White Paper:

RETROSPECTIVE COMMISSIONING

– THE FIRST STEP IN CONVERTING YOUR BUILDING FROM AN ENERGY PIG TO AN ENERGY PRODUCER

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ABSTRACT

Against the backdrop of increasing pressure to divest ourselves from foreign oil, rising energy costs, discussion of carbon caps & building labeling, and increasing operating expenses; now is the time to take a comprehensive look at your facility operations. Consider the following:

- "….. In the area of Energy Efficiency in Existing Buildings, there is a lot of low hanging fruit. I'm fond of saying there is a lot of fruit on the ground ….." - US Secretary of Energy
- "30% of energy use in buildings is used inefficiently." - US EPA
- In the U.S. alone, the "low hanging fruit" in building efficiency could save the economy more than $160 billion by 2030 - McKinsey & Co.
- "Of all the core categories of energy consumption in the United States, the built sector is the Least efficient and has the largest potential for cost-effective improvement." -CoStar Group

The process of designing and constructing buildings has involved a variety of stakeholders including, owners and operators, design and engineering firms, customers and end-users, constructors, suppliers and fabricators, and technology vendors. While each add value, today's existing building stock was designed and constructed by this fragmented cadre of interests and capabilities that were assembled to deliver a product that is unique. Each existing building is the result of its unique location, size, use, and project design/construction stakeholders.

The majority of existing buildings have not undergone any type of commissioning or quality assurance process. Additionally, over time the facility requirements change and the operational efficiencies of buildings tend to degrade. Because of these factors many buildings are performing well below their potential, use more energy than necessary and cost more to operate than they should[1]. Existing Building Commissioning (EBC*x*) is the Quality Assurance process designed to establish building performance. EBC*x* takes the form of either Re-Commissioning (Re-C*x*), Retrospective Commissioning (Retro-C*x*), or Ongoing Commissioning (see definitions side bar). Although many are aware that existing buildings can be commissioned, the process is not well understood and there is no standard scope of services.

Commissioning - Building commissioning provides documented confirmation that building systems function according to criteria set forth in the project documents to satisfy the owner's operational needs. Commissioning provides a quality control check, from project inception through the installation and operation of energy-efficient equipment. Commissioning existing systems may require developing new functional criteria to address the owner's current requirements for system performance.

Re-Commissioning - Re-commissioning involves applying the commissioning process to a building that has been previously commissioned (during new construction) or retro-commissioned. It is normally done every three to five years, or whenever the building experiences a change in use.

Retro-Commissioning - Retro-commissioning is a collaborative process that looks at how and why a building's systems are operated and maintained as they are, and then employs a systematic process for investigating, analyzing, and optimizing the performance of building systems. As a process, rather than a set of prescriptive measures, retro-commissioning adapts to meet the specific needs of each owner.

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

Interestingly, most existing building owners and operators consistently strive to achieve many, if not all, of the benefits achieved by the EBC*x* process. Without a Quality Assurance process, some succeed and many fall short. An independent commissioning agent helps to assure success by utilizing a methodical, proven quality assurance method. As with new building commissioning, elements of existing building commissioning have been practiced for as long as buildings have existed. Only in the past two decades have strides been made to identify the Existing Building Commissioning process and studies implemented to confirm its value.

Recognizing the need for existing building performance enhancements, this paper will focus on Retrospective Commissioning (Retro-C*x*). It will give an overview of the Benefits, Process, and Costs of Retro-C*x*..

RETROSPECTIVE COMMISSIONING BENEFITS

Unlike energy audits, which focus on energy savings, Retrospective Commissioning encompasses a holistic approach to the performance of the building. Generally energy savings in the range of 5% to 15% result from the Retro-C*x* process, but they need not be the sole, or primary driver of a Retro-C*x* initiative. Owners can benefit from implementing a Retro-C*x* project prior to entering into an energy services agreement to assure that those energy savings associated with improperly operated equipment are credited one hundred percent to the owner.

Retro-C*x* is considered successful when a building operates as efficiently as possible, meets the owner's operating requirements, and includes strategies to ensure benefits last over time. Because there are no industry standards for Retro-C*x* work scope, building owners and managers engage the process for a variety of reasons.

Building Performance Improvements can reduce the costs of employee absenteeism and other productivity losses related to worker discomfort and complaints. Numerous studies demonstrate that these costs are not trivial. According to the Buildings Owners and Managers Association (BOMA), payroll costs account for 92% of the cost of building ownership. The U.S. Environmental Protection Agency (EPA) estimates that increased productivity can result in revenues ten times higher than the energy cost savings[2].

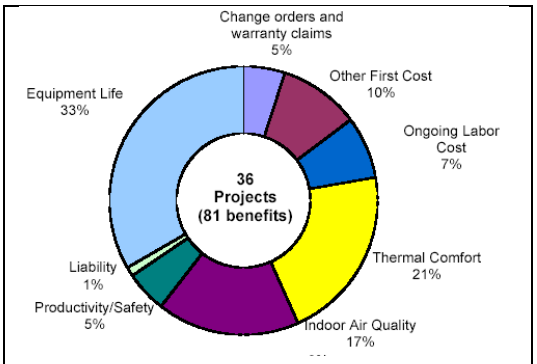
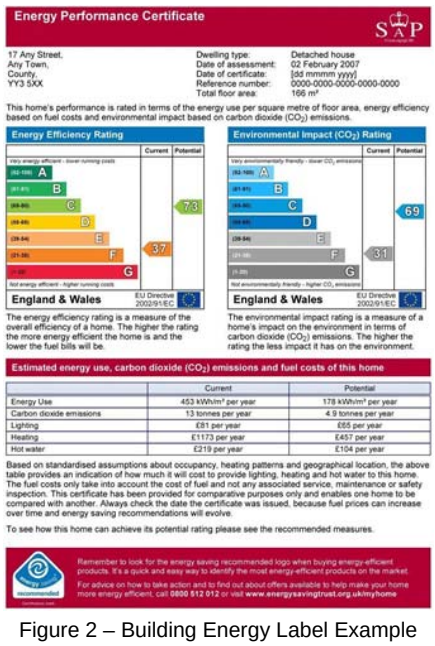


Figure 1 – Existing Building Non-Energy Impacts[3]

Improvements in System Operation and Performance result from the functional testing tasks of the Retro-C*x* process. Systems in modern buildings are controlled by computerized integrated control systems. It is extremely rare that building operators posses the skills to manipulate these systems for optimal performance. In fact, among the highest reoccurring findings of the Retro-C*x* process are problems with the control systems. Because these systems are integrated, a deficiency in one component will often effect the operation of other systems and components. Temporary override of the automatic controls are seldom temporary and often cascade into a manually operated building.

Equipment Life is Extended and *Equipment Repair Costs are Lowered* through both proper performance and routine maintenance improvements. Optimized equipment performance demands less wear and tear on the equipment and motors are not overloaded. The Retro-C*x* process stresses both the routine maintenance and routine operational checks in a well-designed operation and maintenance program, emphasizing the "O" in an Operations & Maintenance (O&M) program.


Energy Performance Certificate

SAP

17 Any Street,
Any Town,
County,
YY3 5XX

Dwelling type: Detached house
Date of assessment: 02 February 2007
Date of certificate: [dd mmmm yyyy]
Reference number: 0000-0000-0000-0000-0000
Total floor area: 166 m²

This home's performance is rated in terms of the energy use per square metre of floor area, energy efficiency based on fuel costs and environmental impact based on carbon dioxide (CO_2) emissions.

Energy Efficiency Rating — Current 37 — Potential 73 — England & Wales — EU Directive 2002/91/EC

The energy efficiency rating is a measure of the overall efficiency of a home. The higher the rating the more energy efficient the home is and the lower the fuel bills will be.

Environmental Impact (CO_2) Rating — Current 31 — Potential 69 — England & Wales — EU Directive 2002/91/EC

The environmental impact rating is a measure of a home's impact on the environment in terms of carbon dioxide (CO_2) emissions. The higher the rating the less impact it has on the environment.

Estimated energy use, carbon dioxide (CO_2) emissions and fuel costs of this home

	Current	Potential
Energy Use	453 kWh/m² per year	178 kWh/m² per year
Carbon dioxide emissions	13 tonnes per year	4.9 tonnes per year
Lighting	£81 per year	£65 per year
Heating	£1173 per year	£457 per year
Hot water	£219 per year	£104 per year

Based on standardised assumptions about occupancy, heating patterns and geographical location, the above table provides an indication of how much it will cost to provide lighting, heating and hot water to this home. The fuel costs only take into account the cost of fuel and not any associated service, maintenance or safety inspection. This certificate has been provided for comparative purposes only and enables one home to be compared with another. Always check the date the certificate was issued, because fuel prices can increase over time and energy saving recommendations will evolve.

To see how this home can achieve its potential rating please see the recommended measures.

Remember to look for the energy saving recommended logo when buying energy-efficient products. It's a quick and easy way to identify the most energy-efficient products on the market.

For advice on how to take action and to find out about offers available to help make your home more energy efficient, call 0800 512 012 or visit www.energysavingtrust.org.uk/myhome

Figure 2 – Building Energy Label Example

O&M Staff Capabilities are Enhanced by involving the operations staff in the process. Staff involvement both lowers the cost of a Retro-C*x* initiative and gives building operators a more comprehensive understanding the building. Taking advantage of the collaborative aspect of a Retro-C*x* project can provide a morale boost to operations personnel who have had to manually operate portions of the building. They know that their time is better spent on the O&M activities.

Building Documentation Improvements are a natural outflow of a detailed performance improvement process. Locating and organizing documentation commonly takes some effort, but is essential to ongoing building operation. A well-designed operations plan encourages documentation libraries be maintained for quick reference, expedited repair/replacement and ongoing operator training.

Indoor Air Quality Improvements and *Protection against Future Liability* are positive consequences of improved ventilation and a trained building operators. Properly operated and maintained HVAC systems, with clean coils, clean air intakes and regularly changed filters, are less likely to contribute to indoor air quality problems. Understanding the relationships between humidity control, indoor air quality, and HVAC operation is essential in hot-humid climates. In addition, trained operators can spot potential air quality and ventilation problems before they develop.

Asset Values Increase as a result of buildings that benchmark and improve their operations. Buildings that cost less to operate and provide both a healthy and productive environment for its inhabitants are inherently more valuable. Leased space in these facilities garner higher occupancy rates and higher rents than their counterparts.

A Lower Carbon Footprint based on decreased energy costs is an increasingly socioeconomic driver for building performance enhancements. There are other reasons, however, that are gaining momentum with our policy makers. Legislators are giving serious credence to both regulating carbon emissions and requiring building performance labeling (i.e. labeling similar to those mandated in Europe – See Fig 2).

The Retrospective Commissioning Process

The Retrospective Commissioning process is generally accepted as having four distinct phases: Planning, Investigation, Implementation, and Hand-Off. An Overview of each phase will be presented here in, but prior to the discussion, it is prudent to identify one additional phase that is widely discussed when presenting the Retro-C*x* process. This additional phase is termed the Persistence Phase (sometimes referred to as the On-Going) phase. Activities of the Persistence Phase are owner performed, either directly or through subcontractors. Persistence strategies are vital to maintaining and improving the facility performance and, therefore, this paper will be include them as an integral element of the Retro-C*x* process.

A Commissioning Lead (C*x*-Lead) plays an important role in facilitating the process. While the C*x*-Lead can be either an internal or third party resource, a third party can add objectivity and experience. Hiring a third party also demonstrates a reciprocal commitment and may help to maintain the project motivation and schedule.

Following is an overview outline of the process:

Planning Phase

Process Steps	**Process Deliverables**
Set the Project Objectives	Owners Operating Requirements
Select a Commissioning Lead	Retrospective Commisioning Plan
Document the Operating Requirements	
Perform an Initial Review	
Develop the Retro-Cx Plan	
Assemble the Cx Team	
Hold a Kick-Off Meeting	

The Project Objectives set the overall process in motion. This is an owner action item and may be used as a vehicle for funding. Since there is no industry standard scope for the Retro-C*x* process, these objectives begin to form a foundation for the initiative. The list of benefits (listed above) can be used as a guide to formulate owner objectives. These objectives will be further defined in the Operation Requirements document as the process gets underway. Selection of the Commissioning Lead (C*x*-Lead) is a pivotal decision. The capabilities and experience of the C*x*-Lead should align with the project objectives. Additionally, the C*x*-Lead will posses team building, communication, report writing, and other requisite skills.

The Owner Operating Requirements is a document authored by the C*x*-Lead that becomes a critical foundational document for the Retro-C*x* process. This document expands the project objectives and defines them as measurable goals. Like an archer aiming at the center of a downrange target, the measurable goals of the Operating Requirements are the bulls-eye. All subsequent Retro-C*x* activities are designed and carried out aiming at this bulls-eye. Ultimately, the project success is measured by how close the measured Retro-C*x* results are to those specified in the Operating Requirements.

The owner conducts an initial project walk-through with the C*x*-Lead and building operations team. Bringing together these key team members presents the opportunity to discuss the Retro-C*x* goals and introduce the C*x*-Lead to the facility operators. A skilled C*x*-Lead will take this opportunity for relationship building and ask insightful questions. The building operator has awareness and intuition about unique facility characteristics that will help to focus the investigation phase.

The Retrospective Commissioning Plan, developed by the C*x*-Lead, establishes the roadmap to success (defined as achieving the Operating Requirements). It presents a brief overview of the facility, goals and scope of the Retro-C*x* initiative, list of systems to be investigated, team members and their responsibilities, schedule, investigation scope and methods, and a description of the expected outcomes. It also outlines additional phases of the Retro-C*x* initiative

such as the Implementation Phase requirements and project Hand-Off activities. A comprehensive draft document is adequate at this point, with the final document deliverable after assembling the Retro-C*x* project team.

By definition, the Retro-C*x* process is a collaborative process. As such, maximizing the facility staff involvement contributes to both cost reduction and enhanced training opportunities. Additional project stakeholders, as outlined in the Retro-C*x* Plan are brought into the process. All primary team members have the opportunity to review and comment on the Retrospective Commissioning Plan prior to it being finalized. Presentation and sign-off on the Retrospective Commissioning Plan presents a good opportunity to conduct a project kick-off meeting.

Investigation Phase

Process Steps	**Process Deliverables**
Review Facility Documentation	Diagnostic Monitoring Plan
Execute Diagnostic Monitoring	Functional Performance Testing Protocols
Execute Functional Performance Testing	Master List of Findings
Perform Simple Repairs	List of Improvements for Implementation
Develop the Master List of Findings	
Prioritize & Select Operational Improvements	

Investigation consumes the largest amount of the project team resources and is at the heart of the Retro-C*x* process. Maximum benefits are derived from a well planned (and documented) process of understanding how the building is intended to operate compared to actual observed and measured operation. This phase starts with a comprehensive review of the facility documentation as related to the systems listed in the Retro-C*x* Plan. Coupled with a detailed walk-through, and some preliminary measurements, this review provides the C*x*-Lead the insights and knowledge to formulate a well-designed investigation plan.

The Investigation typically encompasses both monitoring and functional testing to assess how the systems are performing against expectations. A detailed plan, written for both the diagnostic monitoring and functional performance testing are key elements that align the project team and allow any obstacles (such as building occupancy, Building Automation System [BAS] limitations, schedule conflicts, resource constraints, etc.) to surface. The plans may also identify the need to involve specialty vendors for involvement where the C*x*-Lead does not have expertise.

It is good practice to perform routine maintenance items, instrumentation calibration, and correct known deficiencies prior to executing of the monitoring and testing. The execution of the diagnostic monitoring and functional testing supplies the data for the building performance analysis. Both activities will most likely require the involvement of building operations staff, BAS vendor and the Test, Adjust, and Balance (TAB), vendor. It is not unusual for deficiency findings to occur during the functional testing. These findings will be noted on the Master List of Findings and simple repairs should be addressed immediately.

While testing and diagnostic monitoring can be exhaustive activities, the analysis of the data is the where the rubber meets the road. The output of these activities is a Master List of Findings created by the C*x*-Lead. This list summarizes the findings of the testing and monitoring, including those items that were discovered and addressed throughout the process. Each of the findings is described, implementation cost estimate provided, associated energy savings and payback calculated (if appropriate), recommendations provided, and the C*x*-Lead comments noted.

The Master List of Findings is a tool to establish owner priorities and budgets. The information can provide a backdrop for funding requests and/or directives for in-house remediation efforts. A good practice is to formalize the owner implementation selections into a List of Improvements for Implementation.

Completion of the Investigation Phase is a milestone on the Retro-C*x* process and some owners are tempted to either end the Retro-C*x* process and/or complete the selected improvements without the oversight of the C*x*-Lead. While this approach is plausible, it is a good time to step back and evaluate the value that the commissioning lead brought to the project and the reasons they were invited to participate in the project. Consider again the objectivity, experience, and leadership of your C*x*-Lead as the final phases of the Retro-C*x* process approach.

Implementation Phase

Process Steps	**Process Deliverables**
Implement Selected Improvements	Implementation Plan & Method Selection
Verity Results	Implementation Summary Report

Owner resources and C*x*-Lead capabilities are factors to consider in selecting the best methods to use for implementing the improvements. A turnkey approach via the C*x*-Lead may be a viable option for owners with limited resources. The owner may choose to implement the selected improvements with capable in-house staff, or may outsource the implementation to established contractors maintaining oversight from the C*x*-Lead. C*x*-Lead involvement in the implementation assures continuity and streamlines result verification and project Hand-Off.

The formality of producing an Implementation Plan is recognized best practice for producing a detailed scope of work and guideline for any testing/verification requirements. The Implementation Plan can be used to solicit Requests for Quotation from contractors and/or a detailed Scope of Work for in-house staff. Developing a solid Implementation Plan is key to getting the improvements done and verified correctly.

Testing of the implementation results assures that the systems are working as expected and that the anticipated benefits are achieved. Testing can be via observation, BAS trending or data gathering as previously outlined in the Implementation Plan. It is important to not only test the results of the individual improvements, but also to confirm that multiple improvements and other building systems are properly integrated.

Results of the improvement implementation, along with testing results are complied into an Implementation Summary Report, which provides updated energy calculations (if applicable), final implementation cost and any editorial comments.

Hand-Off Phase

Process Steps	**Process Deliverables**
Conduct Training	Final Report
Conduct a Close-Out Meeting	Systems Manual
	Re-Commissioning Plan

A Final Report, prepared by the C*x*-Lead, summarizes the project and provides a record of the Retro-C*x* activities. It's Table of Contents includes Executive Summary, Project Background, The Master List of Findings (with a Description of the Improvements Implemented), Updated Estimates of Savings, Actual Improvement Costs, results of the Diagnostic Monitoring and Functional Testing activities, recommended Re-Commissioning Frequency, documentation of improvements made and a recommendations of further investigation and improvements. The Final Report is a good reference source for the building owner and operators to aid in maintaining the performance of the building systems. It is also the definitive reference for any future "Re-Commissioning" activities and should be filed with other important building documents.

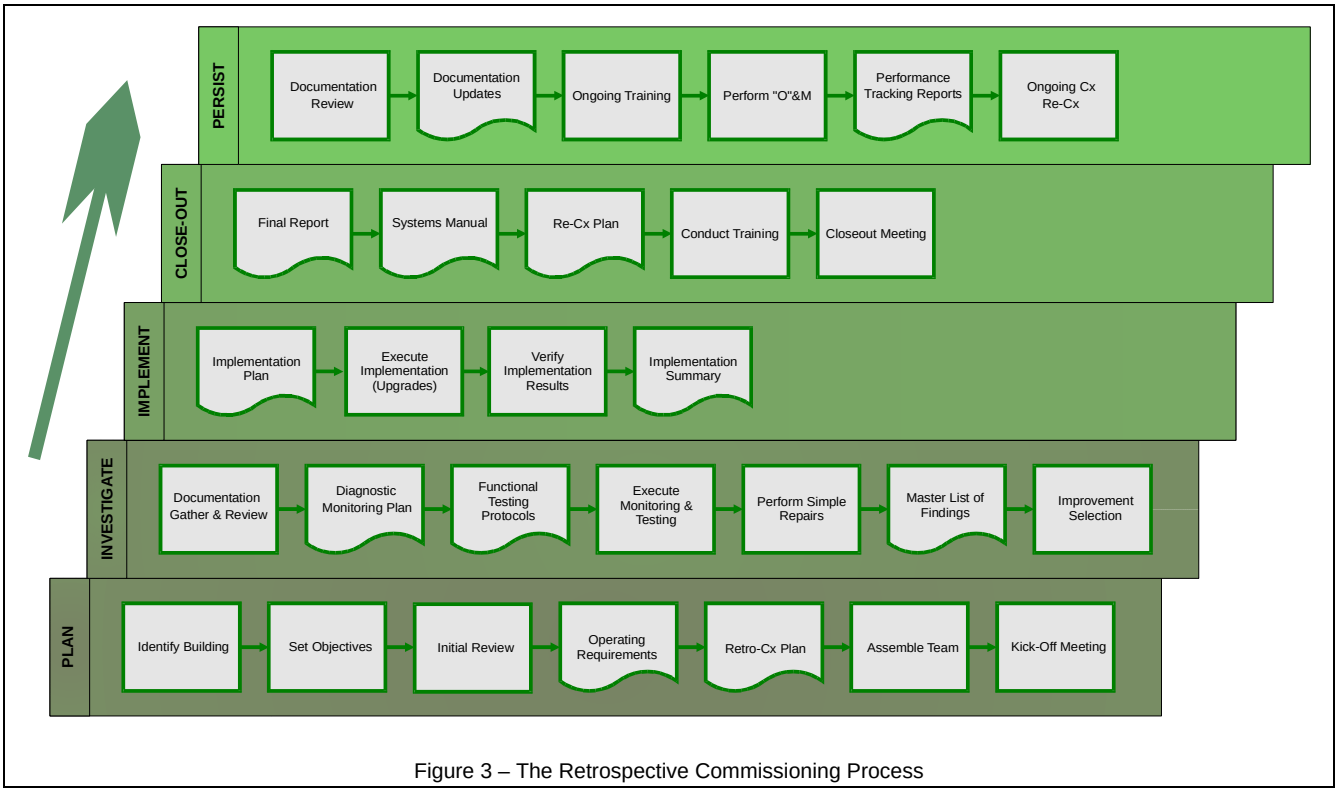


Figure 3 – The Retrospective Commissioning Process

Either included in the Final Report, or as a stand-alone document, the conclusion of the Retro-C*x* process is the ideal time to outline a Re-Commissioning Plan (See previous side-bar for definition). All buildings benefit from periodic attention that is focused on the building performance. Developing a Re-Commissioning Plan at this juncture demonstrated a level of commitment that can be carried into future budget planning. Triggers for Re-Commissioning depend on the performance level and targets for the building. Re-Commissioning can be scheduled on frequency (every two - five years) or based on events such as change of use, unexplained increase in energy consumption, indoor air quality/comfort issues, or other change in other building performance metrics.

A Systems Manual is a best practice document, also developed by the C*x*-Lead, and its requirement, as a project deliverable, would have been defined in the Retrospective Commissioning Plan. Whether planned for or not, a systems manual can be an indispensable resource for both current and future building operators. A Systems Manual is a compilation of documentation intended to describe how the building should operate. For major systems that impact the building performance, the manual includes an overview of the system, simple or detailed Process and Instrumentation Diagrams (P&ID), Descriptive Narratives of Operational Sequences, and other appropriate operational information such as BAS interfaces (point list, alarm settings, trend data, etc.), TAB Report, Operating Schedules, Ongoing Diagnostic Information, O&M information, etc, etc. If provided, the Systems Manual becomes the training handbook and a primary go-to document for building operations staff.

Operator training is essential to maintaining the building performance. Ideally, operators were an integral part of the Retro-C*x* project team and have both offered and gained insights into the performance attributes of building operations activities. The Hand-Off Phase is the ideal time to provide any additional training that the staff needs to maintain and improve the building performance. Training on the building performance metrics is key to the persistence strategies discussed below.

The Retrospective Commissioning project concludes with a Close-Out meeting which is an opportunity to discuss lessons learned from the project and recognize the contributions of the team members.

Persistence Phase

Process Steps

Implement Periodic Building Documentation Review/Update
Practice Ongoing Training
Enhance the Operation Component (O&M)
Implement Performance Tracking
Practice Ongoing Commissioning
Re-Commission when Appropriate

At the conclusion of the Retro-C*x* project, the facility will be operating at a high performance level. Maintaining and improving this level of performance requires effort and may not happen with business-as-usual approach. Proactive measures not only prevent a decline in building performance, but also enhance performance and help to assure that the project benefits persist.

Documentation Review/Update is an action item that commonly falls to the bottom of managers priority list. A well-maintained and accessible building documentation library expedites and lowers repair costs. Systems Manuals, as described in the Hand-Off Phase discussion, are foundational resources for maintaining building performance, seconded by Operation and Maintenance (O&M). The O&M manuals produced by many vendors and equipment manufacturers include multiple models and options, which, if not marked for the buildings specific equipment, can waste appreciable time finding detail information for repair. Other characteristics of system documentation include vendor contacts, performance curves for fans and pumps, spare parts lists, maintenance requirements, start-up requirements, and troubleshooting requirements.

A frequently overlooked documentation requirement is associated with systems that are controlled by microprocessors. In addition to the previously listed items, maintain documentation of software/firmware revisions, configurable parameters, and tested software backup's. Passwords and access codes need to be available for trained operators. For those software systems that undergo recurring revision, it is recommended that training and tools for software back-up and recovery are available.

There is a difference between an Operation & Maintenance (O&M) Plan and a Preventive Maintenance Plan (PM). By incorporating operational and control checks into the PM program operators will monitor and maintain the proper settings for the facility. Procedures for documenting and investigating parameters that are out of tolerance will help to keep the documentation updated and facilitate an ongoing awareness of building system performance.

Ongoing training of operations staff serves as both a motivator and a means for persistent building performance. Unless operators and managers have the right knowledge and skills, it will be impossible for the building to perform optimally over time. The Building Automation System is one of the most powerful and underutilized systems in buildings. Ongoing training for maximum utilization of the BAS trends and alarms will help building operators identify performance enhancement opportunities and spot system derogation.

With training on BAS data trending and data analysis, a System Performance Monitoring program can be implemented. Couple the system level performance monitoring with Utility Monitoring and Building Benchmarking to create a three tier performance monitoring program that provides the high level tools for improvement goals. Energy benefits of any additional improvement strategies can be measured and early detection of problems and equipment failures will be noticed. Building Benchmarking tools such as EPA's Portfolio Manager are available as well as automated Energy Information Systems (EIS) to facilitate energy consumption analysis.

Together, these persistence strategies can be considered Ongoing Commissioning (Ongoing-C*x*). Some building owners have taken advantage of the diagnostic monitoring that was implemented during the Retro-C*x* process and added additional continuous monitoring as either a stand-alone system or an enhancement to their BAS trending. Some owners take advantage of third-party services that install instrumentation and remotely monitor the facility systems.

Re-Commissioning generally costs less than the Retro-C*x* initiatives since much of the planning and documentation from the Retro-C*x* is readily available. Triggers for re-commissioning include change in building use and increases in energy consumption, complaints, or equipment failures. With a building practicing the persistence strategies discussed here, re-commissioning becomes a review and validation of the operating practices and provides an opportunity for enhancing operator training, documentation, monitoring practices and items that can be difficult to budget

RETROSPECTIVE COMMISSIONING COSTS

Costs for the Retro-C*x* initiative can vary substantially depending. Cost variables include:

- Building Type/Use/Age/Size/Location
- Number & Complexity of Systems
- Equipment Age & Condition
- Site Staff - Skill Level & Project Involvement
- Scope of Retro-Cx Process
- Availability of Current Documentation
- Commissioning Authority Rates
- Presence of an extensive O&M Program

Accordingly, it can be difficult to estimate the costs of a Retrospective Commissioning effort at the early planning stages, particularly for a third party provider that may not know the building operating characteristics.

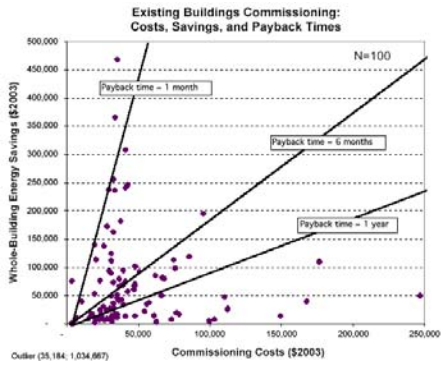


Figure 4 – Payback Times[3]

A 2005 report, issued by the Lawrence Berkley National Laboratory[3] is the most comprehensive collection and analysis of Existing Building Commissioning available. This study analyzed the costs of eighty five (85) existing building commissioning projects. Following are some of the findings:

The median cost of 100 projects, representing over twenty two million square feet of building area was $0.27 per Square Foot ($ft^2$) with a range of $0.27/$ft^2$ to $0.27/$ft^2$ (normalized to 2003 Dollars). Buildings in Texas and California covering all major building types dominated project locations.

The median payback for existing building commissioning was less than one year and ranged from 0.2 to 2.1 years (Figure 4). Larger, more energy intensive and complex buildings, such as laboratories and hospitals cost more to implement, but yielded higher benefits (Figure 5).

A breakdown of project costs showed that approximately two thirds of the costs were allocated to the planning and investigation phases, with the next highest allotment going to implementation. The C*x*-Lead fees ranged from 35% to 71% of the overall cost

The study showed that, within the variation of project scope, those with more process steps faired better than those with fewer steps. As illustrated in Figure 6, most projects incorporated between five to twelve process steps.

Strategies for lowering costs, and gaining maximum benefit, are centered on owner involvement. Involvement with documentation gathering, performing maintenance and calibration prior to the Retro-C*x* investigation, assisting with diagnostic monitoring, trend logging, and functional testing and performing repairs and improvements all serve to lower costs and train staff.

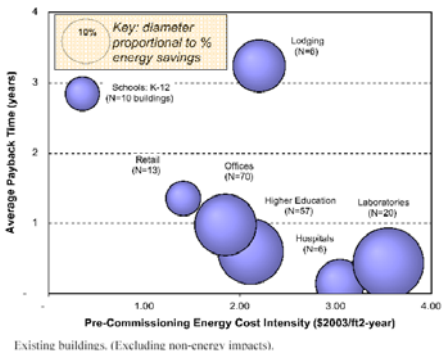


Figure 5 – Cost Intensity[3]

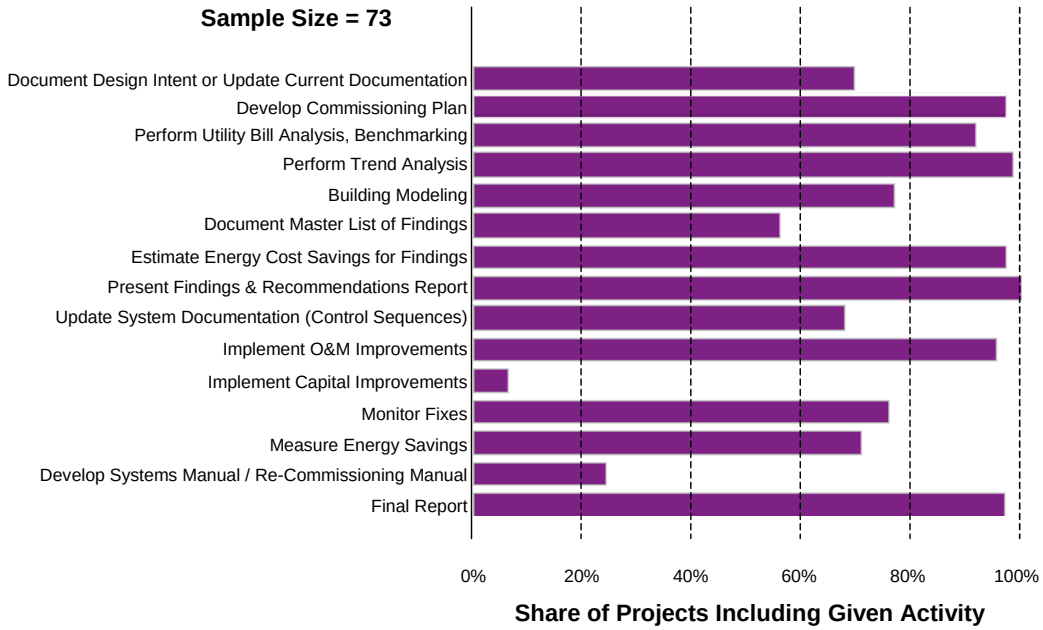


Figure 6 – Number of Steps[3]

CONCLUSION

Retrospective commissioning has enormous potential to simultaneously lower the cost of building operations, increase building performance, and contribute to environmental stewardship. As building systems become more complex in an effort to lower costs and garner energy savings, the risk of under-performance increases. The desire for increased energy efficiency may itself create energy waste if those systems are not designed, implemented, and operated properly. The success of a large majority of complex energy savings and efficiency strategies is directly coupled to a quality assurance process – better known as commissioning.

Investing in a methodical process of systematically analyzing and optimizing building system performance typically pays for itself in less than two years. Additionally, Retrospective Commissioning begins to prepare building owners for a green economy, which may include mandates to label buildings according to their performance matrices and various regulation of carbon emissions.

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