the Jackson Associates web site (see Appendix A). By specifying some of your building characteristics, you can examine the energy use data of U.S. buildings with the same characteristics. Statistical analysis of these can then be done to determine the impacts of the different building characteristics.

ORNL has developed an easy-to-use, spreadsheet-based benchmarking tool for office buildings that uses simple distributional ranking and compensates for the most important secondary drivers of office building energy use.[9] This tool requires between five and eight inputs—such as building location, size, energy use, and number of workers—for its ranking. The tool calculates EUIs for the user's building, calculates the typical EUI of buildings with the same characteristics, and then ranks the building in comparison to others. This tool can be downloaded from ORNL's Buildings Technology Center web site. A similar tool is under development for public schools.

The joint Environmental Protection Agency (EPA)/DOE Energy Star Label for Buildings Initiative has just completed a benchmarking tool for online use. The tool provides an indicator for comparing office building energy performance, also normalized for secondary drivers, and can be found at the Energy Star Building Label home page.

Increasing Cost-Effectiveness

Thorough preparation and participation by building staff prior to and throughout the project reduces overall costs. By employing five strategies, in-house building staff can streamline the project and increase the effectiveness of the commissioning provider's time:

1. gather building documentation;
2. perform appropriate preventive maintenance;
3. perform simple repairs and improvements as the project progresses;
4. perform diagnostic monitoring and functional testing; and
5. implement selected improvements and repairs.

[9] Sharp, "Energy Benchmarking."

These strategies should be planned as appropriate and introduced to the building staff before putting the retrocommissioning process into action. If the project, due to size or complexity of the project dictates, using a bid process for obtaining commissioning services, the request for proposals should state which of the tasks discussed below are in-house building staff responsibilities. This helps the bidders understand what to expect from the owner's staff and develop their budgets accordingly.

Gather building documentation

Compile an *up-to-date* building documentation package prior to the retrocommissioning process. If this is not done ahead of time, the commissioning provider will need to gather this information. This packet should be available on-site and contain as much information as possible, including

- drawings relevant to the systems targeted for commissioning (preferably "as-built" drawings if accurate);
- O&M manuals;
- testing, adjusting and balancing (TAB) reports;
- original design documentation;
- an equipment list with nameplate information, dates of installation, and submittals, including pump curves and fan curves;
- a list of outside service contractors regularly used;
- copies of current service contracts;
- control system documentation, such as sequences of operation, special control strategies, control diagrams, points list, and control program or code;
- energy-efficient operating strategies;
- energy bill (electric, gas, steam, chilled water, etc.) or energy accounting information for at least the last 24 months, along with a rate schedule, unit price, or supply contract information for each energy type; and
- water and sewer usage and billings.

It is possible that some of the information, such as pump curves, fan curves, and written sequences of operation, will not be readily available. However, the more documentation that in-house staff can update and compile, the less time the

commissioning provider will spend obtaining this information. Performance curves are generally available from the original installing contractor or the equipment manufacturer. Have the nameplate information, including the serial number and date of installation, available when contacting either of these parties. Appendix C contains a typical checklist of documentation required as part of retrocommissioning.

Perform appropriate preventive maintenance

Special care should be taken to make sure that all in-house staff or an outside maintenance service contractor completes scheduled preventive maintenance work before retrocommissioning begins. For example, if retrocommissioning occurs during the cooling season, the annual preventive maintenance tasks for the cooling plant and systems should be completed before commencing with the project. It is not cost-effective to hold up the retrocommissioning process because of dirty filters, loose belts, broken dampers, or loose electrical connections. The commissioning provider's time is better used helping the building staff find and solve operating, design, and installation problems rather than addressing equipment-care deficiencies.

Perform simple repairs and improvements as the project progresses

Depending on the skill level of the building staff, staff can perform a number of improvements and repairs as the project progresses. Completing simple repairs and adjustments discovered during the early part of the investigation phase increases the effectiveness of the diagnostic monitoring and testing. For example, there is no reason to wait to calibrate or relocate a sensor or fix a binding damper only to have the diagnostic and testing phase of the project indicate, once again, that this is a problem. Also, finding an effective solution to a problem is often accomplished through a series of "fixes" occurring over the course of the project. Often, correcting what appears to be a simple problem may allow the diagnostics testing to uncover a larger but subtle problem which can then be taken care of. These "simple fixes," no matter how minor they appear, should be logged on the Master List of deficiencies and potential improvements. (This list is discussed in more detail in Chapter 7, in the section entitled "Investigation Phase.")

Note that if energy and/or energy-related cost savings are retrocommissioning objectives, it may be important to ensure that energy and cost baselines are well established prior to performing any significant repairs or improvements.

Perform diagnostic monitoring and functional tests

It is often appropriate and cost-effective to have the most motivated and interested building staff assist with the short-term diagnostic monitoring, trend-logging, and functional testing that occurs during the investigation phase of the project. This helps reduce project costs and provides the building staff with a learning experience that they can reapply later. If building staff are trained to initiate trend logs using the building's EMCS, a commissioning provider can reduce time spent on the task and the owner will not need to hire a controls contractor to do the trending. Building staff may also assist with the installation and removal of portable data loggers used for short-term diagnostics and assist with carrying out functional test plans. This also reduces costs and gives the building staff exposure to different approaches to troubleshooting problems and investigating and verifying equipment performance.

Implement selected improvements and repairs

Depending on availability and expertise, O&M staff may be enlisted to implement the selected repairs and improvements. Using in-house staff to perform these tasks reduces costs. Hiring an outside contractor to implement major repairs and improvements may cause the payback to increase to the point where the project is no longer cost-effective. The success of this cost-reducing strategy hinges on in-house staff training, knowledge, and willingness to carry out the work. Existing workloads of O&M staff should be analyzed to determine how schedules and workloads will be shifted to accommodate any additional work. **O**

6 Roles and Responsibilities of Project Team Members

Retrocommissioning is a team effort. Depending on the project scope, however, the retrocommissioning team may simply consist of the commissioning provider and a designated member of the operating staff. If the project is fairly complex and the commissioning scope is broad and inclusive, the team could include all or a combination of the following:

- owner or owner's representative (project manager, facility manager, or property manager);
- commissioning provider;
- one or more building operators;
- test specialists;
- a design engineer;
- installing contractors, controls and maintenance service contractors, etc.;
- manufacturer's representative(s); and
- utility representative(s).

Budget considerations and the characteristics of the project may dictate the number of team members and their responsibilities. For cost-effectiveness the retrocommissioning team should be streamlined to fit the complexity of the project. Owners should consult with their commissioning provider about the makeup of the team. The commissioning provider can review the scope of work and advise the owner on how to consolidate roles and tasks to best meet the needs of the project. The roles and responsibilities of potential team members are discussed below, with emphasis placed on the roles of the owner, commissioning provider, and building operators.

For cost-effectiveness the retrocommissioning team should be streamlined to fit the complexity of the project. Owners should consult with their commissioning provider about the makeup of the team.

Building Owner or Owner's Representative

The most significant role of the building owner or owner's representative is to support the commissioning provider's efforts to accomplish the work. Other responsibilities may include

- determining the project's budget, schedule, and operating requirements;
- determining the objectives and focus of the project and communicating them to the team members;
- hiring the commissioning provider and other members of the project team;
- assigning appropriate in-house staff to the project;
- defining the building protocols (see the section entitled "Planning Phase" in Chapter 7);
- defining the lines of communication between the team members;
- working with the commissioning provider to determine the commissioning plan and how to best leverage existing resources to streamline the project and reduce costs;
- supporting the commissioning provider by facilitating communication between the commissioning provider and other project team members as needed;
- informing the building occupants of the intended retrocommissioning work as needed;
- requiring and reviewing progress reports and meeting notes; and
- attending training sessions and commissioning meetings when appropriate.

Commissioning Provider

The commissioning provider's tasks and responsibilities depend on the scope of the project, the budget, and the skill of the building O&M staff. The following three lists outline the commissioning provider's responsibilities for a typical retrocommissioning project and for a retrofit project and present additional, but less typical, responsibilities for consideration.

Typical retrocommissioning responsibilities

- Identify what documentation, drawings, data, and other information will be required.
- Develop a building-specific commissioning plan.

- Develop agendas and facilitate all commissioning meetings.
- Submit required progress reports and commissioning meeting notes to the project and facility manager according to the schedule.
- Perform a detailed on-site assessment of the present maintenance practices and operating strategies, noting all possible deficiencies and improvements.
- Understand the warranties and service contracts that are in place and how they can be leveraged on behalf of the project.
- Develop monitoring and testing plans.
- Perform short-term diagnostic monitoring, using EMCS trend-logging where appropriate.
- Develop, oversee, and document functional test procedures as needed.
- Develop Master Lists of deficiencies and improvements.
- Recommend system or energy-efficient capital improvements for further investigation.
- Prioritize the most cost-effective improvements for implementation for existing systems.
- Supervise the implementation of the selected improvements.
- Perform post-installation monitoring and testing activities as needed.
- Calculate the estimated energy savings based on the before-and-after short-term energy measurements.
- Submit a final report and all specified deliverables.

Typical retrofit project responsibilities

When the commissioning of new equipment is integrated with the commissioning of existing equipment, as in the case of an energy retrofit project, the commissioning provider's responsibilities may expand to include the following tasks related to commissioning the retrofit project:

- Develop commissioning specifications for the new equipment.
- Develop a commissioning plan specifically addressing the new equipment.
- Oversee the commissioning of the retrofit project, including the delivery of specified staff training and system documentation.
- Perform short-term diagnostic monitoring of existing systems and the new equipment to ensure that they are properly integrated.

- Develop and oversee prefunctional checklists and manual functional test procedures as needed on the new equipment.
- Develop separate Master Lists of deficiencies for the new equipment.
- Ensure that the identified deficiencies for the new equipment are resolved to the owner's satisfaction.

Additional responsibilities for consideration

A commissioning provider may be asked to fulfill some less typical responsibilities as part of commissioning an existing facility:

- Finalize an O&M plan for the facility, including guidelines for implementing a new preventive maintenance plan.
- Review the present service contracts and make recommendations for improvements.
- Develop complete written sets of sequences of operation for all equipment and systems.
- Develop an energy management plan including strategies for obtaining upper management buy-in.
- Develop a comprehensive training plan for O&M staff. This task may encompass developing recommendations for appropriate building staff to attend training in fundamental O&M concepts as well as more sophisticated methods for specific equipment and systems. The audience could include building operators, property managers, facility managers, and owners.
- Develop guidelines and recommendations for incorporating an energy accounting system into the energy management or facility management program.
- Develop, start up, and train staff to use the energy accounting system.
- If a new EMCS is being considered, develop a list of functional requirements and energy- efficient operating strategies to be included in the new system.
- Develop methods for the owner and building staff to continue to track the performance of the improvements.
- Develop a guideline for including commissioning and retrocommissioning as part of the organization-wide energy management plan.

Building Operators

Assigning building operators to assist with (or at least observe) as much of the retrocommissioning as possible improves their understanding of the equipment and control strategies. It also trains them to be able to retest or recommission systems periodically as part of their ongoing O&M program. The following list includes tasks that building operators are typically responsible for depending on their skill level:

- gathering and updating building documentation;
- providing detailed input into the initial assessment and investigation process;
- performing appropriate preventive maintenance and commissioning-generated checklist tasks prior to any diagnostic or functional testing;
- installing and removing short-term diagnostic monitoring equipment;
- gathering trending information from the EMCS as required;
- assisting with the performance of manual functional testing as needed; and
- attending project meetings and training as required.

Design Professionals

Depending on the age of the equipment and systems involved, and on whether a new installation is occurring during the retrocommissioning process, design professionals may or may not be involved in the project. Design professionals are rarely involved in a pure retrocommissioning process unless the commissioning provider needs additional expertise regarding design issues that are uncovered during the investigation process. In such cases, the design engineer (perhaps the engineer who designed the original installation) may be brought on the team as a consultant to help resolve the issues. When commissioning a new installation is part of the project, the designer responsible for the new equipment and system should be part of the commissioning effort.

Contractors and Manufacturer Representatives

Installing contractors, maintenance service contractors, controls contractors, and manufacturer representatives can be important contributors to the commissioning of existing equipment, especially when equipment is relatively new, still under warranty, or under contract for service by a manufacturer's representative or a particular service contractor. In some cases, one firm may have installed the system as a manufacturer's

representative and also hold the service contract for the system. This is often true for control systems and large plant equipment such as chillers and boilers.

If equipment is still under warranty or under a service contract, it is important that the responsible company or individual be brought on the team early in the process. Contractors or manufacturers are primarily responsible for performing the hands-on testing of the system that they have installed or serviced, especially if a warranty will be void if anyone else manipulates the equipment. They may also be responsible for correcting any deficiencies that are found during the retrocommissioning process. Compensation for these parties depends on the extent of the service contract or warranty coverage.

Some owners do not have full or even part-time building operators, or may have building operators with minimal skills or time. These owners often use service contracts to cover most of their HVAC, controls, and electrical systems. In such cases, the service contractor may take on retrocommissioning tasks that building operators would usually perform. The contractor may be requested to perform certain scheduled preventive maintenance tasks to coincide with the needs of the commissioning project, as well as assist in performing the hands-on testing, diagnostics, and adjusting and calibrating of equipment. Controls contractors may contribute by assisting with trend logs and EMCS programming tasks.

The controls contractor may be a key player on the commissioning team because he or she is often the most familiar with the building's control sequences and programming. The control technician's expertise can expedite the incorporation and testing of new or improved control strategies for the building. Although enlisting the time of a control technician may be expensive, limiting their assistance can reduce the overall cost-effectiveness of the project.

Testing Specialists

Depending on the needs of the project, testing specialists may need to join the retrocommissioning team. Special equipment such as variable-volume fume hoods may require special testing expertise. Although the commissioning provider typically writes the test procedures, the testing may be carried out by others who are experts in their field. Testing, adjusting, and balancing (TAB) professionals may be asked to verify water or air flows using special equipment if the retrocommissioning identifies possible air or water balance problems. While some commissioning providers are also test engineers and are fully tooled to perform almost any type of test required, this is not usually the case. Most commissioning providers are skilled at performing fundamental HVAC functional tests and calibration exercises, but rely on other professionals or test experts for more complicated testing. Appendix D contains a typical list of commissioning tools.

Utility or Government Representative

The role of utility or state and local government representatives in the project is generally limited to assisting with specific items that the customer needs in a timely manner. This assistance might include loaning equipment and providing billing data, technical expertise, or funding. If utility or government representatives are providing funding or a service as part of the project, they may want to be involved in meetings or receive periodic progress reports. **O**