

PECI

O&M Best Practices Series



Operation and Maintenance Assessments

*A Best Practice for
Energy-Efficient
Building Operations*

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O&M ASSESSMENTS — ENHANCING ENERGY-EFFICIENT BUILDING OPERATION

*Best Practices in Operation and
Maintenance*

INTRODUCTION

Although building commissioning¹ is becoming more popular for new construction projects, most buildings have never undergone any type of systematic process to ensure they operate optimally. Several studies² over the past few years have indicated that existing U.S. commercial office buildings hold tremendous opportunities for increasing energy efficiency through low-cost O&M improvements. These improvements can yield savings of five to twenty percent of a building's annual utility bill. Simple paybacks are generally less than 2 years, which equals a 98% IRR (based on a 7 year measure life.)³

Understanding why building systems are operated and maintained the way they are, and where and what improvements are most beneficial and cost-effective is the first step to obtaining energy-efficient building performance. An O&M assessment provides a systematic look at all aspects of the current O&M practices including the management structure, policies, and user requirements that influence them. It may include:

- Interviews with management, O&M personnel and service contractors;

*Low-cost improvements can save
5-20% of a building's annual energy
bill.*

¹ Commissioning is 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,” according to ASHRAE Guideline 1-(1996).

² Piette, 1994. Gregerson, 1993. Haas et al, 1996.

³ John S. Hoffman and John Bruce Wells, Closing the Efficiency Gap: Using Profit to Drive The Capture of Value, 1998, WorkSmart Energy Enterprises, Inc.

- A review of equipment condition, building documentation, and service contracts;
- Spot tests of equipment and controls;
- Trend or data logging of critical data points (temperatures, pressures, electrical, etc.) over time.

The gathering and analysis of this information reveals where improvements are needed and which improvements are most cost-effective.

O&M assessments optimize building performance and identify money-saving opportunities.

The assessment also checks schedules and control strategies to determine if the building is operated optimally and develops a list of recommended improvements that support energy-efficient operation. It can provide a starting point or baseline from which to measure the effectiveness of improvements and ongoing O&M activities. Depending on the scope of work, an assessment may include recommendations for more extensive improvements (such as air or water balancing) and capital improvements for the owner to consider as well as motivational and behavioral issues that affect building performance.

Portland Energy Conservation Inc. (PECI) researched and developed this document with funding from the Climate Protection Division of the U.S. Environmental Protection Agency (EPA), in cooperation with the U.S. Department of Energy (DOE). This document primarily focuses on O&M assessments for commercial building HVAC, lighting and control systems. It discusses what an O&M assessment involves, how it differs from an energy audit, the value of hiring an O&M consultant, and what the benefits and costs are for performing an assessment. It also briefly describes the process and how an owner can increase the cost effectiveness of the process.

WHAT IS AN O&M ASSESSMENT?

An O&M site assessment is a systematic method for identifying ways to optimize the performance of an existing building. It involves gathering, analyzing, and presenting information based on the building owner or manager's requirements. Owners generally perform an O&M assessment for the following reasons:

- To identify low-cost O&M solutions for improving energy efficiency, comfort, and indoor air quality (IAQ)
- To reduce premature equipment failure
- To insure optimal equipment performance
- To obtain an understanding of current O&M and PM practices and O&M documentation

O&M assessments may be performed as a stand-alone activity that results in a set of O&M recommendations or as part of retrocommissioning (a larger more holistic approach to improving existing-building performance).

The goal of the assessment is to gain an understanding of how building systems and equipment are currently operated and maintained, why these O&M strategies were chosen, and what the most significant problems are for building staff and occupants. Implementing O&M changes without fully understanding the owner's operational needs can have disappointing and even disastrous effects. Most projects require the development of a formal assessment instrument in order to obtain all the necessary O&M information. This instrument includes a detailed interview with the facility manager, building operators and maintenance service contractors who are responsible for the administration and implementation of the O&M program. Depending on the scope of the project it may also include an in-depth site survey of equipment condition and gathering of nameplate information. Sample assessment forms are presented in Appendix A. An O&M assessment can take from a few days to several weeks to complete depending on the objectives and scope of the project.

The assessment identifies the best opportunities for optimizing the energy-using systems and improving O&M practices. It provides the starting point for evaluating the present O&M program and a basis for understanding which O&M improvements are most cost effective to implement.

See Appendix A for sample assessment forms.

Retrocommissioning applies a four-phase process for improving or optimizing an existing building's operation and maintenance procedures. Retrocommissioning is applied to buildings that have not previously been commissioned. The systematic retrocommissioning process optimizes how equipment and systems operate, and how the systems function together. O&M tune-up activities and diagnostic monitoring and testing are primarily used to optimize the building systems. This flow chart shows the steps in the retrocommissioning process. This booklet covers the Planning and Investigation Phases.

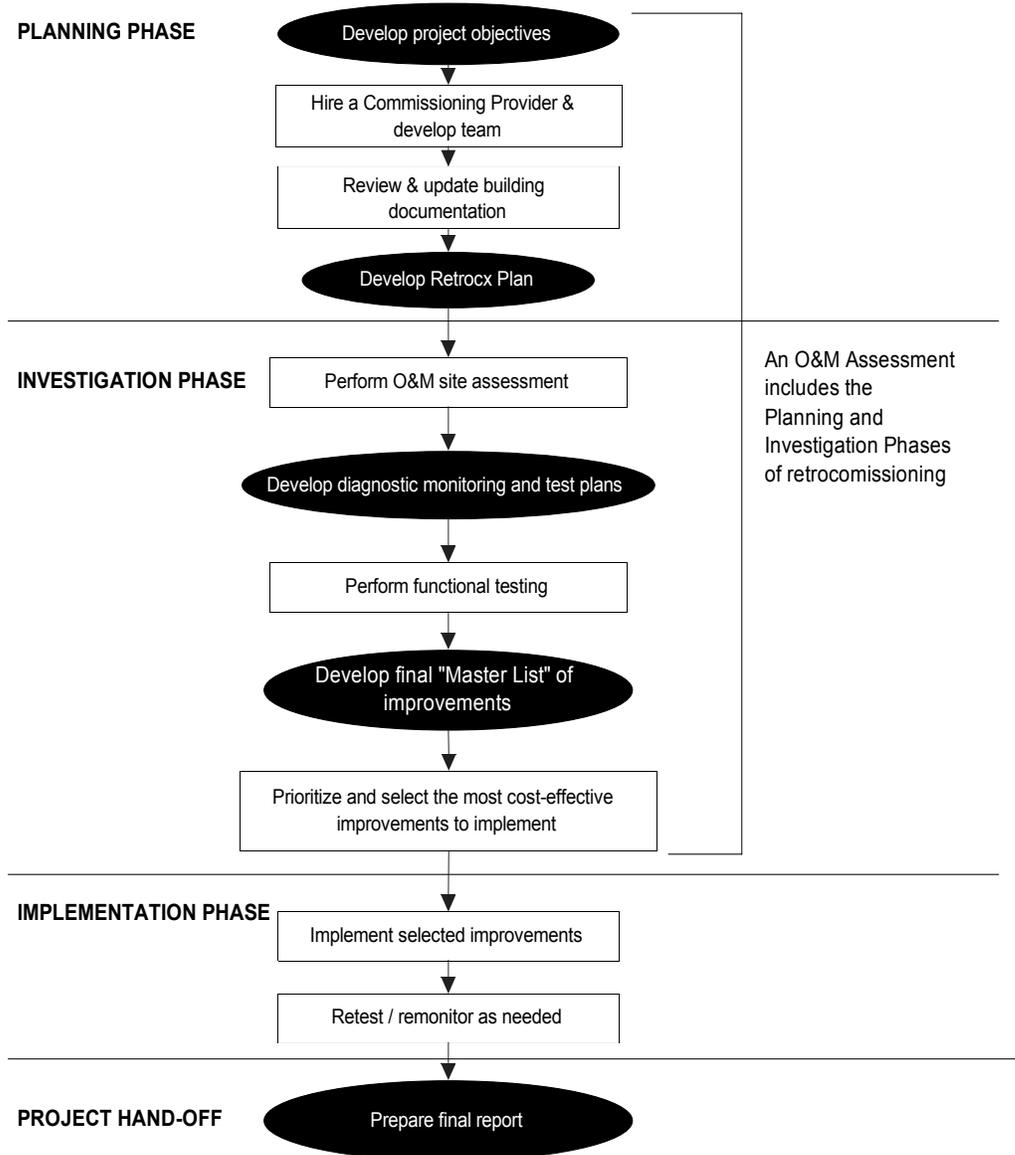


FIGURE 1
Retrocommissioning: A Four Phase Process

Excerpted from *A Practical Guide for Commissioning Existing Buildings* published by Oak Ridge National Laboratory in May 1999.

AN O&M ASSESSMENT IS NOT AN ENERGY AUDIT

An O&M assessment differs from a traditional energy audit, even though they share the goal of reducing operating costs and energy waste and improving the building environment. Traditional energy audits identify technology-intensive, energy-efficient capital improvements. O&M assessments identify low-cost changes in O&M practices that can improve building operation. The O&M assessment may be performed prior to an energy audit because it offers ways to optimize the existing building systems, reducing the need for potentially expensive retrofit solutions. It may also be performed as part of an energy audit, because implementing the low-cost savings identified in the assessment can improve the payback schedule for capital improvements resulting from the energy audit. Table 1 summarizes the basic differences between the O&M assessment and the traditional energy audit.

TABLE 1
The Differences Between a Traditional Energy Audit and an O&M Assessment

Traditional Energy Audit	O&M Assessment
Emphasizes investigating existing building systems for <i>equipment replacement (retrofit) opportunities</i> leading to energy cost savings	Emphasizes investigating existing building systems to identify <i>low-cost O&M improvements</i> leading to energy cost savings
A typical energy audit on-site process is relatively fast (16 hours)	O&M assessment on-site process is relatively time consuming (2 days to 2 weeks)
Seldom includes functional testing of present building systems	Generally includes some degree of functional testing of present building systems
Generally performed by an outside consultant	Generally performed by an outside consultant
May include building simulation models	Rarely includes building simulation models
Results in a list of energy conservation retrofit measures	Results in a master list of O&M improvements
Typical recommendations are time consuming and expensive to implement	Typical recommendations are fast and inexpensive to implement
Typical paybacks are estimated at three or more years	Typical pay-backs are estimated at less than two years (often less than one year).
Generally requires an outside contractor to implement equipment replacements	In-house staff can often implement many O&M improvements

Although the O&M assessment can be as expensive and sometimes more expensive to perform than the traditional energy audit, the findings from the assessment are usually much less expensive to implement because they don't involve installing large capital improvements. In fact, managers can consider most O&M assessments outside of typical corporate hurdle rates, because the risk of not realizing savings is so low. The O&M assessment does not ignore capital improvements and may include recommendations to further investigate certain retrofit opportunities, but its true goal is to identify the low-cost improvements.

O&M assessments identify low-cost, low-risk improvements.

Because energy audits are specifically part of an equipment replacement process, they are often performed as a financing requirement. For an owner to obtain funding either in-house by way of their capital projects department or from third party financing (such as an energy service performance contract), a solid energy audit provides the necessary assurances that the investment is financially sound. It is a good idea to combine the energy audit and the O&M audit, which investigates low-cost O&M enhancements. With financial investment, the O&M assessment can help owners to understand and evaluate the energy-efficiency opportunities in buildings by optimizing performance and minimizing energy waste of existing equipment. This is not to say that an O&M assessment should be done in place of an energy audit. Both have an appropriate place in the overall energy management process and should be considered complementary.

WHO SHOULD PERFORM O&M ASSESSMENTS?

Depending on the complexity of the building systems and the expertise and availability of the in-house building staff, a building owner may choose an outside consultant to perform the assessment. Commissioning consulting firms and engineering firms that provide commissioning and diagnostic or retrocommissioning services as part of their core business activities usually are well-suited to perform O&M assessments. They have the necessary experience and business commitment to the process to help scope and deliver the specified project in a cost-effective and timely manner.

Some good reasons to bring in an outside consultant to perform or assist in performing an O&M assessment include:

- The owner's staff may not have the skill or time to perform an in-depth assessment.
- Consultants specializing in commissioning and O&M services have vast experience with similar buildings enabling them to offer a new or different perspective. In other words, they aren't invested in doing things the "old way."
- Consultants are also "tooled" for performing the work. Most have generic assessment procedures that they can customize to fit the building they are hired to assess.
- Consultants have analytical skills and tools for diagnosing hidden problems and determining the cost effectiveness of selected improvements.

Four O&M assessment approaches to consider include:

1. Hire an outside expert to perform the assessment from start to finish. This approach often works well for owners who have one or more buildings with no O&M staff, or minimal staff with little time or training.
2. Owners or managers with multiple buildings and a well-trained, interested, available O&M staff, may want to hire an outside consultant to work with the building staff for the first one or two buildings. After the building staff is trained in the process they can go on to assess the rest of the buildings themselves.



Commissioning consulting firms and engineering firms that provide commissioning and diagnostic or retrocommissioning services as part of their core business activities usually are well-suited to perform O&M assessments.

3. Use the second approach but retain the outside consultant throughout the entire project to oversee critical parts of the assessment process either as assigned or as needed. Owners who use this approach often ask the consultant to analyze data and estimate savings.
4. Divide the assessment work between the outside consultant and the O&M staff. Depending on the scope of the project and staff availability, the O&M staff can obtain all of the nameplate data and perform the equipment condition assessment. This allows the consultant to concentrate on operating issues and the impact that various building users have on the operation and maintenance of the building.

O&M ASSESSMENT BENEFITS

The greatest benefit of performing a building O&M assessment is informational. The information resulting from an O&M assessment can be used to help prioritize both financial and policy issues regarding the management and budget for the facility. It presents a clear picture of where and what improvements may be most cost effective to implement first. The assessment process, depending on the owner's or manager's requirements, can also provide direct training and documentation benefits for O&M staff.

Depending on the goals for performing the assessment, typical benefits may include:

- Identifying operational improvements that capture energy and demand savings
- Identifying operational improvements that positively affect comfort and IAQ
- Improving building control
- Developing a baseline report on the condition of major HVAC equipment
- Developing an updated and complete equipment list (nameplate data)
- Identifying issues contributing to premature equipment failure
- Identifying ways to reduce staff time spent on emergencies
- Increasing O&M staff capabilities and expertise
- Determining whether staff require additional training
- Identifying and gathering any missing critical system documentation
- Developing a complete set of sequences of operation for the major HVAC systems
- Evaluating the EMS for opportunities to optimize control strategies
- Recommending energy-efficiency measures for further investigation
- Determining original design intent and the cost to bring the building back to original design

New Installations can Benefit from O&M Assessments

A 250,000 square foot office building in downtown Nashville Tennessee was renovated in 1993. The renovation included installing a DDC energy management control system to control the variable air volume (VAV) HVAC system and lighting and a variable frequency drive (VFD) for the chilled water system. The building was not commissioned as part of the renovation. An O&M assessment was performed three years later because the building was experiencing problems and energy bills seemed higher than expected. As a result of the assessment, a total of 32 O&M related problems including a major IAQ deficiency were identified. It was also determined that the majority of these problems had been present since the renovation. Annual energy savings from the recommended O&M improvements and repairs are estimated at over \$42,000. The cost of the assessment was approximately \$13,000 and the cost of implementing the repairs is estimated at \$9,300. The simple payback for both the assessment and implementation is under seven months.

- Providing a cost/benefit analysis of implementing the recommended O&M improvements
- Developing an operating plan and policy to maintain optimal building performance over time

The best benefits keep on giving long after the process is completed. For example, the final master log of recommended improvements along with the estimated savings allows an owner or building manager to prioritize and budget accurately for the implementation process. Also, minor problems that could be solved during the assessment may begin to reduce energy costs and improve comfort immediately; equipment life may be extended for equipment that may have failed prematurely due to hidden problems, short cycling, or excessive run time.

Raytheon Corporation: A Brief Case Study

The Raytheon company was approached by Boston Edison in late 1999 to participate in a pilot retrocommissioning study. As a result Boston Edison hired an O&M consultant to conduct an O&M assessment of three of the five buildings at Raytheon Corporation's Sudbury, MA site. These buildings house primarily office space, along with some process and limited laboratory spaces. The total facility is over 540,000 sf. The three buildings investigated were Building 2 (30,500 sf, 38 years old), Building 3 (67,500 sf, 30 years old) and Building 5 (132,400 sf, 13 years old).

The objectives of the project were, in order of importance:

- Conduct an O&M assessment demonstration for replication at other Raytheon facilities
- Reduce energy costs in the facility
- Bring equipment to its proper operational state

The consultant observed each building's present operation practices in an attempt to find cost-effective improvements that could be implemented primarily by the owner's building staff and service contractors. The heating, ventilating, air conditioning and lighting systems were investigated. The consultant did not extensively investigate capital improvements.

O&M Assessment Process

Develop Scope and Plan. Due to the project being completed in the winter and due to budget limitations, the owner and consultant decided to focus the efforts in Buildings 2, 3 and 5. Within those buildings only the lighting, air handlers, boilers and rooftop packaged units would be evaluated, with the chiller system looked at if time permitted.

Documentation Review. The O&M consultant first obtained and reviewed building documentation to become familiar with the building and its systems. This documentation included equipment lists, control program code, system schematics and energy accounting and billing data.

Initial Site Assessment. The next step was to conduct an initial site assessment. The consultant's team of two engineers spent 2 ½ days in the building interviewing staff, reviewing control code, inspecting equipment, performing a night walk-through, and performing an analysis of the site-gathered data. An analysis of billing and 15-minute demand data was also conducted.

The initial site assessment identified 26 significant findings, as well as areas where additional analysis is needed, including monitoring and testing.

Monitoring and Manual Testing. The consultant used a combination of datalogging, BAS trending, and manual testing to investigate and monitor suspected deficiencies. From this investigation, the O&M consultant identified eight new findings and obtained additional information on seven of the original 26 findings.

The O&M consultant then roughly prioritized the findings, first by energy savings potential, second by how economical the recommendation would be to implement, and lastly by how likely it was that the recommendation would actually be implemented, if selected. These rankings assisted the owner in selecting the recommendations to implement or investigate further.

The O&M consultant discussed the findings on site with facility staff and utility representatives. In that meeting each finding was explained and discussed. Clarifications were made and further understanding was obtained about the findings and recommendations. The owner's intended action on each recommendation was identified.

The consultant estimated energy savings for the recommendations where there was a need and where enough information existed to make an estimate. The consultant then developed a general implementation plan for each of the recommendations accepted by Raytheon. At this point, a formal report was generated.

The report included the following recommendations:

- Significant opportunity exists to reduce off-hours energy use. Freeze protection, a few small process loads and odd scheduled workers were driving large sections of the facility to run 24 hours a day. Energy use during unoccupied periods (nights and weekends) made up 70% of the total energy use. This could be reduced, decreasing the entire utility bill by over 30%, by re-instituting the company's automatic lighting control policy, making adjustments and small capital improvements so the entire chiller plant could be shut down at night, evaluating each of the dozens of pumps and fans and programming them to shut off at night, etc.
- Changing the economizer changeover parameter from outdoor air dew point to wet bulb would allow more free cooling to occur.
- Installing high-quality occupancy sensors in numerous conference rooms and offices would reduce unnecessary lighting energy.
- Changing the control code to keep the cooling tower fans off when there is no load will reduce energy use.
- Incorporating a duct static pressure reset strategy on six of the main air handlers will reduce the fan energy significantly.
- Programming in a chilled water supply temperature reset strategy (it was fixed at the time of the assessment) would further reduce energy expenses.

Energy Savings Estimates

Savings for measures that were estimated totaled over 6,000,000 kWh and \$400,000 annually. This represents close to 40% of the total energy use of the campus (all 5 buildings). Over 90% of the savings came from operating the equipment only when necessary—reducing operation during unoccupied hours and days. The remainder of the estimated savings originate from findings that optimize the operational parameters of equipment. Savings were not estimated for a number of findings, and other building components and systems were not even investigated.

WHAT BUILDINGS MAKE THE BEST CANDIDATES FOR O&M ASSESSMENTS?

The most obvious candidates for an O&M assessment are buildings with any one or a combination of the following: significant energy costs, excessive comfort complaints, control problems, suspected IAQ issues, and repeated equipment failures. However, almost any commercial office building can benefit from an O&M assessment, including new buildings.

There is a misconception that new buildings and recently renovated or retrofitted buildings no longer contain any significant energy-saving O&M opportunities. This may be true for renovations and new construction projects that incorporate formal commissioning to ensure design intent. It may also be the case for retrofit projects receiving investment grade audits (IGAs)⁴ along with formal commissioning of new equipment. Unfortunately, few projects completed today use these quality assurance methods. Because of this quality assurance gap, most newer buildings as well as recent retrofit projects offer some of the best opportunities for O&M improvements leading to energy savings and improved building performance. The idea is to capture as much savings as possible from identifying and implementing low-cost O&M improvements early in the life of a building or retrofit.

Table 2 lists some typical mechanical equipment and controls found in medium to large commercial buildings that are particularly subject to O&M problems. A good O&M assessment investigates each of these systems (and probably others) for improvement opportunities. Buildings with even a few of the systems or components listed on Table 2 may be a good candidate for an O&M assessment. Some of the symptoms that may indicate problems exist with these systems are high utility bills, excessive comfort calls, and repeated repairs on the same equipment. Even if none of these symptoms exist, buildings may be able to realize significant energy savings. Energy waste is often hidden.

⁴ An Investment Grade Audit is a rigorous energy audit that includes O&M assessment features, plus a risk assessment of the likelihood of sustained savings for energy-efficiency improvements.

 *New and retrofitted facilities also contain significant savings opportunities.*

Table 2
Typical Mechanical Equipment and Controls Subject to O&M Problems

System or Component	Typical Problems
Energy Management System (EMS)	Downgraded to timeclocks or switches by disabling or overriding, capabilities were never fully engaged
EMS	Faulty programming or logic, valve and damper hunting
Setpoints	Setpoints incorrect or not optimum for conditions
Schedules	Equipment and lighting operating when not necessary
Air-side economizers	Binding dampers, improper setpoints, sensors out of calibration
Sensors	Out of calibration, broken, or poorly placed
Dampers and valves	Linkage broken, leaky, malfunctioning (not modulating effectively)
Fans and pumps	Operating at higher capacities than necessary
Automatic controls	Not used or poorly programmed
Manual controls	Poorly operated
Reset schedules	Not functioning, or set at inefficient levels
Cooling tower & chiller	Inefficient staging and sequencing
Boiler systems	Inefficient staging and sequencing, inefficient combustion, failed steam traps
Lighting sweep controls	Not functioning, wrong time, overridden, broken or poorly zoned
Compressor sequencing	Improper staging and sequencing
Variable air or water flow	Variable speed drive parameters restrict full modulation or cause hunting
Equipment cycling (motors)	Excessive or mysterious cycling
Air distribution system	Poor sensor location, dirty filters and coils, blockages

HOW MUCH DOES AN O&M ASSESSMENT COST?

How much an O&M assessment costs is influenced by several factors:

- The number and complexity of the buildings, systems, and equipment involved
- The number and type of assessment objectives
- The availability and completeness of building documentation
- The availability and expertise of the O&M staff.

The assessment process includes fixed costs that do not vary with building size. Therefore, the actual cost of a project is more related to scope and complexity than to building size or age.

A project with several objectives will naturally cost more than a project with fewer objectives. Also, a project with complicated controls and numerous pieces of equipment will cost more than a simple building with only a few pieces of equipment. Scoping the project to obtain the most benefit at the least cost can be challenging. The owner must have a clear vision for what the assessment needs to accomplish and impart that vision to the O&M consultant. In some cases the owner may want to hire an O&M consultant to help scope the project.

Considering the factors discussed above, the cost for performing O&M assessments on typical commercial or retail facilities between 50,000 and 300,000 square feet can range from about \$10,000 to \$50,000. The assessment process includes fixed costs that do not vary with building size. Therefore, the actual cost of a project is more related to scope and complexity than to building size or age. For fairly large complicated or multiple buildings, an owner may want to put the assessment project out to bid. One rule-of-thumb for determining the cost of an assessment for commercial buildings with up-to-date and complete documentation and no unusual characteristics (such as laboratories, clean rooms, fume hoods etc.) is to budget approximately \$.11 - \$.35 per square foot for the assessment.

Savings can only accrue if recommendations from the assessment are implemented. Implementing even a few of the operational improvements suggested by the assessment can often pay back the assessment and the cost of implementation in a very short time. Recent field data from a 44-building cost-effectiveness study performed by

E Source⁵ demonstrates that an extensive O&M assessment and the implementation of recommended improvements for all of the “energy-intensive” buildings as well as several “energy efficient buildings” resulted in paybacks of less than two years. Figure 2 is taken from this study and compares a simple payback from the assessment and implementation process to normalized energy cost. Combining the O&M assessment with an energy audit may be beneficial to owners, because the savings from implementing assessment findings can help retrofits pay back faster.

When the assessment process is combined with implementation of recommendations, it is often referred to as retrocommissioning. See the flow chart on retrocommissioning on page 4.

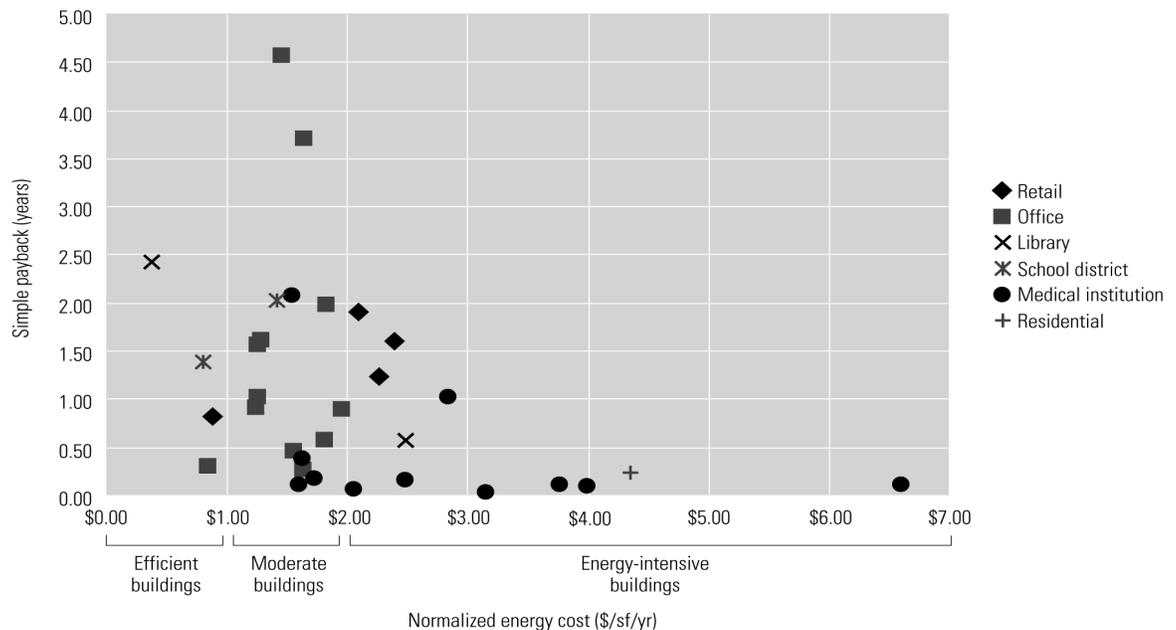


FIGURE 2
Simple Payback vs. Normalized Annual Energy Cost

This figure compares simple payback from commissioning to normalized energy cost. All of the “energy-intensive” buildings had short paybacks (less than two years), but so did several of the “efficient buildings. This information was provided courtesy of E SOURCE, an information services company providing organizations with unbiased, independent analysis of retail energy markets, services and technologies.

⁵ Gregerson, Joan. Commissioning Existing Buildings, a Tech Update (TU-97-3) published by E Source, March 1997.

O&M ASSESSMENT PROCESS

The following briefly describes the assessment process by highlighting the responsibilities of the owner and owner's staff, and the O&M consultant throughout the project. Responsibilities may overlap to some extent.

OWNER'S RESPONSIBILITIES

The O&M assessment process consists of several steps beginning with the pre-assessment planning activities that are carried out by the building owner or manager. These activities may include:

- Setting the objectives
- Assigning staff
- Choosing the approach
- Developing the scope of work
- Hiring an O&M expert/developing the RFP

Setting the Objectives

After selecting one or more buildings to undergo the assessment process, the owner must develop written objectives for the project. It's important that the owner or manager involve the facility staff members who will be affected by the assessment in determining the objectives for the work. For the assessment to be successful, O&M staff need to view the process as a means of enhancing and supporting their work and not as a fault-finding activity. Some objectives may be more specific and detailed than others. Examples of typical objectives include:

- Develop recommendations for optimizing building performance and equipment control to increase comfort
- Develop recommendations for optimizing building performance to reduce energy waste
- Evaluate EMS capabilities and recommend ways to optimize control strategies to improve comfort and save energy
- Investigate specific problem areas of the building or problematic equipment
- Recommend energy-efficient equipment upgrades for further investigation
- Train building staff in the assessment process and increase their skill in tracking the results of energy-efficient improvements

The owner develops the assessment objectives.

- Identify and immediately report any potential IAQ problems found during the course of the assessment

Assigning Staff

Once the objectives are established, the owner or facility manager assigns one or more staff members to assist in the assessment process. The individuals chosen should be those with the most knowledge about the building's history and control system. Knowledgeable building staff can improve the assessment cost effectiveness because they reduce the time the O&M consultant needs to spend investigating how and why the building operates as it does. The amount of time a staff person will spend assisting with the project is generally decided during the scoping process.

Choosing the Approach

As part of the pre-assessment tasks, the owner must choose an approach for accomplishing the work. Will most of the work fall to an outside consultant or to in-house staff? The section titled "Who Should Perform O&M Assessments?" discusses four approaches to accomplishing the work. Most of the approaches assume that the owner has O&M staff to assist in carrying out the assessment.

When knowledgeable building staff can participate in the assessment, they reduce the time the O&M consultant needs to spend investigating how and why the building operates as it does.

Developing the Scope of Work

Before hiring the O&M consultant, the owner or manager, outlines a brief scope of work. A scope of work outline includes:

- The project objectives
- Which buildings, building systems, and equipment will be part of the assessment
- The desired approach, methods and rigor for accomplishing the work
- The timeframe for project completion
- The number and type of expected deliverables or work products resulting from the assessment

Although the owner or manager initially outlines the scope of work, once the O&M consultant is hired, he or she often develops a more detailed scope of work. This is usually the case for complex or multi-building projects. Involving the O&M consultant in developing the scope of work can avert misunderstandings about project expectations and the amount of staff time the project requires.

Appendix B contains an RFP checklist.

Hiring an O&M Expert / Developing the RFP

The owner's last major task in the pre-planning process is hiring the O&M consultant. Depending on the complexity and size of the project, developing an RFP may be the best method for obtaining an experienced O&M consultant. Appendix B presents a checklist of items to include in the RFP. The checklist is not comprehensive in terms of developing an entire RFP from start to finish, but includes critical items that will help owners develop a *realistic* proposal for obtaining a good O&M assessment. Once the owner has hired a consultant and established a detailed scope of work, the next five major steps in the process are the main responsibility of the O&M consultant. Once the assessment is underway the owner's main responsibility is to review and approve the various work products and procedures.

O&M CONSULTANT'S RESPONSIBILITIES

The O&M consultants responsibilities include:

- Developing the assessment plan
- Holding the kick-off meeting
- Performing the assessment
- Diagnostic monitoring and testing
- Reporting the results

Developing the Assessment Plan

After reviewing the building documentation and gaining a clear understanding of the project objectives, the consultant develops the Assessment Plan which is one of the project's major work products. This task involves seeking significant input and review from the owner and owner's staff. Appendix C presents a sample O&M Assessment Plan.

Scheduling of the tasks described in the plan should coincide with the project objectives. For example, if reducing the number of comfort calls is an objective, and these calls primarily occur during the heating season, then any diagnostic testing should be scheduled during peak heating conditions.

Appendix C contains a Sample O&M Assessment Plan.

Holding the Kick-off Meeting

Generally, the O&M consultant facilitates a kick-off meeting to discuss the assessment plan. The meeting brings the owner or manager, O&M staff, consultant and possibly a utility representative or other relevant parties together to review and agree to the plan and schedule. The primary role of the owner or manager during this meeting is to reiterate the objectives for the project and show support for the assessment process.

The owner also defines work protocols during the kick-off meeting. It is important that the consultant and any sub-contractors or service contractors involved are well informed about what is expected of them when they enter and perform work in the building. Work protocols might include:

- Restrictions on building keys
- Sign in and sign out requirements
- Identification requirements
- Parking permits
- Need for escort while in the building or in special areas of the building
- The most acceptable times for performing work in tenant spaces

Performing the Assessment

The O&M consultant and facility staff perform the O&M assessment that results in a master log of deficiencies along with recommendations for repairs and improvements. The goals and scope of the project determines the extent of the assessment process. Using a series of forms (Appendix A presents sample assessment forms) and interviews, the O&M consultant gathers information on the following major issues:

- Monthly utility data for two or more years prior to assessment
- Building energy use and demand, daily load profiles (if available)
- Equipment nameplate information
- Equipment condition (broken dampers, dirty coils, sensor calibration, etc.)
- Current design and operational intent and actual control sequences all equipment included in the project



The owner's goals determine the extent of the assessment activities.

- Operational cause and effect issues (why something cycles on/off, modulates open/shut, varies in speed or flow, etc.)
- Current run-hour schedules (time-of-day, holiday, lighting, etc.)
- Current set point, reset, setback, setup, and lockout schedules
- The most severe control and operational problems
- The most comfort problems or trouble spots in the building
- Current O&M program including PM schedules and service contracts
- Adequacy of building documentation
- Match of O&M staff skills to building technologies
- Which tenants and what activities influence how the building is operated and maintained
- Organizational policies and procedures that impact operating and maintaining the building

As the assessment progresses, the O&M consultant begins to compile the master log of findings and recommended improvements. This list ultimately becomes an important decision making tool for the facility manager and building staff and is a primary product (deliverable) of the assessment effort. Every finding is summarized on this list, including any minor adjustments and repairs made during the course of the investigation. At minimum, the list should include the name of the system or piece of equipment, a description of the deficiency or problem, and the recommended solution. In many cases the list may also include a savings estimate or benefit statement for each item. See Appendix D for a sample Master Log of Findings.

Appendix D contains a sample master log of findings.

Diagnostic Monitoring and Testing

During the O&M assessment the consultant or building staff often performs some diagnostic monitoring and functional testing of equipment. In buildings with energy management systems they may use the system to trend critical data points as part of the investigation, provided the system has trending capabilities and the points chosen for trending are calibrated prior to the effort. Once the initial information from the interviews, forms, and minor diagnostic testing is analyzed, it may be necessary to further

test the systems to help understand how they are performing over a selected period of time.

Diagnostic monitoring not only gathers equipment-specific electrical data but also allows the O&M consultant to observe space, plant, and outdoor temperatures along with flows, pressures, speeds, and lighting levels under typical operating conditions. By analyzing this information, the consultant and O&M staff determine whether the systems are operating correctly and efficiently. Three typical diagnostic methods are EMS trend logging, portable datalogging, and manual functional testing. Often, a combination of these methods is used.

Portable dataloggers are often used alone or in concert with the EMS for short-term (several days to two weeks) monitoring and diagnostics.⁶ For buildings lacking an EMS or where the EMS has limited capabilities, portable dataloggers offer the only solution to tracking equipment performance over time. Short-term diagnostic monitoring serves two main purposes. It helps to more accurately locate and verify problems and it provides more accurate information for calculating energy savings. See Figure 3 for a sample plot resulting from diagnostic monitoring with dataloggers. Any problems or deficiencies that are found during the diagnostic period of the assessment are compiled and added to the master log of findings and recommended improvements.

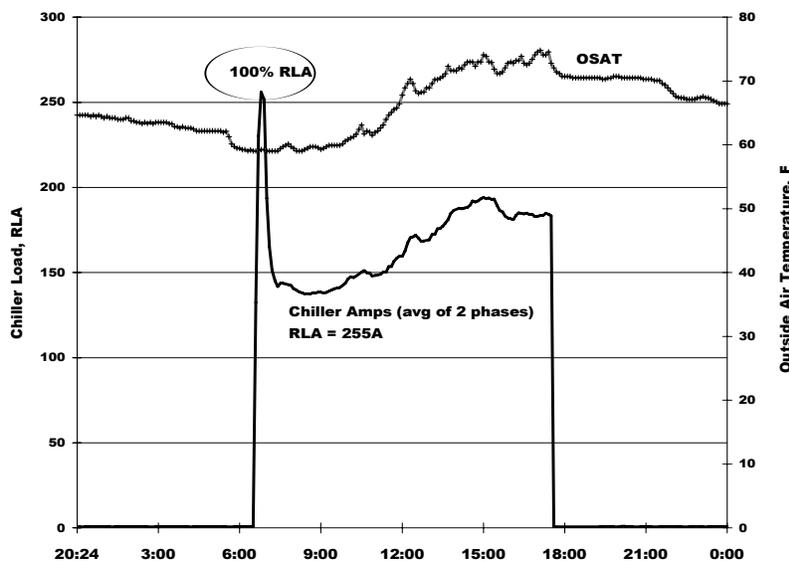


FIGURE 3
Datalogger Plot

This datalogger plot shows a demand spike when the building's chiller starts during a typical morning. This demonstrates that the soft-start capability of the integral controls was never programmed when the chiller was installed. Depending on the electric utility's rate structure this oversight may be costly if it is allowed to continue year after year. Programming of the integral controls to eliminate this problem may take only minutes.

⁶ For more information on portable dataloggers, see "Portable Dataloggers-Diagnostic Monitoring Tools for Energy-Efficient Building Operation," another publication in the EPA O&M Best Practices Series.

Reporting the Results

The O&M consultant prepares a comprehensive final report that may include most of the required deliverables for the project. The following lists the categories for a typical O&M assessment final report includes the following sections:

- Executive summary
- Building / systems description
- Scope of the O&M assessment
- Utility bill analysis (if required by owner)
- The original assessment plan along with corrections and changes
- Complete master log of findings (deficiencies and recommended improvements)
- Estimated cost and benefit analysis for implementing the recommended O&M improvements
- Improved documentation according to the scope of work (updated drawings, written sequences of operation, updated design intent, improved preventive maintenance plan, etc.)
- List of recommended capital improvements for further investigation (as required by owner)
- EMS trending plan and datalogger diagnostic / monitoring plan (optional by owner)
- Resulting data and analysis from EMS trending and portable dataloggers
- All completed functional tests and results

Once the consultant has submitted the final report for review by the owner and owner's staff, it may be desirable, budget permitting, to hold a close-out meeting. The close-out meeting should include those directly responsible for working on the assessment along with any individuals that may be responsible for carrying out or influencing the next steps for improving the building's performance. This meeting is valuable for discussing what worked and what didn't and the lessons learned during the O&M assessment process. It also provides an important opportunity to recognize individual successes, celebrate the overall success of the project, and discuss next steps.

 *A close-out meeting allows the team to discuss lessons learned, celebrate their successes, and review next steps.*

INCREASING COST EFFECTIVENESS

Thorough preparation and willing participation by the building staff prior to and throughout the assessment process can reduce the overall costs. This section reviews some ways that the owner and owner's staff can help increase the effectiveness of the consultant's time. If the project, due to size or complexity, requires using a bid process for obtaining consulting services, the request for proposals should state the assessment responsibilities of the in-house building staff. This helps bidders understand what they can expect from the owner's staff and develop their budgets accordingly.

Staff can gather building documentation beforehand to reduce the cost of the assessment.

Gather Building Documentation

Compile an *up-to-date* building documentation package prior to performing the O&M assessment. Otherwise the consultant will need to gather this information as part of the assessment process, which can be an expensive undertaking. The documentation packet should be available at the building and include as much of the following information as possible:

- Drawings relevant to the systems targeted for commissioning
- O&M manuals
- Testing, adjusting and balancing (TAB) reports
- Original design documentation (if available)
- An equipment list with nameplate information, dates of installation, and submittals including pump curves and fan curves
- List of outside service contractors regularly used
- Current PM logs or schedules
- Copies of current service contracts
- Control system documentation, such as sequences of operation, special control strategies, control diagrams, points list, control program or code, etc.
- 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
- 15-minute electrical demand data, if available

It is possible that some of the information will not be readily available, such as pump curves, fan curves, and written sequences of operation. However, the more documentation that the owner's staff can update and compile, the less time the consultant needs to spend obtaining this information.

Perform Appropriate Preventive Maintenance

The owner or manager should take special care to make sure that in-house staff or an outside maintenance service contractor completes scheduled preventive maintenance (PM) work before the assessment begins. For example, if the assessment occurs during the cooling season, the annual PM tasks for the cooling plant and systems should be completed before commencing with the project. Typical deficiencies (dirty filters, broken or cracked belts, etc.) normally taken care of through scheduled preventive maintenance should not be left to the O&M consultant to find and recommend fixing. The consultant's time is better used helping the building staff to find and solve operating, design, and installation problems rather than equipment-care deficiencies. Also, if the EMS will be used to gather trend data during the project, calibrate all sensors that will be used for data gathering purposes.



Perform all scheduled preventive maintenance before the assessment begins.

Perform Simple Repairs and Improvements as the Project Progresses

Depending on their skill level, building 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 assessment increases the effectiveness of any diagnostic monitoring and testing that may occur later in the process. For example, there is no sense in waiting 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" that occur over the course of the project. Often what appears to be a simple problem, once fixed, may allow the diagnostic testing to uncover a larger but more subtle problem.

Perform Diagnostic Monitoring and Functional Tests

It is often appropriate and cost effective to have the most motivated and interested building staff members assist the consultant with the short-term diagnostic monitoring,

trend logging, and functional testing that occurs during the course of the assessment. This may help reduce project costs and provide the building staff with a learning experience that they can reapply later. If building operators are trained to initiate EMS trend logs, it reduces the amount of time the consultant needs to spend on the task. It also eliminates the need to hire a controls contractor to do the trending. The consultant develops the trend plan and analyzes the data that building operators collect.

Building staff may also assist with the installation and removal of the portable dataloggers used for short-term diagnostics and assist with carrying out the functional test plans. Their assistance reduces costs and gives them exposure to different approaches to troubleshooting problems and investigating and verifying equipment performance.

NEXT STEPS

The O&M assessment expands and enhances the information required to operate a building in an energy-efficient manner. However, much of the information provided by the O&M assessment may be useless if none of the recommended improvements are carried out. Five to twenty percent of the annual utility bill can be saved by implementing low cost O&M improvements. Therefore the most important next step is to implement the recommended improvements.

The owner or manager must decide which items on the master log provide the most benefit and effectively meet the organization's objectives. Although each of the findings may yield definite benefits some are usually more cost effective to implement first. For example, in some buildings it may be more cost-effective to implement plant-related control strategies and schedule changes that obtain comparatively quick paybacks before performing more labor-intensive fixes, such as rebalancing the air distribution system. It's not unusual to expect a simple payback of 18 months or less for the recommended improvements that produce energy savings. The savings generated from these improvements can sometimes pay for other improvements that have less quantifiable benefits.

Next steps may also include:

- Developing an organization-wide plan for performing O&M assessments on all of the organization's buildings.
- Reviewing the recommendations for capital improvements and deciding whether to further investigate their benefits and costs.
- Revising the preventive maintenance plan to include periodically checking operating strategies and schedules for optimization opportunities.
- Tracking critical temperatures, flows, currents, and other indicators of efficient equipment performance.

GLOSSARY OF TERMS

Commissioning. According to ASHRAE Guideline 1-1996, the process of ensuring that new systems are designed, installed, functionally tested, and capable of being operated and maintained to perform in conformity with the design intent.

Datalogger. A stand-alone, electronic data gathering device that utilizes sensors to collect equipment information over time. Data collected could include temperature, pressure, current, humidity, or other operational information.

Diagnostic Monitoring. The practice of collecting data on equipment operation over a period of time for the purpose of assessing the equipment performance. This data may be obtained through a **datalogger** or an **energy management system**. This data may consist of time-series or change-of-value (COV) data that can be collected for digital points such as temperature, pressure, or status.

Energy Accounting. The process of tracking and analyzing energy use for the purpose of detecting problems, trends, or savings opportunities. Typically, energy accounting is performed for an entire building. In the analysis process, adjustments may be made for variations in weather, space use, or other variables from year to year.

Energy Assessment (audit). An investigation of systems in existing buildings with the goal of replacing or retrofitting equipment. This is a quick process that may include building simulation and results in a list of energy conservation measures that involve significant capital investment.

Energy Management System. The automatic system used for controlling equipment in a building. Most likely, this will be a computer-based system, including either pneumatic or digital components, or both.

Investment Grade Audit. An audit that incorporates the aspects of a traditional **energy audit** plus a risk assessment that evaluates the impact that occupancy, management, maintenance and operational behavior will have on energy-efficiency measures.

Nameplate Information. For a piece of equipment, the information that gives the make, model, size, capacity, electrical draw and other relevant factory data. This information is sometimes found imprinted on a plate affixed to the equipment.

O&M Assessment. A systematic method for identifying ways to optimize the performance of an existing building. This assessment involves gathering, analyzing, and presenting information based on the building owner or manager's requirements.

O&M Consultant. A consultant who is hired by the building owner to assist with an **O&M assessment** or **retrocommissioning** in a management or oversight role. This consultant guides the owner through development and distribution of a **request for proposal**, through commissioning provider selection, and possibly assists in creating a program for retrocommissioning implementation at all owner facilities.

Payback. The length of time that an energy-efficiency improvement will take to provide the full return on investment. For example, if a \$1,000 investment will yield \$1,000 in energy or maintenance savings by the end of the first year, that investment has a 1-year payback.

Preventive Maintenance Program. A program that is implemented to address equipment maintenance issues proactively. The goal of such a program is to perform maintenance tasks on a regular schedule so as to maximize the operational efficiency and lifetime of the equipment.

Request for Proposal (RFP). A document that a project manager uses to solicit services. The RFP may ask for a proposed approach, budget, and qualifications. The owner will then select a service provider from among the responses received.

Retrocommissioning. For an existing building, the process of assessing, analyzing, and upgrading its operational performance. A preliminary step in the retrocommissioning process is the **O&M assessment**. Retrocommissioning usually results in a number of low-cost or no-cost activities that save energy while maintaining or improving comfort.

Trend Log. A log of data that is collected through an **energy management system**. This data may consist of time-series or change-of-value (COV) data that can be collected for digital points such as temperature, pressure, or status.

LIST OF ACRONYMS

COV	Change of Value
DOE	U.S. Department of Energy
EMS	Energy Management System
EPA	U.S. Environmental Protection Agency
HVAC	Heating, Ventilating, and Air Conditioning
IAQ	Indoor Air Quality
IGA	Investment Grade Audits
IRR	Internal Rate of Return
O&M	Operation & Maintenance
PM	Preventive Maintenance
TAB	Test and Balance

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This publication is part of the O&M Best Practices Series, which includes the following books:

- 15 Operation and Maintenance Best Practices for Energy-Efficient Buildings
- Operation and Maintenance Service Contracts: Guidelines for Obtaining Best-Practice Contracts for Commercial Buildings
- Portable Data Loggers - Diagnostic Monitoring Tools for Energy-Efficient Building Operation
- O&M Assessments: Enhancing Energy-Efficient Building Operation
- Energy Management Systems - A Practical Guide
- Putting the “O” Back in O&M: Best Practices in Preventive Operations, Tracking, and Scheduling



SAMPLE SITE-ASSESSMENT FORMS

*Best Practices in O & M Assessments
for Energy-Efficient Buildings*

These sample forms are included to help owners and facility managers understand what services and deliverables to expect from an O&M assessment.

Assessment forms help guide the building staff interview process. The O&M consultant develops assessment forms for each piece of equipment and system that is part of the project scope. The forms may address either operation or maintenance issues or both depending on the project requirements. The site-assessment is an information gathering exercise. Minor repairs and simple improvements may be implemented during the assessment. However, the major improvement recommendations become part of the final report and are handed off to the owner for implementation.

The sample forms in this appendix include an initial O&M staff interview script and site assessment forms for domestic hot water control and operation and pumps. The pump assessment form package consists of three types of forms: a control investigation form, a condition investigation form, and a nameplate data form. If gathering nameplate data is a part of the project scope, it may be more cost-effective to assign this tasks to O&M staff prior to the start of the assessment.

Sample Site-Assessment Form – Initial Interview

The following are sample questions for the initial interview process with facility staff members.

General O&M Questions

Has your heating system always met load? Yes No
Under what conditions has your heating system not met load?

What was or is your solution for this problem:

Has your cooling system always met load? Yes No
Under what conditions has your cooling system not met load?

What was or is your solution for this problem:

Do you feel you have any HVAC equipment that is undersized?
If yes, explain: Yes No

How do you compensate for the undersizing?

Do you feel you have any HVAC equipment that is oversized?
If yes, explain: Yes No

How do you compensate for the oversizing?

Is the building mechanical equipment (fans, pumps, etc.) scheduled to start up simultaneously or is the startup staged (explain)?

What HVAC adjustments do you make for unoccupied areas or spaces (turn off HVAC, adjust thermostat to minimum heating and cooling, close off diffuser, etc.)?

In your opinion, is the building HVAC system well balanced?
If no, explain: Yes No

Explain the method of humidifying the building:

Are there any problems with humidification (explain)? Yes No

Explain the method of dehumidifying the building:

Are there any problems with dehumidification (explain)? Yes No

From which areas in the building do you receive the most complaints (explain nature of complaints)?

What is your worst building problem and how do you deal with it?

Do you receive utility bills or energy accounting reports on a regular basis?
If YES, are they useful (explain)? Yes No

Comments and Notes:

Sample Site Assessment Form for Domestic Hot Water

What is the temperature setpoint for each of the building's hot water heaters?

Heater ID	Area Served	Nameplate Data	Temperature Setting	Reason for Setting

- Explain method of domestic hot water control? _____

- If hot water is preheated, explain method? _____

- Do the recirculating pumps run continuously? _____

Notes, Comments, and Observations:

Summarize deficiencies and possible improvements on Master Log:

Sample Assessment Forms: Pump Control

Pump Control Questions:

Circle or explain what function the pump(s) serves:

Condenser Water Chilled Water Primary Chilled Water Secondary

Heating Water Primary Heating Water Secondary

Other _____

Number of Pumps: _____ Parallel or Series (circle one)

Pump ID #(s): _____

Facility Name for Pumps: _____

- What causes the pump to initially start? _____
- What causes the pump to cycle? _____
- How is capacity controlled, VFD, etc? _____
(If a VFD is used attach VFD Assessment Form to the appropriate Pump Form)
- If applicable, what is the differential pressure control point? _____
- If there is a lead/lag strategy, explain: _____
- If pumps are staged, explain: _____

Notes, Comments, and Observations:

(Summarize deficiencies and possible improvements on Master log)

Sample Assessment Form: Pump Nameplate Data

Pump Nameplate Information

Use N/A for not applicable and N/O for not obtainable or available.

Pump Function: → (Heating water, condenser, etc)				
Pump ID or Number				
Pump Manufacturer				
Model Number				
Serial Number				
Age				
Impeller size				
Head pressure				
Suction Pressure				
Discharge Pressure				
GPM				
Motor Manufacturer				
Motor Model #				
Phase				
Volts phase to phase	Nameplate: Measured:	Nameplate: Measured:	Nameplate: Measured:	Nameplate: Measured:
Volts phase to ground	Measured:	Measured:	Measured:	Measured:
Amps for each phase	Nameplate: Measured:	Nameplate: Measured:	Nameplate: Measured:	Nameplate: Measured:
kW	Measured:	Measured:	Measured:	Measured:
Power Factor	Measured:	Measured:	Measured:	Measured:
HP				
RPM				

Notes, Comment, and Observations:

Sample Assessment Form: Pump Condition Checklist

Check if okay; enter comment number if deficient. Document comments by number form provided below checklist. Use N/A for not applicable and N/O for not obtainable or available.

Pump ID:				
General condition good (clean and appear well maintained)				
No unusual noise or vibration				
No leaks				
Thermometers on supply and return				
Pressure gauges installed across pumps and functioning (if so, record pressures)	Suction: Discharge:	Suction: Discharge:	Suction: Discharge:	Suction: Discharge:
Pump rotation correct				
Properly balanced				
Strainers in place and clean? State when strainers were last cleaned				
Piping properly insulated				
Piping generally in good condition				
Valves in good condition - no leaks				
Water treatment in place and operating				

Use the back of this form or attach notes briefly describing the preventive maintenance program for the pumps.

Number	Comment

Summarize all deficiencies and possible improvements on the Master Log:

B



O&M ASSESSMENT REQUEST FOR PROPOSAL CHECKLIST

*Best Practices in O & M Assessments for
Energy-Efficient Buildings*

This appendix contains a checklist of information for preparing an RFP to obtain O&M assessment services. This checklist is not comprehensive, but includes items specific to the assessment process that will help obtain a realistic proposal.

O&M Assessment RFP Checklist

- Include clear objectives (energy, comfort, building control, etc.) and assign a priority to each.
- Provide information about the building or buildings involved in the assessment. At minimum include:
 - A brief building description
 - Square footage
 - A general HVAC description (central plant as well as distribution system for both heating and cooling); controls system description
 - A list of major equipment, including number and age of each type that is included in the assessment
 - A brief renovation, retrofit and equipment replacement history
 - A building use description
- Provide as much information on the trending capabilities of the EMS as possible. Ideally, provide a complete points list. This increases the bidders' ability to more accurately budget the data acquisition tasks. Also state whether the system can be accessed remotely (by modem).
- Provide a list of available, up-to-date building documentation.
- Include as complete a scope of work as possible. If it is unclear what the scope of work can realistically include, allow step one of the project to address developing a detailed scope of work. Or, hire an experienced O&M consultant to help develop the scope of work for the RFP. The scope of work should include a list of equipment and building systems that are included in the assessment. State the extent to which the assessment includes zone level equipment (all, none, or a sampling strategy). Also, clearly state in-house building staff's and/or service contractor's responsibilities in assisting with the assessment. Clearly list the O&M consultant's primary responsibilities.
- Request the O&M consultant's general approach and a skeletal assessment plan for the project. Otherwise specifically ask the bidder to detail their approach on these issues.
- List the specific support that the consultant can expect from the facility staff and service contractors (particularly the controls vendor) and state the skill level of each facility staff member. State how much testing and investigation facility staff can perform.
- When requiring savings calculations/estimates, state the desired method for completing the work (qualitative ranking of measures for implementation using expert judgment, cost estimates and engineering calculations of savings, costs from actual bids and bin or computer simulations of savings).
- List the required qualifications for the consultant and qualifications for any subcontractors.
- Request work examples from previous projects (final reports, Master Log of Findings, etc.).
- List the RFP selection criteria.
- Give a cost range for the project.
- Provide a list of required deliverables.

Other RFP checklist items:

C



O&M SAMPLE PROCEDURES AND PLAN

*Best Practices in O & M Assessments
for Energy-Efficient Buildings*

Appendix C contains sample O&M Assessment Procedures and a Plan for a typical office building. The procedures may be modified for more or less detail depending on the scope and objectives of the project and building type. This appendix is intended to give owners and managers an idea of what to expect from the O&M assessment process.

Sample Operations O&M Assessment Procedures and Plan

Name of Building: _____

Site Address: _____

Version: Draft for Review
 Final Approved

Owner / Manager

Date

Primary Site Contact and Telephone / Fax/ and E-mail:

O&M Consultant: _____

Firm: _____

Telephone / Fax / E-mail:

Overview

This document outlines site procedures for the operations and maintenance assessment for Building 1. Energy savings and improving building control are the primary focus. The assessment objectives are to:

- Gain an in-depth understanding of how and why the building systems and equipment are currently operated and maintained
- Identify ways in which operations might be improved
- Gain information to help focus the diagnostic monitoring and testing
- Identify equipment replacement needs for further investigation

Steps in the assessment process include interviewing the facility O&M staff, conducting site inspections of all primary energy using equipment and examining control sequences, setpoints, control parameters and schedules. The initial site assessment does not include in-depth equipment testing. Problems and improvements are identified solely by gaining information from facility staff, equipment vendors, the control system and written documentation.

The O&M consultant will generate a list of significant improvements based on the assessment alone, prior to any monitoring or functional testing. The assessment information will also reveal areas where formal monitoring and testing have the most potential to identify further operational improvements.

Work Plan and Procedures

The first step in the assessment is to hold an initial kick-off meeting where all parties will meet to review the building operations assessment procedures and protocols and the project schedule. During the assessment, the O&M consultant will interview facility staff to obtain general building information, detailed operations, equipment, and maintenance information. Furthermore, facility staff will accompany the consultant on the initial walk-through and subsequent inspections.

The assessment consists of the eleven tasks listed below.

1. **Obtain an Understanding of the Building Equipment and Systems**

Obtain general information about the building energy use systems, how the systems are controlled and how the building spaces are used.

- Review all requested building documentation (equipment list, mechanical and control drawings, etc.). This task may be completed off-site, prior to other assessment activities.
- Interview facility manager and building operator/engineer for general information about the building equipment, systems, and operation, as needed, depending on how much documentation is available.
- Through all phases, keep a findings and recommendations log.
- Perform a general walk-through of building spaces, equipment and systems to become familiar with their layout and function.
- Interview facility staff again for more detailed information and to answer new questions.
- Interview the controls vendor and HVAC service contractor, if necessary.
- Revisit plans and documentation as necessary.

2. **Understand the Building's Energy Use Profile and Identify the Largest Energy Using Equipment**

Identify what single pieces of equipment and systems or groups of smaller equipment controlled together are the largest energy users. For larger buildings (>60,000 sf) gather and analyze utility bills.

- Gather, tabulate, graph and analyze monthly utility bills for up to four years. Obtain 15-minute pulse data, if available. If necessary, use energy accounting spreadsheet or software.
- Normalize data to weather or occupancy conditions, if possible.
- Graph a 12-month rolling average consumption. Look for trends and changes in energy use. Determine causes.
- Graph consumption and demand over 12 months. Look for anomalies. Determine causes.
- Calculate electric load factor [monthly kWh / (monthly kW X days in month X 24 hrs)]. If less than 0.15, look for demand spikes.
- Examine 15-minute load profile, if available, for spikes and loose schedules.
- Interview facility staff.
- Review equipment lists, nameplate data, plans, equipment and system documentation (some of this task may be completed prior to site visit).
- Visually inspect equipment, if necessary.
- Identify where the majority of costs are being incurred (cooling, heating, base load, etc.).

3. **Identify Known Problematic Control and Operational Problems**

Identify the most severe operational problems for the building operators and facility management.

- Interview operators and facility management.
- Visually inspect problematic equipment, as needed.

Note: During the entire assessment process, improvements that can be immediately and easily implemented, such as control parameter or setpoint changes, and that will not negatively affect the future diagnostic monitoring, may be implemented as they are identified, with the proper authorization and documentation.

4. **Identify the Design and Operational Intent and Control Sequences**

For the largest energy users and for equipment related to the most severe control and operational problems, identify the purpose of the equipment and its operating parameters (such as what causes the equipment to turn on and off, cycle and stage). Also investigate the factors that limit or influence optimal equipment operations. Clearly understand the sequence of operations and all related setpoints, schedules, resets, and lockouts.

- Interview operator (and service contractors if necessary).
- Review plans, control drawings, sequences, building automation system program.
- Discuss the energy-efficient equipment currently installed in the building.
- Gather and review equipment and system documentation.
- Inspect control program(s).
- Document the control sequences for each piece of equipment. Attach the original written sequences (provided by facility staff) with annotations from this task.
- Document control sequences and strategies.
- During the site assessment interviews and documentation review, develop any missing documentation of important control sequences.

5. **Identify Procedures to Reduce Unnecessary Runtime and Unnecessary Capacity Levels**

5.1. Identify when and why each of the significant energy using equipment or systems is operating. Understand capacity control and identify who controls or influences the schedule.

- Interview operator and janitorial staff.
- Inspect control schedules, clocks, etc.
- Conduct a night audit (when diagnostic monitoring is not used).
- Identify equipment monitoring needed to better complete this task. Monitor now if no further monitoring is planned, otherwise feed this information into the monitoring plan.

5.2. Determine the times that the largest energy-using equipment **must** operate and at what capacity level¹ it **must** operate to properly fulfill its intended function.

- Interview operators, janitorial staff, and possibly tenants.
- Review design intent (if available) and required sequences of operation.

5.3. Identify methods to reduce the duration and level¹ of current equipment operation to the minimum point necessary to maintain comfort, productivity and equipment life.

- Analyze the needs and systems based on gathered information, manufacturer requirements and judgment.
- Discuss recommendations with operator.
- Consider changes to control system, time clocks, and manual schedules.
- Consider upgrading to more automated control.
- Document scheduling and capacity control improvements.

¹level here refers to set points of supply air, mixed air, space temperature, quantity of outside air, exhaust fan speed, light levels, etc.

6. Document Identified Equipment Condition Problems (broken dampers, dirty coils, sensor calibration, etc.)

- During the site assessment walk-through and interviews keep a list of equipment that shows significant condition problems.

7. Identify Changes to Control Parameters, Strategies, Set Points, Sequences or Maintenance Activities that will Optimize Efficiency, Comfort, Operation and Control

- Analyze current parameters, setpoints, deadbands, offsets, setups, setbacks, lockouts, multiple equipment staging parameters, interlocks with other equipment or events, energy-efficient strategies, etc. Identify appropriate changes that will reduce energy consumption or improve control while maintaining comfort, productivity and equipment life.
- Explicitly examine and minimize any simultaneous heating and cooling.
- Discuss the ideas with facility staff, as needed, to verify viability of the concepts, including cost considerations.
- Note the agreed solution in the recommended improvement section of the Master Log of Findings.

8. Develop and Implement Diagnostic Testing and Monitoring Plans

- From initial site assessment interviews and walk-through, determine the need for and extent of diagnostic monitoring and testing to help verify the existence of suspected problems.
- Select the method of testing such as trending with EMS, gathering data with portable dataloggers, and/or spot testing with handheld instruments.
- Develop and implement the diagnostic plan.
- Analyze the diagnostic data and record findings on the master log along with recommendations.

9. Identify Facility Staff Training Needs

- Interview facility staff and discuss current levels of staff training, current training policy and ask if additional training is needed.
- Determine whether staff needs additional training.

10. Recommend Equipment Upgrades that may be Cost-Effective

- During the normal course of examining the building documentation and from the rest of the site assessment activities, keep a list of possible upgrades to equipment that may prove to be cost effective.
- At the end of the site assessment, evaluate whether efficiency upgrades for major energy-using equipment are worthy of further consideration, taking into account current efficiency, condition and age. (This list of recommendations is based solely on professional insight and expertise. It is not the result of a comprehensive energy audit.)

11. Document the Assessment Process and Results

- Document the general assessment process and findings.
- Finalize the recommended improvements resulting from the assessment. The recommendations list will include the name of the system or piece of equipment involved, a description of the deficiency or problem, and a suggested solution.
- Suggest areas for further investigation, monitoring and functional testing.
- Submit the assessment documentation to the owner.
- Create permanent documentation of control sequence changes or clarifications, including a listing of all set points and schedules.

D



SAMPLE MASTER LOG OF FINDINGS

*Best Practices in O & M Assessments
for Energy-Efficient Buildings*

Appendix D contains a sample master log of findings from an O&M assessment.

*Acronyms used in the master log of findings
are as follows:*

D = design

M = maintenance

O = operation

AC = air conditioner

CT = cooling tower

EMS = energy management system

MFG = manufacturer

OSA = outside supply air

RA = return air

TOD = time-of-day

VAV = variable air volume

VFD = variable frequency drive

Sample: Master List of Deficiencies and Potential Improvements (from an actual project)

Item #	Equipment or System ID	Description of Finding	Recommended Improvement	Type*	Status
1	All Plant Equipment	Manual Start up and shut down of boilers, chillers, pumps. Automatic scheduling not incorporated.	Include and implement automatic scheduling for plant equipment. Using optimum start incorporate setup and set back strategies.	O	Done.
2	Boiler Control	Control strategy for loss of boiler not programmed.	Add programming to allow automatic start up of 2nd boiler on loss of 1st boiler.	O	Done
3	Chillers 1 and 2	Lacks interface with EMCS - (see also #2).	At minimum, allow EMS to enable and disable the chiller and add monitoring points for water temperatures and run status.	O	Done. Retest deferred until cooling. Season.
4	Chillers 1 and 2	Chilled water reset capability not used.	At minimum, allow the chiller's integral controls to reset chilled water temperature. (See manufacturer's instructions.)	O	Reset installed through EMS system.
5	Chillers 1 and 2	Energy tracking.	Add points to EMCS to allow energy and demand tracking for both chillers.	O/M	Done.
6	Chillers 1 and 2	Chillers do not operate in parallel per original design intent.	Have design engineer and chiller mfg. review present chilled water system. Request a proposal for design changes necessary to allow chillers to stage as a lead/lag system.	D	Design referral. Design review in process.
7	Chiller 1 and 2	High demand on start up.	Consider employing soft start through EMS or integral controls.	O	Soft start added to chiller start up.
8	EMCS	Trending not installed.	Add trending capabilities to EMS to improve building staff troubleshooting abilities.	O/M	Done.
9	Heat/Cool Change over	Manual change over between heating and cooling.	Add points needed to incorporate automatic change over strategy.	O	Done.
10	Chilled Water Pump, P-1	Pump is possibly oversized. Piping is possibly undersized.	Investigate sizing of the pump. Check amps against nameplate during full load conditions. Review piping.	D	Pump review Done. Piping design referral review in process.
11	Condensate Pump inside AC-1	Pump located inside of AC-1 may cause high discharge air temperatures.	Investigate possible relocated pump or venting it to mech. room. (Does the pump run continuously?)	M	Insulated for temporary solution.
12	Cooling Tower Fans	Diagnostics show tower cycles on primary fan only. Pony motor not working.	Troubleshoot CT. to determine staging problem Repair so pony motor cycles as 1st stage.	M/O	Done.
13	Cooling Tower Control	Integral chiller control for staging cooling tower fans not used. Temperature bulb for sump may be poorly located.	Investigate using the chiller capability of staging the cooling tower fans based on condenser differential refrigerant pressure. If present strategy is kept, relocate temp. bulb lower in pan and closer to outlet.	O	Delta P Strategy not appropriate. Staging from sump temp. better method. Bulb relocated.
14	Cooling Tower 3-way Valve	According to functional tests, the valve doesn't modulate to maintain condenser water temperature as it should.	Troubleshoot problem and repair so valve modulates as designed.	D/M/O	Repaired. This will be rechecked as part of the design review and PM recommissioning.
15	Heating System	Data shows heating water supply temperatures. Between 80 and 90°F.	Investigate. Normally heating water temp is between 140 and 180°F.	O	Resolved with new reset schedule.
16	Plant Instrumentation	Pressure and Temp gages missing from plant piping.	Install pressure and temperature gages on chiller, boiler, and pumps as needed to facilitate maintenance and troubleshooting.	M	As time and budget permits for building staff.

Sample: Master List of Deficiencies and Potential Improvements (con't)

Item #	Equipment or System ID	Description of Finding	Recommended Improvement	Type*	Status
17	East Primary Air Unit AC-1	Data shows inconsistent control of supply and mixed air. Steam valve erratic during temps below 35 deg. F.	Correct through EMS.	O	Done
18	West Primary Air Unit AC-12	Data shows erratic control of supply air and no drop in supply air temp when chillers were on.	Investigate. Remonitor during second round of diagnostics by measuring mixed air temp also.	O	Done.
19	AC-13 (Multizone Unit)	Data shows wide swings in hot and cold deck temperatures resulting poor control of space temperatures.	Improve control through EMS. Investigate damper and valve functions	O/M	Done. Retest show correction successful.
20	AC-13 (Multizone Unit)	Data shows poor economizer control.	Improve economizer control through EMS. Investigate damper function. Consider enthalpy control using EMS.	O/M	Same as 18.
21	All Air Handlers:	TOD scheduling not used.	Include and implement TOD scheduling. Stagger start time at occupied target and following power loss.	O	Scheduled from plant equip. through EMS.
22	Air Handler AC-1s OSA Preheater	Preheat coil is not functioning properly. Present averaging bulb sensor (input for controlling the steam valve) was found to have 70% of its sensing element outside of the unit.	Relocate averaging bulb sensing element to read temperature of air stream. Ensure freeze protection operates to shut OSA damper when OSA conditions dictate. Check control strategy through system.	M/O	Done. Averaging bulb relocated.
23	Air Handler AC-11 through 18	OSA dampers not controlled to take advantage of economizer capability.	Program system and add humidity sensors (outside and inside) to employ enthalpy control for economizing. At minimum use dry bulb control.	O	Done. 11, 13, 15, 18 fine tuned.
24	AC-15 and 18	Data shows AC-15 OSA damper always closed and AC-18 opening partially some of the time.	Improve economizer control with EMS program and investigate damper function. (See also above #22)	O/M	Same. Done.
25	Air Handlers AC-4,5 and 10	No air side economizing.	Add actuators to OSA and RA dampers along with EMS points and program to take advantage of economizer function.	O/D	10 are done. Others dependent on AC-1. Design review in progress.
26	VAV Operation and Control for west conf. space	VAV boxes are secured open and the VFD is circumvented. Test need for duct heaters.	Consider reinstating the VAV system using the VFD. Repair reheat if they are needed.	M/O	Done. VFD working. Reheats not needed.
27	OSA Temperature Sensor	Calibration issue.	Check calibration of OSA temperature sensor, relocate, and properly shield if needed.	M/O	Done. Relocated to roof using weather resistant type sensor and shielding.
28	EMS	Facility staff did not receive adequate training on EMS.	Provide 40 hours of training to facility staff using original specification. Train building staff to present data in graphical format.	O	40 hours of training specified and complete.
29	Domestic Hot Water	High water temperature (140).	Lower domestic hot water to 110°F for restrooms and 120°F for showers. Kitchen needs for hot water have priority over this strategy.	O	Presently, higher temp needed for kitchen. Point of use water heater to be installed in kitchen.

* O = operation; M = maintenance; D = design.

