Building Commissioning: The Path to Nirvana or the Woods of Ichabod Crane?

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Two years ago, in a national effort focused on reliability and persistence of savings, leaders in commercial energy conservation and related building industries charted a course to champion building performance excellence. Once a year they continue to share ideas, implement new practices and document measurement for building commissioning (Cx), operation and maintenance. These representatives of more than twenty trades and professions are growing in number, and are committed to achieving the most energy efficient buildings possible.

The authors relate technical results of these parties' efforts, lay out obstacles that remain in the path leading toward excellence in building performance, and describe innovative methods currently in use to overcome them. They present creative solutions under way in the U.S. and Canada that are integrating the complex issues surrounding consistent delivery of Cx services such as standards and guidelines and indoor air quality issues.

This paper will provide an authenticated map and some important tools for utilities and a host of other interest groups to chart their course toward long-term savings.

Introduction

Imagine yourself, like Ichabod Crane, racing terrified through a forest in the dark of night. The difference is, you are working overtime, racing to meet a completion deadline in a forest of still-bare wires reaching out to grab you, and open ducts waiting to suck you in. Too many change orders have mangled the once-straightforward design. A stranger hovers eerily outside the double-glazed window, "Stop!" He calls out, then confides quietly, "I can show you some practical steps that will make this building safe, energy-efficient, and easy to maintain." A third character hastens out from behind an uninsulated wall, obviously the building owner. "Hey, wait a minute! I thought that's what I was already getting."

Behind every building owner's concept lies the assumption that a fully functional, reliable, safe, energy efficient and comfortable building will be delivered for the money. This owner pays professionals to design, build and operate a commercial building. Generally, s/he believes that the discrete tasks of these professionals are integrated, from design concept through occupancy, with checks and balances that ensure all systems functioning at their highest capability *and* energy efficiency. They are not.

To close this gap, a nucleus of concerned energy specialists gathered in 1992[1] to discuss ways for utilities to protect their demand side management (DSM) investments. The resulting annual National Conference on Building Commissioning (NCBC) has met twice subsequently. Its purpose is to provide a forum for utilities, Cx practitioners, researchers, and building industry professionals to share applications and information leading to delivery of safe, healthy, energy efficient, productive commercial building space for human occupancy. Participation now includes representatives of over twenty professions (primarily in the categories of design professionals, utilities, building owners, educators, equipment providers) interacting to support the Cx process.

Each of these professions brings a different perspective to the definition, scope and objectives of Cx. On one hand, utilities design Cx programs to sustain energy savings, provide a customer service and meet resource acquisition goals. On the other side of the meter, building owners want complete systems that work; developers want building systems that are available to purchase and quick to install; architects and engineers want energy systems to integrate seamlessly with building use and aesthetics; facility managers want uncomplicated operation and maintenance requirements.

The barriers faced by utility and customer-related participants, solutions they have developed, and the measured costs and benefits of delivery as reported at NCBC will be summarized. The paper is intended to provide a broad look at how Cx is addressed in the current market by a spectrum of professionals involved.

What Is Cx?

A comprehensive, if idealistic, definition of building Cx was established at the first NCBC:

> *Commissioning is a systematic process of assuring by verification and documentation, from the design phase to a minimum of one year after construction, that all building facility systems peform interactively in accordance with the design documentation and intent, and in accordance with the owner's operational needs, including preparation of operation personnel.*

Everyone *really* wants accessible, good quality, inexpensive, energy-efficient equipment that is designed as part of the whole building vision, maintenance free, with a long operating life at minimal cost to operate. Building owners generally believe that is what they're getting. But because Cx—as a partner in every phase of design and construction, including the process of training O&M staff and providing manuals-is rarely accomplished, poor building performance often results. Still, ensuring performance by Cx is far from common practice.

The definition offered above is comprehensive. Conference results indicate that three Cx perspectives actually reflect the market:

- Utility perspective, concerned with performance of funded energy efficiency measures
- Government, institutional and private building owners' energy efficiency perspective, driven by conservation performance objectives or mandates
- Government, institutional and private building owners' whole-building perspective, driven by concern for building productivity (hence, profitability), indoor air/environmental quality, and health/safety liability.

All three perspectives are supported by design, construction, testing and verification contracts in the building and retrofit processes.

Who Are the Players?

Commissioning a commercial building can include some or all of the items in Table 1.

Table 1. Tracks for Cx Information and Execution

Programs, Incentives & Regulatory Push	Applications, Technologies & Market Pull
Utility companies	Appraisers
Regulatory agencies	Architects
	Building owners
	Commissioning Agents
	Contractors
	Controls installers & trainers
	Designers
	Developers
	Energy mgmt consultants
	Engineers
	Facility managers
	Installers
	Insurers
	Lenders
	O&M personnel
	Researchers
	Building occupants
	Test & balance professionals

Drivers: Why Commission?

Benefits of Cx

Cx assists in the communications path of a project, from concept to occupancy. The benefits listed in Table 2 are perceived by both providers and recipients of Cx services[2].

Indoor Air Quality, Liability and Insurance

Negative drivers may be more powerful than the benefits of commissioning. According to recent studies in Canada and the U.S., inadequate ventilation (caused by design and operation of HVAC systems and exacerbated by the presence of contaminants) is the main cause of indoor air quality problems (Sterling 1994).

While mechanical systems are the concern of Cx for energy efficiency, indoor environmental issues are not limited to HVAC. Construction materials and furnishings containing pollutants; drinking water systems; mold,

Table 2. Benefits of Cx

Benefits to Owner	The owner takes delivery of a high quality system that works as designed
	The owner receives far more in terms of benefit/cost ratios than what was paid for; he or she gets a good, clean, healthy working environment
	The hand-over process is smooth
	Satisfied tenants
	Documentation provides a reference for future renovation
Benefits to Facility Managers & Occupants	Training of building staff; operators know what to use, and what not to do
	Documentation is in place (and in *one* place for future reference when changing operators)
	Continuous learning
	Fewer complaints
	Energy conservation
	The building is easier for operators to maintain, leading to persistence of savings
Benefits to Contractor	No (or fewer) call-backs
	Training of owner's own staff
	Cx compels the customer to pay the bill
	There is a definite stopping point for the contract period and start for the warranty period, which is good for everyone (timely and more formalized closeout)
Building Design Team	The designer gets the design demonstrated
	There is a foundation to measure performance against
	The project is likely to be completed on time
	Equipment reliability
	Identifying and quantifying opportunities for improvement

mildew and structural damage caused by moisture are environmental problems that should be addressed in the whole-building Cx process.

Indoor environmental problems are primary drivers for Cx. As the body of litigation grows against target defendants (building owners, managers, developers, architects, engineers, contractors, consultants and manufacturers), theories of liability are being tested. Not only are individuals suing for personal injury damages, but also corporate tenants sue for "claims of business interruption, lost profits and lost future value . . . cases based upon the following causes of action have been successful in most states (Silberfeld 1994):

- Contract/breach of lease
- Professional malpractice/negligence
- Strict ability
- Fraud/misrepresentation
- Punitive damages"

Because of an apparent tendency of individual and corporate plaintiffs to claim damages against all parties involved in design, construction, installation and manufacture, offensive Cx (a bidder's proposal to include Cx) can be used to deflect or diffuse litigation. "The owner's refusal to pay for the commissioning services that encompass the duties the owner later feels *should* have been performed is a pretty good defense..." (Hornreich 1994).

A national professional liability insurer reviewed its records from January 1991 through December 1993, and reported (based on records in its division covering architects and engineers) that mechanical/HVAC systems and components are the "#1 contributor to our losses during those three years with losses totaling over $19,000,000. Further, mechanical/HVAC claims are the #1 claim type, in terms of frequency, with over 500 closed claim files" (Brady 1994). While this should be a wake-up call for design professionals, it may not provide sufficient incentive to modify their design criteria. In fact, a comprehensive 1989 study of California architects ranked the individual criticality and frequency of aspects of their practice. The study, used to develop a new licensing exam, resulted in architects responding with the following ratings of *importance* for the 44 listed aspects of Life Safety/Mechanical, Plumbing, and Electrical systems (Brady 1994):

- Extremely important: None
- Very important: 5 (mostly related to fire systems)
- Somewhat important: 15
- Slightly important: 24 (primarily lighting design)

Although the liability and insurance issues may motivate Cx among owners and design professionals who are aware of them, certain barriers have prevented Cx from becoming common practice.

Barriers and Solutions in the Path of Excellence

Prior to each conference, speakers and utility program managers were asked to respond to polls that collected opinions about the state of the Cx market. The results are shown below.

1993 Confidential Speaker Poll

"Describe the barriers to making Cx business as usual"

Twenty-two authors responded by describing their own experience and perspectives in the Cx field. The number of opinions totaled eighty-four, for an average of four opinions per person. While these do not represent a statistically valid sample of the range of professionals involved in Cx, this sample does confirm market indications. Almost all respondents identified a complex set of problems rather than one primary barrier.

The most frequently listed barrier to implementation of Cx as common practice was, of course, cost. Whether Cx is perceived as additional first cost, an easy cost to cut from an overburdened construction budget, or an unrewarding task for professionals who build Cx into their design, cost is the prevailing issue. Nearly 70% of those surveyed said the perception exists that Cx is too expensive, although they asserted that they disagree with this belief.

The *perception* of higher cost is no surprise. Building systems' performance problems are most often blamed on small budgets. However, additional attitudes and behaviors underlie the lack of support and funding for Cx. The diversity of responses suggests that removal of barriers *other* than cost will ultimately help to drive the market.

Four categories of barriers were identified that impede Cx as commonly accepted practice: organizational infrastructure, financial, perceptual/attitudinal, and legal/regulatory. Specific barriers named by respondents are listed in Table 3.

1994 Confidential Polls

Speakers: "Describe the solutions to making Cx business as usual"
Utilities: "Describe the hot issues affecting delivery of Cx services"

Two polls were conducted in 1994:

- A poll of conference speakers asked for market solutions under consideration or being implemented. The poll requested each speaker to list three primary solutions to making Cx common practice.

- A poll of 52 utilities asked DSM managers to describe the most salient ("hottest") issues that are likely to affect utility involvement in delivery of Cx services, either as a component of programs targeted to energy efficiency measures or as a stand-alone DSM program measure.

Responses from 34 utilities were collected and compared. Of more than 100 opinions offered, 36% related to quantifying the value of commissioning in terms of its costs, savings and benefits. Second, education and communication are required to get buy-in from staff and customers alike. Third, utilities are struggling with their approach—what is the place of Cx in the present utility market environment, and what modifications in utility operations may be necessary to implement Cx cost-effectively? While the process of designing a utility program for commissioning, and the availability of commissioning expertise, were listed as issues, utility program concerns centered around acceptance by management and customers, and verification of value. These utilities consider commissioning an important element in future business plans as:

- a customer service

- an evaluation tool that can demonstrate kW savings as part of the net effect on revenues

- a means of satisfying regulators

- insurance to protect their DSM investments.

Figure 1 demonstrates the distribution of important commissioning issues under consideration by 34 utilities across the United States and Canada as of April, 1994.

To summarize the relationship between the three polls and their relevance to implementation, Table 4 lists the barriers, solutions and hot issues described by respondents.

Table 3. Barriers to Cx as Common Practice

Financial: *budgets, costs and rewards*	
	Perception that Cx is too expensive
	Cx is perceived as an additional project cost
	Owner/architect cut Cx from short project budget
	Not enough rewards for design community
Organizational Infrastructure: *process, standardization, qualifications*	
	No consensus or clarity on the definition of Cx
	No single party in the design & build process responsible for Cx
	Lack of defined qualifications for Cx agents
	Lack of qualified, experienced Cx personnel
	Lack of standard equipment, test instructions, procedures, reporting
	Lack of formalized educational resources
	Extra time and paperwork involved in construction process for Cx
	Highly competitive and fragmented design/build market
	Not enough vested interest from utilities
	Introduction of yet another "inspector" (i.e., Cx agent) to satisfy at job site
	Not enough research taking place
Perceptual/Attitudinal: *understanding, level of interest, and benefits*	
	Lack of understanding of the benefits of Cx
	No consensus on measurable benefits
	Developers and owners already think they are getting Cx
	Developers, owners, lenders, investors don't understand Cx as the link between design and implementation
	Failure to understand difference between building and measure Cx
	Owners do not demand integrated systems from design team
	Need for Cx not acknowledged early in design/build process
	To cover owner or builder, workmanship or installation problems are passed on to operation and maintenance staff
	Why should system be commissioned if work is done right first?
	Responsibility by all professionals to make their best efforts
Legal/Regulatory: *code, legal consequences, and regulatory support*	
	Not enough fear of consequences, such as indoor air quality lawsuits
	Public service commissions/public utility commissions do not fully support Cx effort
	Codes not stringent enough
	Codes not enforced

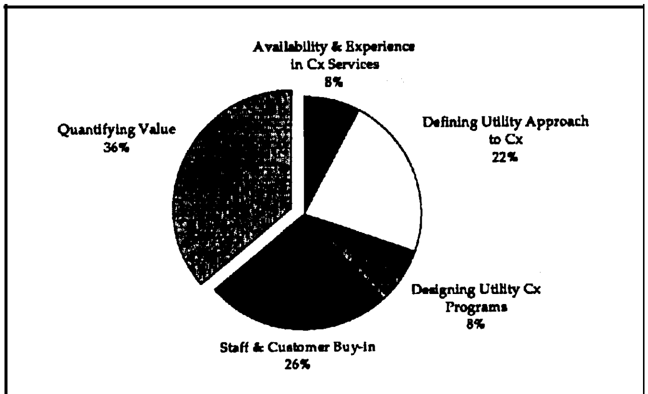

Figure 1. Distribution of "Hot" Cx Issues (34 utilities)

Results of Commissioning: Quantifying Costs, Benefits and Savings

Reporting Methods

Among those attempting to quantify the costs of Cx, results are expressed in a variety of ways within each industry (see Table 5).

To provide a common basis for quantification, results presented at NCBC were calculated in dollars per square foot. This reporting method, however, can be misleading and does not necessarily reflect the most important variables encountered in building Cx: number of measures

Table 4. Summary of Barriers, Solutions and Utility Delivery Issues

Speakers 1993 Barriers	Speakers 1994 Solutions	Utilities' 1994 Delivery "Hot" Issues
Financial (Perception of high cost, extra project cost, and insufficient rewards)	*Research, Demonstration, Promotion* • Document results and translate into understandable benefits • Support broad-based efforts to support Cx • Publish more about savings and benefits from commissioned projects • Develop new ways to present quantified benefits • Pilot and demonstration projects to showcase cost-effectiveness and systems performance	• Quantifying costs, savings and benefits • Measuring the reliability and persistence of energy savings • Guarantee of savings • High cost of this added service • Economical program approaches • Risk of initiating new programs at this time • Impact of lost revenues on rates • Getting utilities out of the Cx business
Lack of organizational infrastructure	*Support and Documentation* • Tighten specifications to include Cx • Develop user-friendly procedures • Develop guidelines specific to each building sector • Get endorsement by building sector associations • Provide incentives from utilities and governmental agencies upon proof of performance • Lower premiums from professional liability insurers on Cx'd bldgs • Support development of Cx specifications • Encourage and enhance interdisciplinary partnership/performance	• Developing and applying standardized practices • Documentation for O&M • Documentation for planners and regulators • Developing criteria for approach • Timing of Cx in the life of a project
Perceptual/Attitudinal (Lack of understanding of process, scope, benefits and interdisciplinary relationships)	*Education* • Education of all vested parties about savings, costs, reliability, persistence, specifications and difference from current practice	• Getting buy-in from utility management, staff and regulators • Selling Cx to customers • Getting stakeholders to value Cx
Legal/Regulatory	• Lobby for legislation • Require Cx to get building permits • Incorporate Cx into codes • Make building construction team liable for negligence	• Utility design liability

being commissioned, measure costs, savings and Cx rigor. Cost is not necessarily a function of building area. Unless benefits and savings are reported along with costs, the value of Cx and savings achieved are lost except as a line item in the construction process. It will be difficult to establish a baseline until common methods for quantifying costs and savings can be agreed upon and tested.

Because of the irregularity of actual reporting methods, it is difficult to analyze costs across the range of professions, procedures and mechanisms involved. Another problem that affects acquisition of accurate cost data is the disaggregation of Cx costs, particularly if Cx is covered in the pricing of equipment installation.

Costs and Savings Attributed to Cx

An overview of requirements for Cx HVAC and refrigeration equipment, provided by a U.S. university with an established energy management program, included documentation of U.S. and Canadian costs. By "general consensus of several experts" the economic assessment of

Table 5. Methods Used to Estimate Costs of Cx

Estimation Method	Estimated Cost Range
Percent of construction cost	1% to 2%
Percent of design fee	10% to 15%
Percent of ECM installation charge	8%
Professional testing fee	15% to 30% of automation system design
Percent of mechanical contract	1% to 4%
"Sanity check" built into contract	5%

Cx, design and construction costs, and the resulting reduction-in operating costs, was reported (Dorgan 1994) as illustrated in Table 6.

Outside the U. S., "Canadian and British data suggest that commissioning adds only ~1-4% to the HVAC contract cost, i.e., . . . ~0.09-0.35% of project cost or ~8-30 cents/ft^2. Yet not making this tiny marginal investment can sacrifice enormously larger benefits in worker productivity, tenant satisfaction, and leasing income" (E Source 1992).

Utility Data. The most comprehensive information available to date comes from utility databases and utility/research collaboration. For example, a Pacific northwest utility's new construction Cx program, in progress since May 1991, has carefully tracked costs of 50 completed commercial projects on a per-building as well as a program-wide basis. The *per-building* average Cx cost for all buildings is \$0.237/ft^2, and \$0.21/ft^2 for buildings larger than 12,000 ft only. The *program-wide* Cx cost for all buildings is \$0.146/ft2 and \$0.140/ft2 for buildings larger than 12,000 ft^2 (Yoder 1994). Ongoing research based on this program has resulted in the following recommendations for documenting Cx, for performance improvement and cost data acquisition, thus far (Piette 1994):

- Catalog Cx and O&M issues (description of problems and systems affected, severity, detection methods, actions taken, results, likelihood of detection and life of correction)
- Couple Cx and evaluation of benefits with evaluation of energy efficiency measures and monitoring
- Document building conditions to help quantify non-energy benefits
- Encourage better design intent documentation
- Provide feedback on performance problems
- Standardize diagnostic tests and performance documentation

An east coast utility's Cx program has expanded from thermal storage in 1991 to multiple measure and comprehensive Cx in 1994. The utility, with 4,225 MW in peak demand and 21 billion kWh in annual sales, serves 1.2 million customers in three states. Sixty percent of the service territory is commercial or industrial. The Cx cost per project of this utility's 32 completed projects averaged 3.5% of the funded incentive amount, including a

Table 6. Economics of the Commissioning Process

Building Description	Cx Cost	Design Cost	Construction Cost	Operation Cost
Small Building	+3%	+5%	No Change	-8%
Large Building	+2%	+3%	-6%	-10%
Innovative System (i.e., thermal storage				
Total commissioning	+3%	+6%	No Change	-15%
Utility incentive verification	+4%	+1%	+2%	-7%
Industrial System	+1.5%	+1%	+2%	-12%

post-installation site visit featuring up to 11 tasks (Della Barba 1994). In one case, the funded incentive for a single customer reached over $1 million.

Two DSM programs offered by another northeast utility include Cx as a funded component. While actual measured savings figures have not been calculated, the utility has found it economical to estimate its Cx costs (financial incentives) at $0. 35-$0.70/ft^2. The utility is "off-setting the cost of Cx on the implementation side of Conservation and Load Management, by investing M&E [monitoring and evaluation] dollars in specific measures, systems, and variables that have the greatest uncertainty and post the best opportunity to calibrate our savings models" (Balinskas 1994).

Savings due to Cx are more difficult to quantify than costs. A study of seven new buildings commissioned with a similar level of rigor indicates that, from the utility point of view, some measures are more cost-effective to Cx than others. Engineering calculations were used to estimate savings for each measure, and EEMs were prioritized as follows:

- Large savings potential (not necessarily large buildings)
- Complexity (interactive with other systems or relying on controls)
- Probability of poor performance without verification (based on experience)

Only those measures with predicted savings were fixed. The savings from identified problems "ranged from 8%-31% of the original ECM savings" (Stum 1994).

While cost consciousness is not new, utilities are increasingly mindful of *economical* Cx as a valuable customer service. Recommendations for cost-effective delivery presented by the technical coordinator of a utility Cx program (Kaplan 1994) are based on experience with three categories of measures:

- ECMs that fail without Cx, but are not cost-effective with Cx
- ECMs and systems that fail without Cx, and whose savings justify the cost of Cx
- ECMs and systems that generally work properly without Cx

Institutional and Private Industry Data. A survey of architects, engineers, developers and building owners was conducted in March 1994 by an R&D branch of the Canadian government. Twenty-six questions structured to address Cx background, knowledge and experience were sent to 240 members of the building sector. While cost data were of secondary importance to this instrument, many respondents offered costs in the forms of $/ft^2, or percent of construction, system, or unit (Larsson 1994).

Data presented from other Cx projects in Canada (Heimer 1993), described as "typical" are based on involvement from the design phase and completion after construction and operations staff training. The per-system Cx costs are reported in Table 7.

Table 7. Per System Commissioning Costs

System Type	System First Cost (ft^2)	Cx First Cost (ft^2) Complexity Low	Medium	High
HVAC	$10	$0.20	$0.20	$0.50
HVAC Controls	$1.50	$0.10	$0.15	$0.20
Lighting	$4	$0.05	$0.075	$0.10

One government agency reports results from Cx twelve new and major renovation sites with a combined construction value of $27 million. The cost of Cx ranged from 1.2% to 2.8% of construction, or $2.85/ft^2 to $5.00/ft2, depending on system complexity. Savings attributed to correction of deficient systems alone "have shown to average $1.95/ft2° (Tseng 1994).

Case studies presented by a U.S. Cx firm include school and hospital facilities. The Cx calculations listed in Table 8 result from four projects (Zachwieja 1994).

Table 8. Commissioning Costs and Paybacks: Four Case Studies

Facility	Cost/ft^2	Utility Savings/ft^2	Payback
High School	$0.46	$0.25	1.8 years
Hospital Facility #1	$2.22	$0.74	3.0 years
Hospital Facility #2	$6.00	$3.20	1.9 years
Hospital Facility #3	$3.00	$1.02	2.9 years

An architect who reported on his state's efforts to move the market toward design and performance excellence demonstrated how costly *not commissioning can* be: a study of his state's capitol building showed energy consumption of $2 million per year in electricity costs, or 1.5 times the cost of construction over a period of 30 years. For an additional design fee investment of -$200,000, only 0.05% of the construction cost, a 50% reduction (annual savings of $1 million) could have been achieved. "The state agencies must be willing to invest in these quality design services because they will yield a return on their investment in reduced life-cycle energy expenses, operating and maintenance costs. These design services are a 'value-added' investment, not an increased expense" (Peterson 1994).

Methods and Tools for Delivery of Commissioning Services

The barriers and issues identified by building professionals and utilities are slowly being addressed by technologies and services. As the need for standardization and cost-effectiveness of the Cx process becomes more critical, the industries concerned with good building performance are at least examining the available information. In some cases, streamlined approaches are evolving.

Barrier: Organizational Infrastructure

Standardized Approach to Cx. A basic outline of the eight-step approach to commissioning any commercial or industrial building is:

1. Write a Cx plan at the predesign phase
2. Include a Cx agent in the scoping meeting with design professionals
3. Gather design documents
4. Write a functional test plan
5. Oversee functional testing
6. Develop or review operation and maintenance manuals and plans
7. Develop training plans, review/recommend training plans, or deliver training
8. Write a final Cx report for the building owner

Using Results of Measure Risk Analysis. Although the best of worlds would include Cx of all building systems including shell measures, cost-benefit analysis may determine the extent to which an owner can afford to commission. A measure risk analysis study for a midwest utility[3] confirms what common sense tells us - that many factors can contribute to loss of anticipated savings due to measure performance. This study began by listing all the lighting and HVAC measures that the utility expects to offer within a designated horizon in the commercial sector. After combining the measures into groups appropriate to the study, the measures were analyzed and the reliability and persistence risks associated with each measure group were identified and categorized. Those measures that have a low probability of risk, and particularly those with high gross energy savings, are prioritized for the utility's DSM programs. The information acquired as a result of measure risk analysis can help minimize Cx costs, and can be extremely useful in determining how building owners and utilities can receive the best value for their investments.

Standards and Guidelines. Cx guidelines have been written for specific technologies, such as ASHRAE's guidelines for HVAC and smoke detection systems or guidelines for thermal energy storage. Procedural Cx guidelines have been written for utilities[4] and service providers. Consulting firms can customize existing guidelines for their clients. Documentation for operations personnel, however, where the persistence of savings is achieved after Cx, is often limited to manufacturers' specifications. This is an area that should be examined further to 1) establish guidelines that approach the Cx process and program elements from the utility perspective, and 2) provide guidance on cost-effective measure Cx and streamlined steps to maximize energy savings.

Specifications. "An early step for any organization with a standard spec-book should be to review it in detail to ensure that it requires the right equipment and eliminates loopholes. The phrase 'or equal' needs special scrutiny . . . 'Equal' is also often assumed by constructors to mean 'of equal *or larger* size or capacity'. That way lies serious waste of capital and energy" (E Source 1992).

Because of increasing litigation, the importance of complete specifications from a liability standpoint cannot be overemphasized. The owner should be directly involved in producing the specifications by answering these questions (Hornreich 1994):

- What is the desired end product?
- How will the work be inspected during installation?

- How will the performance be evaluated?
- What are the warranty obligations?
- How will the system be maintained?
- When will the owner's maintenance obligations commence?

The components of Cx specifications should include data related to the physical characteristics of a building; roles; scope for executing and documenting verification forms; the intended operation and building management plans; standards that must be met for testing criteria, components, systems and integrated systems; applicable (and precluded) codes; and procedures necessary to complete the process. It is important that "the specification notes shall provide clear delineation between the contractor's normal responsibilities in the construction process and services that relate to commissioning" (Dunn 1994).

Training. A full curriculum of targeted on-site training has been developed that closes the loop in delivering reliability and persistence of energy (as well as other resource) savings (Clumpner 1994). Program highlights include HVAC&R services and troubleshooting, cooling tower fundamentals, energy/water accounting and tracking, and integrated systems.

Video-based training tools are being used in some environments to bring O&M staff into the Cx process and to train new personnel, reducing the barriers created by personnel turnover. "Based on studies . . . the commissioning process can produce an operating savings of 15-30% per year over the life of a building" (Lewis 1994). Estimated savings of $1.50 to $3.00/ft2 on a 100,000ft^2 building could result in a value of $30,000 to $60,000 each year, a substantial amount of which can be attributed to well-trained operation and maintenance staff.

Barrier: Legal/Regulatory

Codes. Although pre-conference polls established that weak or unenforced building codes are a barrier to Cx as common practice, the reverse - enforcement of codes that require high-performance, energy efficient building systems and components - can help to bring about a market change. The fact is that building inspectors are not necessarily trained in the principles of Cx. At best, they will enforce existing codes stringently, and can provide useful field information about practices that can be improved.

Low bid requirements are inherent in most bidding processes, particularly for construction of government and institutional buildings, and are strongly affected by code requirements. "If the building owner will only put in the cheapest equipment code will allow, then the battle cannot be fought over quality. When code minimum becomes performance maximum, no one can win."[5]

Why Are Utilities Involved?

Utilities are in a unique position to move the market toward national and local energy conservation goals. At the same time, they can encourage customers to achieve and maintain their systems excellence and skilled operator's proficiency and will ensure that conservation goals are met over time. In the short term, utilities can provide guidance, financial incentives and other mechanisms to push the market toward acceptance. The long-term objective is to make utility involvement in Cx less necessary, but utilities may be the only entities with enough "power" to push the market toward widespread implementation of energy-efficient measures that deliver long life and quality performance.

The basis for utility competition is changing from a territorial relationship to one of reliability, service, quality, and price. This portrait of the utility industry includes customers who can defect from one utility to another based on their perception of the total value provided. As environmental issues finally move out of the realm of "moral obligation" and into the realm of competitive strategy for economic reasons, one of the strongest values a utility can offer is assurance, through commissioning, that building systems that use energy will work reliably and will provide sustained efficiency over time.

In addition to having the ability and authority to stimulate Cx activity, utilities are perhaps the only entity that can vitalize energy-saving activities on a broad and regular basis, and prove their value in investment terms. They are in a position to quantify demand-side change as the results become available, and to insist upon results. The acceptance of Cx as fundamental to reliable, long-term energy- and cost-savings is being triggered by programs implemented by utilities.

The challenge in defining Cx for use by regulators, utility program designers and building professionals is the scarcity of supporting data to pin down its value to the utility in terms of resource acquisition, savings persistence, and avoided cost in real dollars, and sufficient value to the customer to assure a market shift.

Summary

Results of the National Conference on Building Commissioning indicate that three Cx perspectives actually reflect the market: utilities concerned with performance of funded energy efficiency measures; building owners' energy efficiency perspective; and building owners' whole-building perspective.

Two information tracks exist: 1) information feeding into and resulting from utilities and regulators regarding programs, incentives and regulatory push, and 2) information feeding into and resulting from the demand side in terms of applications, technologies and market pull.

The positive drivers of Cx are benefits to consumers (owners, tenants, facility managers) and building professionals (contractors and design team). The negative drivers may be more powerful, and include insurance and litigation issues, usually stemming from poor indoor environmental quality that can be traced back to ventilation.

Four categories of barriers have been identified that impede Cx as commonly accepted practice: organizational infrastructure, financial, perceptual/attitudinal, and legal/regulatory. These barriers are being addressed by both utilities and the building sector. While viable solutions are suggested, the barriers are not easy to remove for delivery of quality services.

While Cx costs and savings are difficult to quantify, important steps have been taken by utilities and the building industry to define the scope of information required, gather sample data and provide results. Most results are preliminary at this time, but the efforts of the past year have provided a significant foundation in methods.

Some tools and methods to address the barriers to Cx, are in stages of development, such as standardizing the basic approach to Cx, using results of measure risk analysis, developing both comprehensive and streamlined standards and guidelines, writing meaningful Cx specifications, developing training programs for persistence of savings, examination and revision of codes.

In spite of the inherent complexities of carrying out the Cx process, if everyone involved in constructing or retrofitting a commercial building can find the *path* to excellent building performance, we are on the way. If everyone insists on following the same path toward excellence, we are closer. However, although we may be on the path, we are not yet out of the woods.

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Endnotes

1. January 1992 Commissioning Roundtable for California and Pacific Northwest utilities, organized by PECI and sponsored by Bonneville Power Administration

2. Source: review of papers submitted to NCBC, 1993 and 1994

3. Study conducted by PECI for Wisconsin Power & Light

4. Notably, Bonneville Power Administration, Los Angeles Department of Water and Power, and Pacific Power/Utah Power

5. Price, Lawrence T., Florida Energy Office, telephone communication resulting from conversation at NCBC, 1994.

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