



Proposed ASHRAE Guideline 32P

Public Review Draft

ASHRAE® Guideline

Proposed New Guideline 32, *Sustainable, High- Performance Operations and Maintenance*

First Public Review (**May 2011**)
(Complete Draft for Full Review)

This draft has been recommended for public review by the responsible project committee. To submit a comment on this proposed addendum, go to the ASHRAE website at <http://www.ashrae.org/technology/page/331> and access the online comment database. Comments submitted will provide input to the committee prior to issuing a formal public review draft. This draft document is not final and is subject to formal public review, further modifications, and final approval by the ASHRAE Board of Directors. The current edition of any guideline or standard may be purchased from the ASHRAE Bookstore @ <http://www.ashrae.org> or by calling 404-636-8400 or 1-800-527-4723 (for orders in the U.S. or Canada).

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(This foreword is not part of this guideline. It is merely informative and does not contain requirements necessary for conformance to the guideline. It may contain material that has not been subject to public review or a consensus process. Unresolved objections on informative material are not offered the right to appeal at ASHRAE.)

FOREWORD

The concept of sustainability has had a major impact on what we expect from our buildings and the built environment. It has brought new focus on energy, water, health and productivity dimensions of how our buildings perform and of measurement of this performance. This has been a significant and continuing change in the buildings industry.

This guideline is intended to assist those who operate and maintain buildings to achieve high performance: safe, productive indoor environments; low economic life cycle cost; low energy, water, and resource use and low impacts on the environment. It applies to the systems of commercial, institutional, industrial and laboratory buildings as they affect occupant comfort, indoor air quality, health & safety; and the energy & water consumed. These systems include the building envelope, HVAC, plumbing, complementary energy systems, utilities and electrical systems. The guideline is intended to provide next steps beyond compliance with ANSI/ASHRAE/ACCA Standard 180, Standard Practice for Inspection and Maintenance of Commercial Building HVAC Systems, and to provide concepts, methods and details that will meet the intent of the “minimum standards of care” under ANSI/ASHRAE/USGBC/IES Standard 189.1, Standard for the Design of High Performance Green Buildings

The guideline recognizes that many newly designed buildings are designed to be “sustainable” and “high performance” and that many more will be retrofitted to achieve such designations. Such new and retrofitted systems will require performance-monitored O&M to maintain their intended performance. However, this guideline is written to apply to all buildings, not just new, labeled ones. The authors believe that all buildings can move towards sustainable high performance in their operations and maintenance.

The authors, a committee of volunteers with a range of practical experiences in building performance work, recognize that the present work is not definitive and that the buildings operation industry is changing rapidly. We hope that this guideline can provide a starting place for many more practitioners and building operators to gain knowledge of current best practices and, in turn, to shape, develop and evolve this document through future editions.

This guideline is not written in code language as it is intended to be a reference document and not developed for referencing within building codes.

1 Purpose: The purpose of this guideline is to provide guidance on optimizing the operation and maintenance of the building to achieve the lowest economic and environmental life cycle cost, without sacrificing safety or functionality.

2 Scope: This guideline applies to the ongoing operational practices for a building and its systems, particularly with respect to energy efficiency, occupant comfort, indoor air quality, health and safety.

3 Definitions, Abbreviations, and Acronyms

3.1 General

This section contains definitions for certain terms, abbreviations, and acronyms for the purposes of this Guideline. These definitions are applicable to all sections of this Guideline. Terms that are not defined herein, but that are defined in standards that are referenced herein (e.g. ANSI/ASHRAE/USGBC/IES Standard 189.1) shall have the meanings as defined in those standards.

3.2 Definitions

Change Management: A process for directed organizational change.

Commissioning: A quality-focused process for enhancing the delivery of a project. The process focuses upon verifying and documenting that the facility and all of its systems and assemblies are planned, designed, installed, tested, operated, and maintained to meet the Owner's Project Requirements.

Commissioning, Ongoing: A continuation of the commissioning process well into the Occupancy and Operation Phase to verify that a project continues to meet current and evolving Owner's Project Requirements. Ongoing Commissioning Process activities occur throughout the life of the facility; some of these will be close to continuous in implementation, and others will be either scheduled or unscheduled (as needed).

Commissioning, Re-: Testing and tuning a building that has been previously commissioned to return it to acceptable operation.

Commissioning, Retro-: Commissioning an existing building after acceptance that was not previously commissioned.

Competencies: Groups of skills, behaviors, or knowledge that are identified as performance standards for a particular job. Competencies are applied to a particular job rather than an individual employee. They are typically validated by employees who are performing the competency at least an acceptable level. This level may also be called a "journeyman" level to distinguish between the entry level and mastery level of a skill. In writing competencies, consider how each will be evaluated.

High Performance Building: A building that consistently delivers a highly productive environment without wasting resources. Such buildings may have specialized systems that

require specific knowledge and awareness on the part of operators in order to maintain the intended operation and performance.

High Performance Operations and Maintenance: A set of actions that results in enhanced indoor environmental qualities while minimizing use of energy and other resources.

Maintenance: the day-to-day activities required to preserve, retain or restore equipment and systems to the original condition or to a condition that it can be effectively used for the intended purpose.

Maintenance, Predictive (planned): Use of periodic or on-going measurements to detect evidence that machinery is deteriorating. Special diagnostic equipment, which requires additional staff training, is needed, but it will maximize equipment life and efficiency. Also described as Condition-based Maintenance.

Maintenance, Preventive (planned): Preventive maintenance occurs at time intervals or at run-hour milestones. As equipment and systems are capital intensive, this is more cost-effective than reactive maintenance.

Maintenance, Reactive (unplanned): A “run it until it breaks” maintenance approach. In the short run, this saves staff time and expense but over time it is costly in terms of unplanned equipment downtime, repairs and shorter equipment life. Also described as Breakdown Maintenance.

Needs Assessment: A structured approach to identifying and achieving skill development goals, typically involving interviews, work observations, and surveys to obtain information to design appropriate training solutions.

Operations: Any work completed to keep a building functioning to meet the needs of the building occupants; the process of running building systems to meet facility requirements.

Performance, HVAC: Measure of the success of an HVAC system in achieving thermal comfort, energy efficiency and indoor air quality (See ANSI/ASHRAE/ACCA Standard 180.). May be measured against established standards, specifications, criteria.

Performance Objective: The stated metrics for evaluating performance which may include written statements of performance, descriptions of normal operating characteristics and measurable and observable indicators that are the basis for evaluating or inspecting a system. (See ANSI/ASHRAE/ACCA Standard 180.)

Repair: Work required to restore a system or piece of equipment to the original condition after a failure or when predictive tools indicate defective operation and likelihood of failure.

Sustainable: (1) A process that meets the needs of the present while not compromising the ability of future generations to meet their own needs. (United Nations Brundtland Commission, 1987). (2) Able to be maintained at a certain rate or level. (Oxford English Dictionary)

Note on Sustainable as used in this document: Sustainable is used to indicate that building systems will be operated and maintained to minimize resource use while providing high quality building services, following meaning (1) above. Per meaning (2) above, sustainable is used to indicate that O&M practices can be kept at a certain level of performance and can keep building systems operating at intended levels of performance.

3.3 Abbreviations and Acronyms

ACCA	Air Conditioning Contractors of America
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.
BACnet	Data Protocol for Building Automation and Control Networks
BAS	Building Automation System
BCA	Building Commissioning Association
BIM	Building Information Modeling
BMS	Building Management System
BOC	Building Operator Certification
CA	Commissioning Authority
CAD	Computer Aided Design
CE	Commissioning Engineer
CIBSE	Chartered Institute of Building Services Engineers
CMMS	Computerized Maintenance Management System
COBie	Construction Operations Building Information Exchange
EBOM	Existing Building Operations and Maintenance (one part of the LEED Rating System)
EPA	Environmental Protection Agency
ERP	Enterprise Resource System
FDD	Fault Detection Diagnostics
FM	Facility Manager
HP O&M	High Performance Operations and Maintenance
HR	Human Resources
HVAC	Heating, Ventilating and Air-Conditioning
IEQ	Indoor Environmental Quality
IFMA	International Facility Management Association
KPI	Key Performance Indicator
LEED	Leadership in Energy and Environmental Design (Rating program from the USGBC)
LEED AP	LEED Accredited Professional

O&M	Operations & Maintenance
OPMP	Operations Performance Management Professional (ASHRAE Certification)
SHP	Sustainable High Performance
SM	Senior Management
USGBC	United States Green Building Council

4. Intended Users of the Guideline

This guideline is written for building owners, senior managers, facility managers (FM) and technicians. Maintenance service providers, energy efficiency service providers, commissioning agents and others who conduct business related to the performance of buildings may also find it valuable. The guideline is divided into three levels, as shown in Table 1. Each level is intended to provide the information that is most relevant to the identified user group.

Guideline users in larger organizations may find that some, or even many, of the recommended steps have been or are being implemented. For such users this guideline should provide confirmation and affirmation of their direction and, hopefully, some new ideas. For guideline users from smaller organizations or smaller facilities, much of the guideline content may be new and point towards future directions that represent organizational “stretch.” Such users may have more difficulty in application of the guideline but actually have the most to gain in adopting the perspective and steps described.

Table 1: Organization of the Guideline

Guideline Level	Topics Covered
Level 1: Senior Management	Benefits of HP O&M Management Commitment and Assignment of Responsibility
Level 2: Facility Managers	Establishing and Implementing the HP O&M Program Elements of Proactive, performance-monitored O&M
Level 3: Technicians	Skills, Knowledge and Training Tools for HP O&M

5 LEVEL I- SENIOR MANAGEMENT STEPS

5.1 Establishing Support From Above.

Commitment from the top of the organization is essential to move effectively towards Sustainable High Performance Operations and Maintenance (**SHP O&M**) in management of their facilities. The case for such a commitment is briefly reviewed here; it is developed at greater length in other documents.

5.2 Benefits of Sustainable High Performance (SHP). SHP workplace environments can be a significant strategic element as they affect the organization along multiple dimensions including: workforce productivity, brand image, environmental compliance, corporate social responsibility, valuation of real estate assets and net earnings. Organizational outcomes (such as profit for a business, learning for a school) are directly affected by the workplace environments their buildings produce.

High performance buildings produce environments that are highly productive for their occupants (Wargoeki 2000, 2006; Tom 2008). Workforce productivity decreases and utility costs increase in the building if the building performance is not sustained. The organization will pay more to accomplish less. While typically reducing utility costs from 10%-30%, effects of greater value are seen in the workforce:

- Higher productivity of building occupants

- Reduced employee turnover
- Improved job satisfaction and morale
- Reduced absenteeism
- Attraction of better employees

Successful managers of high performance facilities focus on sustaining the best atmosphere for the organization. Results include workplaces that are safe, comfortable and tuned to the operational requirements for people- and process-productivity.

5.3. Costs.

Costs for SHP are the investments in organizational change that result in the increased profits described above. The investments required will vary from organization to organization but usually fall into skills development, tools, and computerized task and performance tracking systems. When the benefits of SHP are quantified, the costs to achieve SHP are usually well justified. If the change process is to be implemented successfully, senior management must accept this business case and fully support those responsible for moving the facilities organization in the desired direction.

5.4 Actions

A series of actions are recommended for senior management to establish organizational commitment to SHP O&M in its facilities. These actions comprise a *change management process*. Senior managers may be familiar with change management: a substantial literature exists although it has not been widely applied to facilities management organizations and practices.

5.4.1 Make a Policy Statement. The organization should make a policy statement committing the organization to SHP O&M in its facilities.

5.4.2 Assign an O&M “Champion”. Properly managing any change effort requires a champion. The champion reports to the President or CEO and is responsible for the overall management of the process. He or she will work with other senior management members, the company facilities management organization, and facilities users to lead the change effort. In this case, the champion must be knowledgeable of, and an advocate for, the proper design, use, operation, and maintenance of facilities, buildings and building systems. The champion understands the details and knows how to meet management’s goals and objectives in the safest, and most cost-effective way possible. To succeed, a champion must have management support. Management support includes technical training for the champion and others, establishing and managing key performance indicators, and commitment to implementing change to increase performance. Identify characteristics necessary for Facilities Team leader and individuals who will serve on an implementation team.

5.4.3 Create an implementation team. The implementation team should consist of no more than eight people who represent facility users, managers, finance and human resources. The champion will manage this team to design and implement the changes to achieve SHP for the company. World class O&M requires a team effort with well established and communicated goals. Members of the implementation team should include representatives from the executive, finance, human resources, and engineering branches of the organization. Participation of an

upper-level manager is key to sending the message that the program is supported from the top of the organization. Appoint an O&M project manager as the project leader and focal point for accountability. Early participation of line-level engineering staff is essential to the long-term success of the SHP O&M program. As with any initiative, be sure to establish roles, responsibilities and communication channels.

5.4.4 Fund the Change Effort. Moving the facility management function towards high-performance will require a commitment to staffing and staff-skills improvement. Training is an essential aspect of improved performance in facilities. It should be viewed as a continuous improvement process from which the pay-offs, measurable facility conditions and resulting productivity and morale gains can be significant. Funding for the champion and an implementation team is needed to start. As the team works, it will prepare budgets for implementation stages as they progress. It should be anticipated that there will be increments requested to O&M budgets and/or for various capital improvement projects.

5.4.5 Align Facilities Performance Information with Organizational Objectives and Functions. The policy must make clear the connection between facilities performance and organizational strategies and objectives. Provide information to functional managers that shows the effect of building performance on their organizational functions. Work with the managers to set expectations within their units and translate these expectations into building performance objectives for the FMs.

5.4.6 Staff for Change. Coordination through the Human Resources (HR) department or functional equivalent is especially important. Task HR with developing policies for FM staff in collaboration with FM leadership, such as:

- Skills assessment and development that become part of formal personnel evaluation. On-going training strategies should be part of HR planning.
- Incentive-based team goals for safety, customer response, energy and other resources that are tied to the corporate SHP goals and dash board.
- In-house versus outside support plan to determine which SHP tasks will be performed with in-house staff versus contracted staff.

5.4.7 Assess. Assess each building with respect to production of aligned business environments, costs of utilities to produce the business environments, skills of operating and maintenance staff, SHP management tools and systems. This will involve meeting with Facilities Team(s) to review senior management objectives and to develop the facility-specific application of the SHP program and to determine the resources necessary to support the program, including:

- Coordination with overall objectives for safety, environmental health and emergency preparedness.
- Facilities team schedules, reporting processes and formats.
- Metering, measurement and verification tools available within the facility that will be used to measure use and performance characteristics of all utilities and energy sources utilized within the facility or facilities.

5.4.8 Plan and Execute. Plan and execute the change work needed to close the gaps found during assessment. This plan will likely have two sections. The first section would set up uniform practices, tools, training, etc. that will be used at all facilities. The second section would be a plan for implementation at each building.

FMs should be held accountable to evaluate the current approach and adopt an operation and maintenance strategy that best supports long-term strategic and asset management plans. The FM should track effort and progress of the SHP O&M plan, execution, and adjustments using available data sources.

5.4.9 Measure and Report. Establish measurement and reporting on facilities performance with other business performance metrics in periodic (monthly, quarterly) senior management review meetings. When selecting performance metrics the emphasis should be on leading metrics. Leading metrics are a predictor of future results, whereas lagging metrics provide a snapshot of current performance.

Key reporting criteria from a senior management perspective should be developed, leading to a Senior Management “Sustainability Dash Board” that provides a consistent executive summary of key data and statistics for sustainability performance. Then formulate the reporting strategy that feeds into such a dashboard or other reporting tool.

Although energy is only one dimension of facility performance, it is an important one. An energy accounting system may be a useful addition to management systems that will help in setting realistic baselines and in measuring results. Some utilities offer their customers excellent free or low-cost programs with automatic data uploading. Programs are also available from private vendors. Energy-accounting programs have a wide variety of features and user interfaces; evaluate several programs before selecting one.

5.4.10 Recognize and Reward. Recognize and reward effort and successes as progress is made. Employee recognition will help create enthusiasm and interest for achieving SHP goals. Meeting or exceeding building performance goals is an occasion for celebration. Use recognition, awards and meaningful incentives to encourage the entire staff to develop ideas for improving building performance. Ultimately, the success or failure of the new SHP O&M program lies with the line-level staff.

5.4.11 Balance Multiple Goals. Facility management professionals are responsible for overseeing all activities that can occur within a building or campus of buildings. Responsibilities include overseeing operations and maintenance activities, management of real estate and assets, project management, environmental health and safety, emergency preparedness, project planning and management, budgeting and finance, quality assurance and keeping abreast of new technologies that will allow the facility to operate efficiently (IFMA 2009). It is quite common for multiple, sometimes contradictory, goals to exist. Budgets, staffing and resources available to meet all of these demands are often limited. As a result, many maintenance programs are reactive, instead of proactive. Level II of this guideline provides guidance of how to move towards the proactive operations and maintenance management that is associated with SHP O&M. FMs need to receive a clear signal from senior management that SHP O&M is the organization’s desired direction and is a mandated priority.

5.5 Checklist. A checklist is provided for summary recommended actions for senior managers.

CHECKLIST FOR SENIOR MANAGERS

MOVING FACILITY ORGANIZATIONS TOWARDS SUSTAINABLE HIGH PERFORMANCE

- Make a Policy Statement** committing the organization to SHPO&M.
 - Assign** a senior management “Champion” and create an Implementation Team for the process.
 - Fund** the Change Effort.
 - Align** facilities performance information with business objectives and functions.
 - Staff for change**, tasking Human Resources to develop appropriate policies.
 - Assess** buildings, workforce, practices, management tools and systems.
 - Plan, Execute and Track** the changes needed to implement new practices.
 - Measure and Report** on building performance as part of regular business analytics.
 - Recognize and reward** effort and successes.
 - Balance multiple goals** and send clear messages about priorities.
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6 LEVEL II – ACTION AREAS FOR FACILITY MANAGERS: IMPLEMENTING THE CHANGE

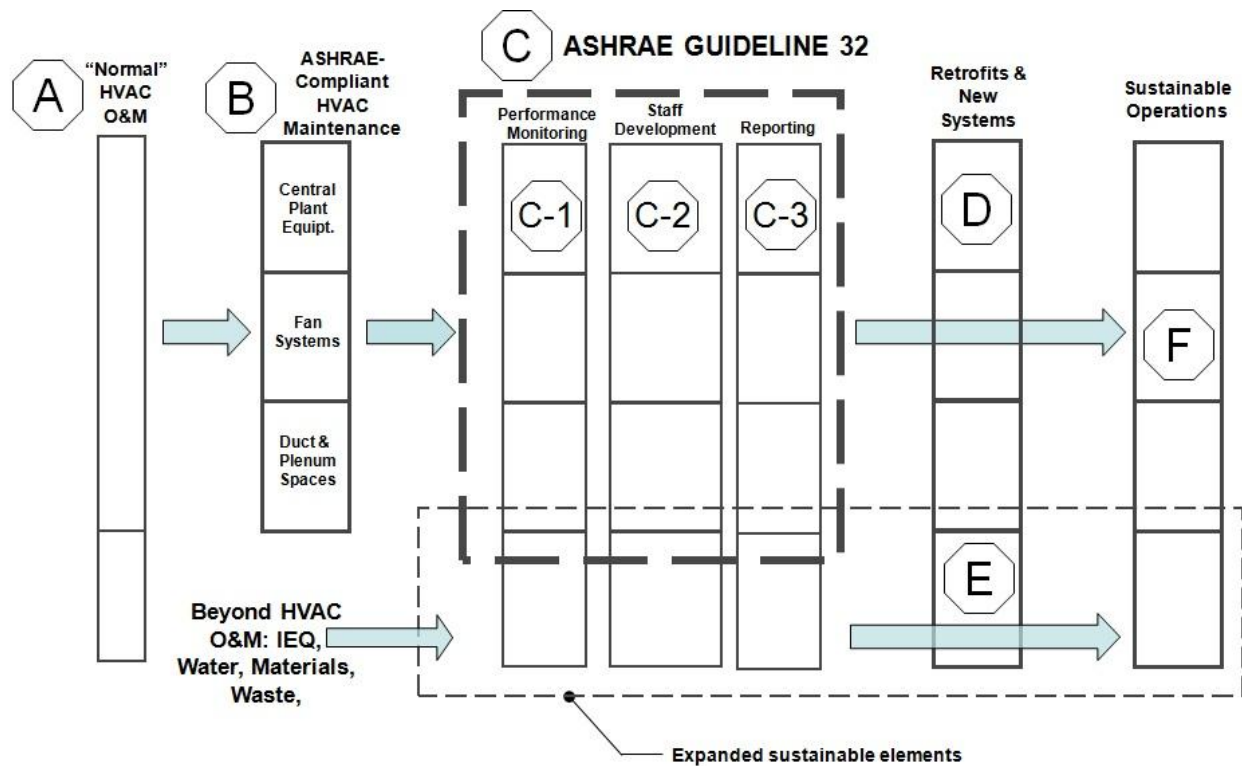
The FM translates the mission and mandates articulated at the corporate executive level into the work practices of facility and technical staff and contractors at the operations level. In creating a Sustainable *High-Performance Operations and Maintenance* (SHP O&M) program, it provides the bridge between strategic goals, maintenance strategies and daily O&M activities.

6.1 Establishing the SHP O&M Program When senior management mandates movement towards sustainable *high performance O&M*, FM will have to determine what this will mean for the operations they lead. The FM will need to align planned O&M with organizational goals, specific asset plans, and available resources.

6.1.1 Managing the Shift via Standards and Rating Systems. The FM will need to be familiar with emerging concepts, standards and rating systems that are becoming current in the market and can be seen as organizing and executing the move towards high-performance. Summaries of key standards are found in the following section. Summaries of key building performance rating systems are found in Informative Annex B. FIGURE 6.1 provides a schematic view of the transition from a starting point of “normal”, often only reactive, maintenance to high performance.

Shifting the O&M organization in this direction includes quantitative measures of performance, on-going assessments, skills development, improved facility information and regular reporting. These management disciplines provide a solid foundation for achieving the standards-compliance and labeling increasingly sought by upper level management.

Figure 6.1: High Performance Operations and Maintenance Transition



KEY TO FIGURE 6.1	
A	“Normal” maintenance as a combination of reactive and planned maintenance, based on published best-practices, standards or codes.
B	ANSI/ASHRAE Standard 180 as the standard for code-based planned maintenance of HVAC systems
C	Movement towards <i>high-performance O&M</i> , based on a combination of approaches and processes described in this guideline.
C-1	Use of various building intelligence techniques – BACnet, dashboards, IEQ measurement, post-occupancy surveying, on-going commissioning, etc.
C-2	Application of human resource policies, training, certifications, including but not limited to ASHRAE Operations Performance Management Professional (OPMP), BOC, LEED AP, IFMA CFM, etc (see Informative Appendix E).
C-3	Reporting includes performance-based building labeling (such as ASHRAE BeQ, Energy Star and ISO/ANSI energy management), corporate sustainability indicators and carbon

	disclosure.
D	ANSI/ASHRAE/IES Standard 100 for energy efficiency compliance in existing buildings and ANSI/ASHRAE/IES Standard 90.1 for energy performance of renovations, new systems and major retrofits. ANSI/ASHRAE/USGBC/IES Standard 189.1 for energy performance that exceeds Standard 90.1 by 30%.
E	ANSI/ASHRAE/USGBC/IES Standard 189.1, USGBC LEED and/or other rating programs integrating systems beyond HVAC.
F	Achieving and maintaining advanced standards of sustainability in performance: ANSI/ASHRAE/USGBC/IES Standard 189.1 and USGBC LEED ratings sustainable rating programs.
Note to the Key: See the Guideline text for explanation of many of the referenced elements.	

6.1.2 Building upon Basic Policies

a. *Baseline maintenance for safety and environmental performance.*

At a minimum a baseline level of O&M policy and practice should be implemented to meet local and national occupational safety, health, and environmental protection laws. A thorough review of local and national codes and laws should be conducted to determine what is actually in place and what is required in the jurisdiction.

Several ASHRAE standards establish industry baselines of good practice and care should be taken to determine the most current version of any standard. Note that ASHRAE Standards are under periodic or continuous maintenance and are updated periodically; this is indicated by a year following the number of the Standard and care should be taken to use the most current version of any standard.

b. *ANSI/ASHRAE/ACCA Standard 180, Standard Practice for Inspection and Maintenance of Commercial Building HVAC Systems.*

For commercial HVAC systems, ASHRAE/ACCA Standard 180 provides a minimum set of requirements for HVAC inspection and maintenance. The Standard provides tables of minimum HVAC inspection and maintenance requirements that with the addition of the concepts and practices included in this guideline should be converted into a customized checklist for the minimum level of HVAC system maintenance in a *high performance building*.

c. *ANSI/ASHRAE Standard 55, Thermal Environmental Conditions for Human Occupancy.*

Standard 55 provides minimum requirements and parameters that need to be met to insure a reasonable degree of human comfort for the building occupants. While saving energy is an important goal, comfort conditions are most valuable as it affects productivity. Since salary costs on a unit area basis usually substantially exceed the cost of operating and maintenance

costs, costs of lost productivity will greatly exceed additional O&M costs for improving comfort, satisfaction and productivity.

d. ANSI/ASHRAE Standard 62.1, Ventilation for Acceptable Indoor Air Quality

Standard 62.1 provides ventilation system design requirements. The standard is the basis for many building codes. While not written to govern operations of a building, the standard provides quantitative guidance for system performance to be maintained by operators.

e. ASHRAE Standards 90.1 Energy Standard for Buildings Except Low-Rise Residential Buildings and 189.1 Standard for the Design of High Performance Green Buildings

Standard 90.1 provides energy conservation requirements for new buildings, major renovations, and system replacements. The standard is the basis for many building codes.

Standard 189.1 goes beyond Standard 90.1 to provide requirements for designing a green building. The standard provides guidance and requirements consistent with the LEED rating system.

(f) ASHRAE Standard 100 Energy Conservation in Existing Buildings

Standard 100 provides guidance for energy conservation in existing buildings including operations, maintenance and evaluative actions that may lead to projects under Standard 90.1 or Standard 189.

6.1.3 Communicating O&M Needs to Senior Management.

The FM may be a key person in describing to senior management the potential gains in moving facilities towards high-performance and the steps necessary to do so. The FM should be prepared to work along with external consultants. The FM needs to be able to develop, or at least work with, a clear vision of facility performance and quantifiable improvement and report on progress in measurable goals. Beyond existing policies for safety and minimum environmental performance (cleanliness, thermal comfort), the FM must master a new set of performance dimensions that are consistent with sustainability goals.

6.1.4 Providing Facilities Staff Leadership.

The FM has a leadership role with respect to facilities staff. Staff looks to the FM to provide clear objectives, resources and motivation. The leadership relationship is even more important during a change process when new goals are being defined and pursued. Besides staff, the FM will have to make new objectives and practices clear to outside contractors.

6.1.5 Relating to Other Departments

Besides looking “up and down” the reporting chain, the FM will need to relate to other departments, such as human resources (HR), purchasing, accounting and IT. If the executive level is doing its job, these departments will be getting the same message as the FM. Coordination with HR will be necessary for arranging skills assessments and training, new hires, and developing appropriate forms of evaluation and incentives. With purchasing, the FM will have to develop appropriate product and service criteria to be included within the specifications and contract language. For example, requirements for certain specific kinds of system-performance tests and adjustments may need to be written into service contracts. "Working with

IT departments around data center efficiency and performance has become a major area of concern subject to much discussion and published guidance

6.1.6 Checklist. The FM may find the following checklist useful in tracking that appropriate steps are being taken to move towards high-performance O&M.

CHECKLIST FOR FACILITY MANAGERS

- Support upper management in drafting an appropriate mission and/or policy statement for *sustainable* high-performance facilities
- Work with financial accounting management to establish financial targets and tracking for building performance.
- Provide input to Human Resources for new staff competencies, skill sets, job descriptions, performance evaluations.
- Provide technical input to HR and collaborate around staff training.
- Develop and implement protocols for good facility/system documentation.
- Investigate, identify and implement appropriate levels of building intelligence.
- Identify and implement appropriate performance metrics.
- Benchmark against other similar facilities.
- Establish performance baselines and targets. Institute a system for regular reporting and evaluation.
- Provide recognition or reward system for optimized or improved performance.
- Identify and develop practices and projects.
- Seek budget allocations for projects and changes to work processes.
- Consistently communicate priorities and protocols to staff and service providers.

6.2 Dimensions of Performance. Sustainability dimensions have been well advanced and continue to evolve. The FM should be familiar with the basic schema that includes energy, water, indoor environment, materials and resources. The FM has a role in how assets perform on all of these sustainability dimensions. Location is a sustainability dimension over which the FM would seem to have little influence, however; even in this case provisions for creative transportation solutions may be within the purview of the FM.

6.2.1 O&M for Measured Indoor Environmental Quality (IEQ).

A building management team seeks to develop an improved environment to promote productivity and improved performance of its occupants. Since the indoor environment is increasingly understood to have a direct relationship to the performance of its occupants, achieving and maintaining superior IEQ can have significant impacts on organizational productivity and economic performance. For the purposes of this guideline, indoor environmental quality includes ventilation, thermal comfort, lighting and noise. ASHRAE Special Publication Performance Measurement Protocols for Commercial Buildings (ASHRAE 2010) provides methods for quantifying each of these dimensions and suggests methods of data collection. Guidance for maintaining IEQ is provided in Informative Annexes C and D.

6.2.2 Rating and Labeling Systems and Metrics.

The FM must be familiar with the various rating and labeling systems used in the marketplace. Upper level management will base much of its evaluation on achievement of labels. The United States Green Building Council (USGBC) Leadership in Energy and Environmental Design (LEED) has particular strength within the US real estate industry. Of particular importance for the purposes of this document is the LEED Existing Building Operations and Maintenance (EBOM) category, although other rating systems, such as Green Globe, also provide approaches to existing facilities.

Energy performance benchmarking and disclosure using ENERGY STAR® Portfolio Manager or other tools available in the market has gained acceptance as a management best practice. It may become a widespread regulatory requirement, at this date having been adopted as such by five U.S. states and various municipalities. This kind of public disclosure parallels legal requirements for commercial buildings in the European Union.

Multiple metrics and monitoring tools to help manage energy and maintenance proactively are available for free and on the market today. Several tools available for free in the public domain include but are not limited to: ENERGY STAR® Portfolio Manager and the ASHRAE O&M database. Multiple companies also provide software products to help manage meter and sensor data through user-specific dashboards, report generation from building automation systems and post occupancy evaluation surveys and studies.

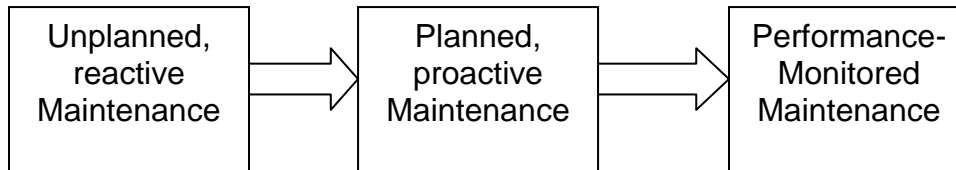
Further information on such tools and maintenance metrics, emphasizing those available in the public domain, is provided as Informative Annex B.

6.3 Proactive Maintenance Management.

Proactive maintenance incorporates planned maintenance, scheduled preventive and instrumented predictive maintenance techniques. To fully implement proactive maintenance at a facility may require refining existing policies and procedures to move from reactive to proactive techniques, fully utilizing or installing a computerized maintenance management system (CMMS), having well developed plans for how to address retro-commissioning, documentation, staffing levels and training, and major renovation project management. Facility managers should also be aware of developing trends in building intelligence, such as integrating the CMMS with the building automation system (BAS) and enterprise resource systems (ERPs), fault detection diagnostics, and building information modeling (BIM), all which can be used to improve the

efficiency of the maintenance organization. Proactive maintenance will involve using many techniques that monitor the performance of building systems and of the maintenance organization itself.

Figure 6.2 LEVELS OF MAINTENANCE



In most cases, implementing high-performance O&M practices can be accomplished by building upon existing practices and policies. Whether to frame the transition as a dramatic shift is up to the individual manager and the particular situation. Refer to the discussion of Change Management in section 5 above.

6.3.1 Computerized Maintenance Management Systems (CMMS)

A computerized maintenance management system (CMMS) is an effective proactive maintenance management software tool that automates manual work order systems and adds significant capabilities. A CMMS can be used to plan, schedule and track maintenance activities, store maintenance histories and inventory information, communicate building operation and maintenance information, and generate reports to quantify maintenance productivity. A CMMS can be used by facility managers, maintenance technicians, third-party maintenance service providers and asset managers to track the status, asset condition and cost of day-to-day maintenance activities.

The number and type of modules within the CMMS is determined by the facility management team, depending on the needs of the facility and the goals of the facility management team. Typical CMMS modules include: work order generator and tracking, work order requests, inventory control, preventive maintenance, equipment histories, real-time technologies, maintenance contracts and key performance indicator (KPI) reporting.

Although a CMMS is not required to manage maintenance activities, having a CMMS should be strongly considered as part of a high performance O&M program. As HVAC equipment becomes more sophisticated, managing work orders and service requests can become more complex if managed using a paper-based system or spreadsheet.

6.3.2 Building Intelligence.

The FM should be concerned with trends in building information and control systems. This is an area of rapid change that includes advances in Building Automation Systems (BAS), development and incorporation of Fault Detection and Diagnostics (FDD), and the provision of information to operators and occupants (e.g., -“dashboards”). A related topic, discussed below, is the management of building documentation with advanced methods such as Building Information Modeling.

6.3.2.1 Building Automation System (BAS)

The optimized function of building controls and control systems requires on-going FM attention. Full documentation of the system and a working relationship with the controls vendor or integrator should be maintained. It may be possible to develop programming skills in-house. At minimum the FM should ensure that staff understands the functions of the BAS, the interfaces available, and how to perform basic operations such as checking equipment status, building conditions, trend-logs, schedules, set-points and making non-permanent adjustments. BAS sensors and other components will require periodic calibration.

Existing BAS have various degrees of integration, scope of control over building functions and ability to collect and store data. An assessment should be determined to establish the baseline condition compared to an ideal-type of control. Such an assessment can guide the evaluation of system up-grading decisions.

There are on-going developments in control system routines for optimized performance. The FM should stay abreast of such opportunities through various informational resources. Opportunities for such improvements and need for system tuning may be discovered through periodic re-commissioning. Regular use of BAS trend logging for multiple system components underlies an awareness of interactive system effects and the need for control loop tuning.

6.3.2.2 Integrating CMMS and BAS. Of the hundreds of CMMS vendors, many are able to communicate with building automation systems to automate BAS alarms. Although often considered a more advanced functionality of CMMS, rules can be written within the CMMS software to receive notifications from the BAS for specific alarms. The CMMS then uses automation to generate a work order based on the BAS alarm. The use of rules within the CMMS can be used to allow only critical alarms or the alarms desired by the facility manager to automatically generate a work order.

6.3.2.3 Fault Detection Diagnostics (FDD)

Fault detection diagnostics (FDD) is an advanced control technique that uses acquired data and mathematical algorithms to detect and diagnose mechanical equipment faults. FDD can also be used to help identify operational challenges before the faults significantly decrease equipment life or cause emergency repairs. FDD logic can be programmed into a BAS or embedded within a stand-alone controller for a specific piece of equipment (Schein and Bushby 2005). Diagnostic information is provided to a building operator for corrective action. A less developed FDD application is the use in identifying and diagnosing faults in energy performance.

6.3.2.4 Building Performance Information

Building performance information must be conveyed in ways that are appropriate, intelligible and usable by the specific users for which it is intended. This will vary, for example, between executives, facility managers, technicians, and the general public, all of whom have their own interests in how facilities are performing.

Dashboards present building operating information following the model of the automobile dashboard by summarizing key data into graphical indicators. Dashboards may be developed for

use by operators and/or for informing building occupants of building conditions. Showing the environmental impacts of building operations is a popular application for public views.

Dashboards and other forms of reports can be built using data from the BAS.

6.3.2.4 Self Diagnostics and Predictive Maintenance.

Self-diagnostics refers to the addition of instrumentation to equipment to provide monitoring and assessment of key operating conditions as indicators of the need for maintenance. As with FDD, self-diagnostics may be embedded in equipment controls. Whether embedded, added externally, or provided via outside testing services on a regularly scheduled basis instrumented monitoring of operating conditions lays the groundwork for *predictive maintenance*.

Predictive maintenance, also called root cause analysis or condition-based maintenance, uses a series of measurements to determine the condition or integrity of the piece of equipment. The data is often saved in a database to establish a baseline to compare future data against. Using *predictive maintenance* enables a FM to identify problems before a failure occurs and to schedule the repair, avoiding unscheduled downtime and the costs of secondary damage.

Predictive maintenance squeezes the greatest possible life out of parts – without letting them fail. *Predictive maintenance* techniques include vibrations analysis, thermography, pressure measurements, motor current analysis, oil analysis and refrigerant analysis .

6.3.3 Documentation.

Creating and maintaining comprehensive, accurate, accessible and usable building documentation is a key responsibility of the FM. Building documentation is usually contained in building drawings, specifications, and operating manuals. Building documentation formats that bring together key operating information are discussed in section 7 below. An important industry trend is to have all building information integrated in electronic format as a Building Information Model (BIM).

6.3.3.1 Document Control. Plans and manuals should be kept up-to-date with record of changes from original building conditions. This should include tenant fit-outs as well as base building and system alterations.

6.3.3.2 Building System Operating Manuals. Manuals should be full system descriptions, incorporating design intent, narrative description, performance criteria, and detailed control sequences of operation. Equipment and component cut-sheets and installation guides are useful and should be included but are not by themselves sufficient to comprise the Manual. The Building System Manual is an important document for use in staff training. Detailed guidance for the preparation of Building System Operating Manuals is provided by ASHRAE Guideline 4.

6.3.3.3 Building Drawings and BIM. Many facilities have moved from maintaining hard copies of building drawings to electronic CAD files. This generally facilitates access to building system information but requires minimum electronic capabilities within the FM staff. Many *high performance building* teams are now moving towards a next level of electronic building data integration, BIM. BIM is a graphic based database structure that describes a building down to the level of its components (National BIM Standard 2007) and enables various graphic and analytic representations. BIM and BIM-based data functions are still at early stages of

development for O&M practice, as data formats must be integrated with computer-based operations applications (such as BAS, CMMS). An example of an early effort in this direction is COBie, Construction Operations Building Information Exchange is utilized by the General Services Administration for federal building projects. More detailed information about BIM and developing data-exchange structures is included as Informational Annex 10.5.

6.3.3.4 Document Accessibility. Documentation should be kept organized and available in a reference library that can include both hard copies and electronically stored resources.

6.3.4 Retro-commissioning, Re-commissioning and Ongoing-Commissioning.

The FM should have a plan for maintaining performance levels. This requires a definition of performance standards and a repetitive process for assuring compliance with them. This may be considered a quality assurance process for facility operations. Commissioning processes are applied at the equipment, system, and whole-building levels incorporating definition of performance criteria and functional testing (PECI Functional Testing Guide, 2006). As level of testing moves higher, the interactions between equipment and systems are taken into account.

If the building did not undergo a rigorous performance qualification prior to acceptance, it is unlikely that the building is performing optimally. In this case, retro-commissioning is needed. Even when the building has been initially commissioned or successfully retro-commissioned, performance naturally degrades over time without appropriate attention. If such attention is provided on a periodic basis, often with outside consultants or service providers, it is called Re-commissioning. If it is integrated into regular operations with added procedures, it is called On-going Commissioning. A specific version of on-going commissioning developed by the Energy Systems Lab at Texas A&M University is trademarked as Continuous Commissioning®.

The re-commissioning model accepts that building performance will be allowed to degrade for a period of minimum maintenance effort. The level of maintenance effort is determined by the FM. At the end of this period, the building is re-commissioned. The building is thoroughly tested, tuned and returned to its original (or better) performance. Re-commissioning is typically managed and conducted by a third party consultant.

The on-going commissioning model attempts to prevent or minimize performance degradation. It uses what was learned from the original commissioning to establish performance indicators such as energy use, system operating pressures, and other physical parameters. Acceptable limits are set for these indicators and they are monitored, either by periodic manual testing or by the BAS. If the indicators go out of range, corrective action is taken. On-going commissioning is managed by the FM and conducted largely by facilities staff with consultation from a “commissioning authority” (CA), a professional or firm with specialized skills in the commissioning process, retained to supervise and coordinate the process.

6.4 RENOVATION AND CONSTRUCTION WITH COMMISSIONING

6.4.1 Life Cycle Considerations in Design and Renovation. The building life cycle begins and at construction and is reset at renovation. For *high performing buildings*, it is critical that the FM be part of the project team from conception through acceptance. Maintaining high performance starts with understanding the internal environment users require and the energy

consumption standards the building is to meet. The FM must ensure that this performance can be easily maintained. This means setting the expectation at conception for good maintenance access, reliable equipment, integration with existing systems, eliminating unsatisfactory equipment, etc. It then means following through with design reviews, equipment selections and construction inspections to ensure the proper conditions are realized for maintainable-high-performance.

6.4.2 Commissioning in Renovation. A skilled Commissioning Engineer (CE) should be part of the renovation project team from conception through project break-in period. For work in an existing facility, the FM should establish a close working relationship and understanding of project goals, objectives and performance criteria with the CE. The CE will manage the performance aspects of the project, ensuring that information is documented and handed off from stage to stage and, ultimately, for turn-over to the FM.

The *commissioning* process sets performance based acceptance criteria at the beginning of the project, then follows through to ensure that the built project performs as required. The *commissioning* requirements and performance tests should be included as part of project documentation in the hand-off to the FM and staff as this information provides baseline criteria for maintenance of intended performance.

Detailed guidance on commissioning is provided in ASHRAE Guideline 0. Reference is also made to publications of the Building Commissioning Association (BCA) and Guide M: Commissioning Management of the Chartered Institute of Building Service Engineers (CIBSE).

6.4.3 New Technology. New technology will almost always be part of a building project, as building technologies are continuously changing. For this reason good building system Documentation is extremely important. The ASHRAE Green Guide (ASHRAE 2010) and the ASHRAE Systems and HVAC Equipment handbooks are sources of information on innovative, high-performance HVAC systems and equipment.

The FM must manage and prepare for new technologies by their own education and the education of staff about the equipment that will be new to them. Ideally this education takes place during construction, and is completed by participation in the performance testing and tuning that is part of commissioning. The commissioning process contains provisions for operator training, described in the ASHRAE Guideline 0 and accompanying guidelines in the series.

6.5 Staff Capacities for HP O&M.

Just as the building must be intelligent, so must its operating staff. It is up to the FM to determine the practices to be implemented (“best practices”), assess staff capabilities (knowledge, skills, experience, licensing etc), determine facility needs, and address any gaps. The organization’s Human Resources department can be a valuable ally in needs assessment and planning of training. Human Resources will also be critical for establishing policies that incorporate desired skills and performance in considerations for promotions, wage increases, bonuses and other incentives.

6.5.1 Assessment of Facility Needs and Staff Capabilities. Needs assessment is a fundamental starting point for training design. It uses a structured approach to identifying and achieving skill

development goals and typically involves interviews, work observations, and surveys to obtain information to design appropriate training solutions. The ability to conduct such an assessment may be available within a Human Resource department and/or through training consultants. Knowledge and skill needs are established based on the requirements of facility equipment, systems and operating objectives. Staff can then be evaluated (by testing and/or other means) against these needs. The resulting gap between facility needs and skills on-hand establishes the objectives of training.

The Needs Assessment may also affect the structure or re-structuring of staff. Testing and training may also be completed by new employees. Informative Annex 9.5: Training Needs Assessment provides an overview of the training needs assessment process and sample worksheets and aids. The source of this material is the National Employee Development Center (NEDC) Instructional Systems Design Guide. The American Society for Training and Development (ASTD) also publishes a variety of checklists, interview guides, and task analysis guides which could serve as a reference for the facility manager and HR department.

6.5.2 Training and Certification. Training should be provided based on identified areas of knowledge and skill needs. It should address specific facility requirements but also general principles that underlie specifics. Facility-specific training may best be conducted on-site, often through or with the collaboration of equipment vendors and manufacturers. Training on underlying and more generalized knowledge and skills may be conducted through outside programs and local community colleges or similar institutions. A checklist of effective approaches to on-site training was published by the Washington State Energy Office and is provided as a reference in the Informative Annex E.

Certifications can provide important milestones for achieving skill and knowledge levels. Relevant certifications are offered by many organizations. In most cases, certifications have training programs associated with them, offered either by the certification organization or by independent organizations who train to the certification standards. The ASHRAE Operations Performance Management Professional (OPMP) is one type of certification appropriate for the FM. Further information on training, certificate and credential programs for FMs, technicians, and building operators is provide in Informative Annex E. While many of these programs do not emphasize energy efficient or *high performance building* operations, they do offer foundational training in the knowledge and skill areas of building systems and equipment, energy management, and building operation and maintenance. The target audiences for these programs range from the facility management level to the technician.

6.5.3 Use of Outside Contractors. For specialized functions where certain skills are necessary, it may be cost-effective to use outside contractors. One example where outside services may be used is when sophisticated periodic test procedures are needed.

Outside contractors, such as service contracting firms, may also be used for more routine services as an alternative to in-house staffing. In this case, the owner and FM should investigate the vendor's training practices and the knowledge and skill levels of its staff. Since this vendor will have a major, perhaps determinative, role in the facility's operating efficiencies, including specific performance-related skills and practice requirements in contracts, vendor evaluations should be part of the procurement process.

6.5.4 Human Resources Issues and Policies. The FM should work with HR officers to establish policies and procedures that support the O&M objectives with respect to staffing. Policies for hiring, promotion, bonuses and other incentives should reflect specific knowledge, skill, and behaviors that are desired. Personnel evaluations should be conducted on a regular basis also reflecting these skills and documenting progress of individual staff members.

7 LEVEL III: ACTIONS AND TOOLS FOR TECHNICIANS : CARRYING OUT BEST PRACTICES

The role of the technician is critical to *sustainable* operations and maintenance. Once the commitment is made to operate and maintain a building in a *sustainable* manner, technicians are the primary actors responsible for fulfilling this commitment. All members of the facility management team, including technicians, will be required to move away from a reactive mode to a proactive mode. To proactively maintain and operate buildings requires a higher level of awareness, knowledge and skill. It will be important to understand how:

- the building is designed to operate,
- proactive maintenance procedures can help realize superior performance,
- diagnostic procedures can be effectively applied in day-to-day activities,
- timely correction of operating problems can reduce emergency work, and
- new technologies are being applied and how this affects the technician's work.

Enacting proactive best practices requires strong knowledge and skill levels. Technicians must be familiar with a wide range of system information, routine inspection protocols, diagnostic techniques, and corrective procedures. Tools include such things as building documentation, system and hand-held instrumentation, and checklists.

Level III of the Guideline provides an overview of several methods and tools for use by technicians and building operators to fulfill high performance buildings commitments. Additionally, Informative Annex 9.10 provides a series of checklists to serve as a starting point when developing proactive operations and maintenance management practices.

7.1 Technicians' Knowledge, Skills and Training.

Building technicians and operators must be knowledgeable of the principles of building systems and their operations. Technicians and operators must request and seek training during installation or soon after a new piece of equipment or a control upgrade is installed in the building. Technicians and operators should alert their supervisors when additional training is required.

CHECKLIST OF TECHNICIANS' KNOWLEDGE AND SKILLS FOR HIGH-PERFORMANCE O&M

Know how to

- Access, use, maintain and update building / system documentation.
- Check for correct scheduling in BAS.
- Access BAS trend logs, including how to read and interpret data.
- Check for proper ventilation rates.
- Check the performance of key energy-using systems and components.

- Interpret key gauge and BAS readings and their implications.
- Monitor, implement, and track work efforts in CMMS.

Understand

- How Planned and Preventive Maintenance procedures are implemented.
- How energy is measured and how energy performance is benchmarked.
- O&M impacts on energy and water efficiency and IEQ.
- How energy and water audits are conducted.
- Environmental performance rating systems, such as LEED EBOM.
- Dimensions of IEQ and how they can be measured.
- Energy efficient control sequences of operation for all building systems.

Have a plan for

- Responding to discovered deviations from normal building performance.
- Personal skills development and continuing education.

7.2 Building Documentation Tools.

The ability to use building documentation is critically important to maintaining high performance. Clear and comprehensive documentation must be kept and readily available. Technicians should be familiar with all building system documentation including being able to read, interpret and implement it. In cases where documentation is incomplete, it may fall upon technicians to initiate actions to obtain, develop, and establish proper documentation.

7.2.1 Building Systems Manuals. The building systems manual is a tool where the design intent is translated into working knowledge that can be used by the technicians and operators to operate and maintain a high performance building. The building systems manual should include a schematic and narrative for each major system in the building. The narrative should:

- Describe how the system was designed to operate including the sequencing of equipment;
- Detail the sequence of operation including set-points for temperature, humidity and other controlled conditions;
- Include equipment performance information from the manufacturers (i.e. fan and pump curves, design conditions and performance, etc.); and
- Provide operations and maintenance information

Refer to *ASHRAE Guideline 1.1* for more information.

7.2.2 Building System Operations Map. A building systems operations map is a document that can be included within the building systems manual. A building system operations map documents current conditions, focusing on scheduling and on targeting HVAC systems and

equipment where common opportunities are found in similar buildings and systems. The map clearly identifies areas for immediate improvement (e.g., changing thermostat setpoints or equipment schedules) and provides the basis for additional evaluation. When completed, the map should document the current uses in the building and how well the operation of the energy systems matches the actual use. The map should identify major energy-using systems and occupancy types by area. Developing the map requires reviewing utility bills, as-built drawings, and sequences of operations; interviewing building operations and maintenance staff; and cursorily reviewing systems and equipment with a focus on targeting particular HVAC systems and equipment for potential energy savings.

A typical building system operations map includes the following for central boilers, chillers and cooling towers:

- Operating schedules and sequences of operations,
- Areas served and requirements,
- Large pumps and circulation loops served,
- Fan systems served (terminal units and air handlers),
- Major energy systems served (e.g. water heating, sterilizers), and
- General maintenance practices, safety and equipment conditions.

A typical building system operations map includes the following for each major fan system:

- The operating schedule and set-points,
- Occupancy schedule of the area(s) supplied, noting any areas with special extended operating hours,
- Any capability of terminal units or baseboards to run independent of main fan ,
- Sequence of operations for terminal units/baseboards,
- Sequence of operations for air handlers with particular focus on outside air dampers, mixed air temperature and supply air temperature controls, and
- General maintenance practices, safety and equipment condition.

A typical building system operations map should include the following for each major occupancy:

- Occupancy schedule,
- Equipment, equipment characteristics, areas served, and maintenance responsibilities,
- Equipment schedules, temperature and other set-points, and control methods, including areas served, and
- Lighting and lighting control schedule and including location, luminaire identifier, control, recommended settings, and circuiting for each piece of lighting equipment.

The building system operations map should be used to continually document on-going problems and what building operators are doing to compensate for the following:

- Undersized equipment,
- Oversized equipment,
- Spaces that can't maintain temperature settings,
- Indoor air quality issues,
- Building pressurization problems, and
- Major HVAC equipment with higher failure rate than typical.

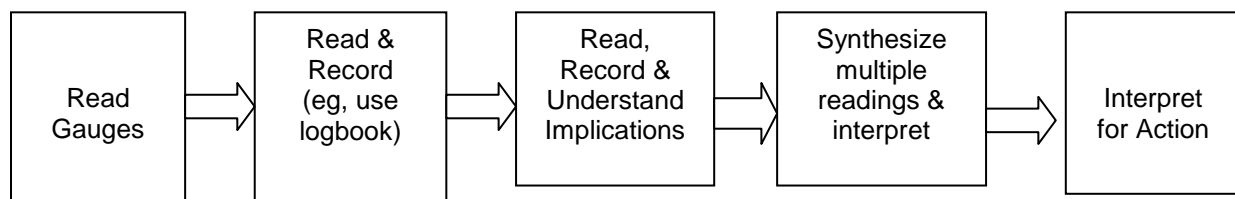
7.3 Instrumentation.

Instrumentation includes system and equipment gauges, digital data displays at local control panels, data acquisition and storage at a central BAS, and portable, short-term and hand-held measuring instruments. Technicians' proper use of the various types of instrumentation available is key to establishing actual facility operating conditions over time for comparison to specifications and requirements and for troubleshooting, adjustment and corrections as necessary.

7.3.1 Hand-held instruments. The technician should be familiar with the wide variety of hand-held instruments available for diagnostic use and their application to solve various problems. Most such instruments are now digital and can include memory for storage of readings. Data-loggers are portable data acquisition devices that can store large amounts of information for download to a computer where the data can be displayed and manipulated.

7.3.2 System instrumentation. The technician should be aware of installed system instrumentation including gauges and sensors. The system instrumentation provides valuable indications of system performance, especially when viewed over time for variation. Technicians should continuously develop their understanding of gauge readings and use in diagnostic interpretation. Figure 7.1 describes the process of using instrumentation for decision making and trouble shooting at increasing levels of skill and understanding.

Figure 7.1 Progression of Cognitive Skill in Use of Instrumentation



7.3.3 Building Automation System. In addition to programmed control functions, BAS act as a data acquisition system, providing the technician with large amounts of data. Current data is readily accessible, displayed on screens. However to view the accumulated masses of data

requires access to trend logs. The large amount of data in these histories is shown graphically, as time-series, scatter and other types of graphs or “plots”. Technicians should learn to use this information in its various formats to observe system performance.

Using Data Visualization for Spotting Problems. BAS provide large amounts of data that can show problems that are otherwise hard to see. Technicians should gain skills in interpreting a variety of data formats for the identification of building system and control problems, such as:

- Simultaneous heating and cooling
- Sensor error
- Meter calibration
- Equipment schedules
- Set-points
- Control loops that need tuning

Note for Technicians: Regular or frequent manual schedule overrides may be symptomatic of system and equipment problems. Investigate and resolve reasons why equipment schedules may have been overridden. Regularly review actual BAS set-points against the building systems manual and the original design intent set-points

7.4 Regular Maintenance of Key Building Systems.

Regular maintenance of key building systems is at the heart of high performing, energy efficient buildings. Key building systems include:

- Chillers, cooling towers and pumps,
- Boilers and pumps,
- Air handling units,
- Controls and Building Automation System,

The following sample checklist can be used as a starting point for structuring basic regular maintenance of key building systems.

CHECKLIST FOR MAINTNEANCE OF KEY BUILDING SYSTEMS

- Develop an HVAC system maintenance program using ASHRAE Standard 180 as a reference. Customize the activities (inspections, etc) to match equipment within the building.
- Use commissioning performance reports to set ongoing performance acceptance criteria and monitoring to detect performance degradation before it is noticeable to users.
- Maintain access and code required clearances to all HVAC and electrical equipment.

- Keep instrumentation (gauges, sensors) in good working order.
- Keep equipment and surrounding areas clean.
- Track and maintain records of run-times, work effort, maintenance and repairs.

7.4.1 Operations and Maintenance Checklist. A checklist is a list of tasks to complete for a complex task. As many *high performing buildings* contain sophisticated control systems that may use more complex control sequences, and may also contain different types of systems and equipment, checklists can be a useful tool to ensure all tasks necessary to keep systems and equipment operating efficiently are completed at the required time interval. Sample checklists and guidance on how to create equipment, system and facility specific checklists are provided in Informative Annex 9.10.

7.4.2 Visual Inspections: Observing the Building Operation with a Critical Eye *The high performance building* technician and operator must observe the building with a critical eye during their regular activities to look for potential operating problems. Observation of the operation of systems and equipment outside of the original design intent may be possible symptoms of poor energy performance and potential negative impacts on occupant comfort. A *high performance building* technician must be diligent in observing and resolving abnormal operational issues.

For example, a chilled-water pump might operate significantly more hours than the chiller. The technician and operator must find and resolve the underlying cause of the symptom. The cause of the symptom may in fact be a problem (for example, incorrect control settings) or it may be a condition that is not a problem or cannot be avoided (for example, set-points that are based on the needs of a process load and not on occupant comfort). If a technician or operator cannot resolve the discrepancy, the technician should raise the issue to their supervisors for their assistance in resolution.

The Better Bricks website, www.betterbricks.com, of the Northwest Energy Efficiency Alliance provides further useful examples of abnormal equipment and system operation that may indicate problems in system operation. Better Bricks includes a Symptom-Diagnosis Tool (within the Building Operations section of their website).

7.4.3 Instrumented Monitoring of Equipment for Predictive Maintenance

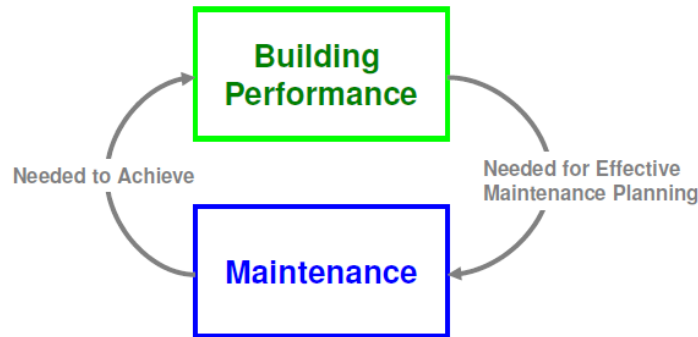
Predictive maintenance is a form of scheduled maintenance, but is based on equipment condition, instead of time, like *preventive maintenance*. Measurements are collected periodically and used to determine changes in equipment condition over time. Technicians should be aware of the numerous instrumented methods available for *predictive maintenance*, some of which they may perform directly and others of which will be done by outside, specialist service providers. Specifics of many of these techniques are provided in Informative Annex 9.7.

7.5 Maintenance and Energy Performance

There is an interdependent relationship between energy and maintenance: in order for equipment to operate efficiently, it must be proactively maintained. If equipment is not maintained, the

performance of the equipment will degrade (Lewis 2010). This relationship is shown in Figure 7.2.

Figure 7.2: Interdependent relationship between energy and maintenance



7.5.1 Capturing Low-Hanging Energy Efficiency. Many of the largest sources of energy waste are easily captured by attentive managers, technicians and operators. Many are simple things, like having maintenance crews turn on lights as they enter a space at night and turn them off as they finish and leave.

7.5.2 Implement the Top Four HVAC Savings Opportunities To be *sustainable*, a facility should use only as much energy as necessary to meet operational requirements. Most buildings can reduce their energy consumption 10-30 percent by taking steps to eliminate excess energy use. Saving energy through improved building operation starts by finding opportunities in four areas that have been found to have the most frequent problems and the potential for the greatest benefits:

1. Equipment scheduling: Equipment runs when it is not needed.
2. Sensor error: Erroneous sensor data causes increased heating, cooling, or equipment operation which can also affect occupant comfort.
3. Simultaneous heating and cooling: The same air gets heated and cooled, or hot and cold airstreams get mixed together to make warm air.
4. Outside air usage: Economizer does not functioning optimally or excessive outside air causes increased heating and/or mechanical cooling; sometimes too little air compromises

Further discussion of these opportunities is provided in Informative Annex H.

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(This annex is not part of the guideline. It is merely informative and does not contain requirements necessary for conformance to the guideline.)

INFORMATIVE ANNEX A ADDITIONAL RESOURCES

Many websites provide important resources for further information on high performance building operations and maintenance. These resources include:

- (1) US General Services Administration Whole Building Design Guide
<http://www.wbdg.org/om/om.php>.
- (2) US Environmental Protection Administration Energy Star Tools and Resources Library
http://www.energystar.gov/index.cfm?c=tools_resources.bus_energy_management_tools_resources
- (3) US Environmental Protection Administration Indoor Air Quality <http://www.epa.gov/iaq/>
- (4) California Commissioning Collaborative <http://www.cacx.org/>
- (5) Portland Energy Conservation Inc (PECI) <http://peci.org/resources/index.html>
- (6) Energy Design Resources <http://www.energydesignresources.com/>
- (7) New Buildings Institute <http://www.newbuildings.org/>
- (8) Northwest Energy Efficiency Alliance Better Bricks, <http://betterbricks.com/>

The following table is intended to help users in accessing information on specific topics from the BetterBricks website

Resources by Specific Topic from BetterBricks

Topic	Source
Identifying problems	http://www.betterbricks.com/DetailPage.aspx?ID=493
Conducting a building tune-up	http://www.betterbricks.com/DetailPage.aspx?ID=490
Sensor error	http://www.betterbricks.com/DetailPage.aspx?ID=690
Normalization	http://www.betterbricks.com/DetailPage.aspx?Id=530#NormalizingForDifferenceBetweenBuildings
Tracking utility bills and benchmarking	http://www.betterbricks.com/DetailPage.aspx?ID=491
Trend logging	http://www.betterbricks.com/DetailPage.aspx?ID=523 http://www.betterbricks.com/DetailPage.aspx?ID=527
BAS screen checks for on-going commissioning	http://www.betterbricks.com/graphics/assets/documents/BAS_Screen_Checks_for_Ongoing_Commissioning.pdf

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INFORMATIVE ANNEX B BENCHMARKING AND BUILDING RATING SYSTEMS

The purpose of this Annex is to provide an overview of benchmarking and building rating systems. Benchmarking is the use of data to compare one facility against another with the purpose of tracking building performance. Benchmarking can be done using historical data for the building itself; data from peer buildings; current operational performance against the basis of design; against standards, such as ANSI/ASHRAE/IES Standard 90.1, or other metrics. The importance of benchmarking is increased in the United States because the 110th Congress, under the Energy and Independence Act of 2007 requires benchmarking of energy and water performance of federal buildings. The bill specifically requires (but is not limited to):

1. Energy managers to comply with specific benchmarking requirements
2. Public disclosure of benchmarking data

A building rating system is a structure that evaluates building characteristics and performance using a point system to classify buildings into different levels of performance, sustainability or other classifications. Some building rating systems focus on one area of sustainability, such as energy, while others focus on multiple areas of sustainability. Building rating systems can be used as a benchmarking tool.

The list of building rating systems is provided for information only. It is not intended to be all inclusive or to recommend the specific rating systems discussed. For a more comprehensive list of building rating systems see the IFMA Foundation Sustainability How-To Guide:

http://www.ifmafoundation.org/programs/sustain_wp.cfm

B.1 Use of an Energy Use Index (EUI) for Benchmarking.

An energy use index (EUI) is a measure of energy use per square foot of building floor area that can be used for benchmarking energy performance. By converting energy use to a normalized index, buildings can be benchmarked and compared for relative energy performance. EUI can be applied to whole building energy use or to specific end uses such as lighting or heating.

Whole building EUI is a good measure of overall energy savings potential. There is a wealth of data on whole building EUI available for many building types. If a building has a higher EUI than the average similar building, it increases the likelihood of finding energy saving opportunities and gives an indication of the magnitude of potential savings.

Comparing the buildings past performance to current energy performance can provide further insight and lead to additional potential energy saving opportunities. During this process, it is important to determine if the EUI has increased or decreased over time. There are generally three reasons why the EUI may increase over time:

- The number of hours the building is occupied, or the number/type of occupants, increased
- A decrease in vacant space

- Equipment was added or operational parameters were changed

B.2 Maintenance Metrics/Key Performance Indicators.

Maintenance metrics are often part of computerized maintenance management systems and other facility management software. Although maintenance metrics, often called key performance indicators (KPIs) have been a part of the maintenance industry for many years, proactive use of maintenance metrics is currently not standard practice.

When selecting maintenance metrics to determine maintenance efficiency, it is important to select leading metrics, opposed to lagging metrics. A leading metric is one that is a predictor of future results. A lagging metric quantifies current performance. The use of leading metrics for sustainable building operations and maintenance is important to ensure proactive management to prevent building performance from significant degradation.

Examples of leading key performance indicators might include:

- Percentage of coverage by predictive maintenance practices,
- Charts detailing equipment fault types,
- Trending of preventive maintenance hours versus emergency labor hours, and
- Percentage of rework.

B.3 EPA ENERGY STAR Portfolio Manager. ENERGY STAR Portfolio Manager is a free energy management tool provided by the United States Environmental Protection Agency (US EPA) that can be used to track and assess energy and water consumption for a building or campus of buildings. For many types of facilities, ENERGY STAR Portfolio Manager provides an energy performance rating using a scale of one to 100, relative to similar buildings nationwide. A rating of 50 indicates that the building, from an energy consumption standpoint, performs better than 50 percent of all similar buildings nationwide, while a rating of 75 indicates that the building performs better than 75 percent of all similar buildings nationwide. Buildings that receive a rating of 75 or higher are eligible to receive the ENERGY STAR label.

ENERGY STAR Portfolio Manager ratings are based on statistical representative models for specific building types, not other buildings within the nationwide database. The statistical model is developed from the results of the Commercial Building Energy Consumption Survey (CBECS). The CBECS is conducted every four years and gathers data on building characteristics and energy use from thousands of buildings across the United States.

The energy and water consumption of any building can efficiently be tracked and managed through the use of Portfolio Manager. The tool allows you to streamline your portfolio's energy and water data, and track key consumption, performance, and cost information portfolio-wide. For example, a user can:

- Track multiple energy and water meters for each facility,
- Customize meter names and key information,
- Benchmark your facilities relative to their past performance,
- View percent improvement in weather-normalized source energy,
- Monitor energy and water costs, and

- Share your building data with others inside or outside of the organization.

Entering energy consumption and cost data into the Portfolio Manager will assist in benchmarking building energy performance, assessing energy management goals over time, and identifying strategic opportunities for savings and recognition opportunities. The US EPA has developed a Benchmarking Starter Kit to help get things started quickly.

For many types of facilities, rate energy performance can be rated on a scale of 1–100 relative to similar buildings nationwide. The source building is *not* compared to the other buildings entered into Portfolio Manager to determine the ENERGY STAR rating. Instead, statistically representative models are used to compare the source building against similar buildings from a national survey conducted by the Department of Energy’s Energy Information Administration. This national survey, known as the Commercial Building Energy Consumption Survey (CBECS), is conducted every four years, and gathers data on building characteristics and energy use from thousands of buildings across the United States. The source building’s peer group of comparison is those buildings in the CBECS survey that have similar building and operating characteristics. A rating of 50 indicates that the building, from an energy consumption standpoint, performs better than 50% of all similar buildings nationwide, while a rating of 75 indicates that the building performs better than 75% of all similar buildings nationwide.

For more information and to use Portfolio Manager see:

http://www.energystar.gov/index.cfm?c=evaluate_performance.bus_portfoliomanager. A free step by step how to guide of how to use Portfolio Manager has been developed by the IFMA Foundation’s Sustainability How-to Guide Series: EPA’s ENERGY STAR Portfolio Manager (http://www.ifmafoundation.org/files/sustain_wp/EnergyStar.pdf)

For more information about receiving the ENERGY STAR label, and other ENERGY STAR recognition programs see the following websites:

- ENERGY STAR label: www.energystar.gov/index.cfm?c=evaluate_performance.bus_portfoliomanager_intro
- ENERGY STAR leaders: www.energystar.gov/index.cfm?c=leaders.bus_leaders
- ENERGY STAR Partner of the Year: www.energystar.gov/index.cfm?c=pt_awards.pt_es_awards

B.4 ASHRAE Building Energy Quotient (Building EQ).

In 2010 the American Society of Heating, Ventilating and Air-Conditioning Engineers (ASHRAE) launched a new building rating system called the Building Energy Quotient (Building EQ). The rating has an As-Designed and In- Operation component. The operational component is for buildings in operation and is based on actual utility bills. The In-Design rating provides an assessment of the design and results of a building energy model. Having a rating system with both as-designed and in operation ratings provides a metric to demonstrate the divergence between estimated and actual building performance. The rating is based on a

numeric scale where zero is best and 100 is the median. Values greater than 100 indicate that the building performs below average. The numeric rating allows buildings to be compared to other peer buildings.

Building EQ focuses only on energy, but allows for a side-by-side comparison of the as designed versus in operation ratings, peak demand reduction and demand management opportunities, on-site renewable indoor air quality indicators, potential commissioning activities, energy efficiency improvements and tips on how to improve building energy efficiency.

B.5 ASHRAE Service Life and Maintenance Cost Database. The database provides information on the service life and maintenance costs of HVAC equipment. The database allows users to gather cost and service life data by type of equipment, region, State, BOMA class and function. Users can specify criteria to create summaries for an equipment service life evaluation and for HVAC maintenance cost evaluation. For more information about the database and to use the database see: <http://xp20.ashrae.org/publicdatabase/>.

B.6 LEED EBOM. The United States Green Building Council Leadership in Energy and Environmental Design (LEED) Existing Building Operations & Maintenance (EBOM) rating system is becoming widely recognized. The certification is received from complying with LEED EBOM is based on actual building performance, not design expectations. While LEED predominates in the United States real estate industry, other standards exist and may be preferred, especially in other countries or in jurisdictions where mandatory provisions are needed to establish a minimum. The FM should have some knowledge of standards used outside of the United States, such as BREEM which started in the United Kingdom and GreenGlobes in Canada.

The LEED® rating system, created and supported by the US Green Buildings Council, has become widely accepted within the US real estate industry as a certification of sustainability. It establishes a structure of performance dimensions with which the FM should be familiar as they can be the basis of high performance O&M planning and metrics. The rating system uses six categories under which points are grouped: (1) Site (2) Water (3) Energy and Atmosphere (4) Indoor Environmental Quality (5) Materials and Resources and (6) Innovation. These categories are used consistently across the several LEED “products” – for new construction, commercial interiors, residential projects, existing buildings, and so forth; see information available from the US Green Buildings Council, creator of the LEED rating system. ANSI/ASHRAE/USGBC/IES Standard 189.1, *Standard for the Design of High-Performance Green Buildings Except Low-Rise Residential Buildings*, applies a category structure that is consistent with the LEED® system.

B.6 BREEAM: Building Research Establishment Environmental Assessment Method. BREEAM, the Building Research Establishment (BRE) Environmental Assessment Method, is the oldest building assessment system, which was started in 1988 by BRE, the national building research organization in the United Kingdom. BREEAM includes the following assessment areas: management, energy use, health and well-being, pollution, transportation, land use, ecology, materials and water. Credits are awarded based on performance. A weighting method is used to add the credits together to generate a single score. Buildings are rated on a scale of

pass, good, very good or excellent. BREEAM has been adopted in Canada, several European and several Asian countries. More information can be found at www.breeam.org/.

B.7 GREEN GLOBES. Green Globes is a question-driven building rating protocol developed in Canada developed from BREEAM. Green Globes was acquired by the Green Building Initiative (GBI) in 2004. In 2005 the GBI was the first green building organization to be accredited as a standards developer by the American National Standards Institute (ANSI). The categories of Green Globes include: project management – policies and practices; site; energy; water; resources, building materials, solid waste; emissions and effluents; and indoor environment. Between 1 and 4 Green Globes are awarded, depending on the number of points earned (Kibert 2008). More information can be found at www.greenglobes.com/.

B.8 BOMA BEST. The BOMA BEST, Building Operators and Managers Association (BOMA) Building Environmental Standards (BEST), is Canada's national environmental certification program for all types of existing buildings. The BOMA BEST program builds upon the BOMA Go Green program which sets minimum requirements for best practices. The Go Green best practices include an energy audit, energy management and reduction plan, water audit, a recycling program, hazardous materials management, indoor environmental management and tenant communications. The BOMA BEST program has four certification levels:

- Level 1: Meet Go Green Best Practices
- Level 2: Meet Go Green Best Practices and achieve 70 to 79% on the Go Green Plus assessment
- Level 3: Meet Go Green Best Practices and achieve 80 to 89% on Go Green Plus assessment
- Level 4: Meet Go Green Best Practices and achieve 90 to 100% on Go Green Plus assessment

The Go Green Plus Assessment is a two level questionnaire about six categories of best practices: energy, water, waste reduction and site, emissions and effluents, indoor environment and environmental management system. The first level of the questionnaire consists of 14 questions and can be completed quickly. The second level of the questionnaire includes approximately 150 questions. The questions include yes/no and questions that require specific energy and water bill data. For more information see <http://www.bomabest.com/>.

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INFORMATIVE ANNEX C: MAINTAINING INDOOR AIR QUALITY (IAQ)

Maintaining the indoor environmental quality (IEQ) of a *high performance building* revolves around three main activities:

- Regular assessment of building operations and activities,
- Regular maintenance of key building systems, and
- Proper operation of building activities and systems to prevent potential IEQ problems.

Before a maintenance and operational plan can be developed, the performance goals of the building systems relating to IEQ must be clearly identified. The building systems manual should identify all ventilation systems (including supply, return and exhaust systems) include the design flow rates, fan performance (CFM), static pressure and brake horsepower, the design ventilation effectiveness rate (refer to ASHRAE Standard 62.1 for definition of ventilation effectiveness), known sources of potential contamination from within and external to the building (i.e. Std 62.1-2004 Assessment of local IAQ). For new buildings, these elements are commonly included as part of the design intent and owner program requirements.

After the building's ventilation systems performance is identified, the overall performance needs to be reviewed and documented on a regular basis. Each system should have its regular maintenance activities and the frequency included on the ventilation systems summary. Minimum maintenance activities should include frequency of filter changes, physical maintenance such a belt replacement and tensioning, and ventilation rate confirmation through airflow measurement (i.e. TAB measurement). Provisions should be made for seasonal variations for local conditions that may impact system maintenance. For example, pollen from blooming trees or dust from blowing sand may require shorter intervals between filter changes.

The ventilation systems performance can be summarized in a simple spreadsheet and included in the building system manual for quick reference. As the building systems are altered, the building ventilation systems summary table must be updated. Other examples of IEQ system forms and checklists can be found in the Indoor Air Quality Building Education and Assessment Model (I-BEAM) developed by the U.S. EPA (www.epa.gov/iaq/largebllds/baqtoc.html).

Maintaining good IEQ does not depend solely on the ventilation systems in the building. The building activities have a significant role in maintaining a high performance environment. A *high performance building* should have a proactive IEQ plan that identifies common activities and actions that need to be taken to maintain a quality environment. The following components should be included in a *high performance building's* IEQ plan:

- An environmental tobacco smoke policy including designated smoking areas and proper signage.
- Identification of potential sources of contamination in the building with precautions and operational changes required for typical building activities (carpet cleaning, painting, new carpeting and furniture, pesticide application, etc.).

- Operational changes may include extended operational hours of HVAC systems to dehumidify the building after carpet cleaning or floor washing, flushing building with outside air after volatile organic compounds (VOCs) have been introduced into the building, etc.
- A list of building performance standards for furniture, paint, carpet, etc. and a list of approved housekeeping materials and equipment (i.e. cleaning agents and types of cleaning equipment that can be used. (Refer to LEED EBOM IEQ for performance standards.) In multi-tenant buildings, the building performance standards should be periodically updated and distributed to all building tenants.
- A list of all common areas with minimum housekeeping requirements including periodic service/cleaning of anti-tracking devices.
- Identification of space acoustic performance (in RC or NC) and minimum sound performance of demising partitions.
- Identification of lighting system performance in measureable quantities (i.e. footcandles) and quality (glare, lamp color, etc.) with periodic testing and maintenance to assure system performance is being maintained. Also identify plan for periodic testing and calibration of daylighting control systems to verify their proper operation.
- Develop a building specific guideline on maintaining acceptable IAQ in a building based upon the ANSI/SMACNA IAQ Guidelines for Occupied Buildings Under Construction, 2nd edition. The customized guideline should detail specific methodologies that can be implemented in the facility (i.e. which systems must be isolated or can be shutdown during construction, minimum dust mat locations, how building envelope can be penetrated to accommodate negative pressure fans, when systems need to be functional prior to occupancy, testing required, etc.).
- A methodology and action plan for responding to IEQ complaints. The Indoor Air Quality Building Education and Assessment Model (I-BEAM) developed by the U.S. EPA (www.epa.gov/iaq/largebldgs/baqtoc.html) contains sample forms.
- Routine inspection for evidence of moisture incursion and a plan for immediate removal of moisture contaminated materials.
- Update building systems manual after any building modifications.

A comprehensive and very useful reference is the US EPA's Indoor Air Quality Building Education and Assessment Model (I-BEAM), released in 2002, a web-based guidance tool designed for use by building professionals and others interested in indoor air quality in commercial buildings. I-BEAM updates and expands EPA's Building Air Quality guidance (the BAQ is still available via the web at www.epa.gov/iaq/largebldgs/baqtoc.html) and was designed to be a comprehensive state-of-the-art guidance for managing IAQ in commercial buildings. I-BEAM contains text, animation/visual, and interactive/calculation components that can be used to perform a number of diverse tasks.

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INFORMATIVE ANNEX D MEASUREMENT AND OCCUPANT SURVEYS FOR COMFORT AND INDOOR ENVIRONMENTAL QUALITY (IEQ)

Keeping a building at a comfortable temperature and relative humidity is important for occupant satisfaction. To keep building occupants comfortable while operating equipment efficiently requires a balance between energy consumption and comfort. Although many FMs measure energy, it is often more difficult to measure comfort. Comfort is difficult to measure because it is subjective and depends on individual perceptions.

To determine if building occupants are comfortable, three basic approaches can be used:

1. Monitor the number of comfort complaints (hot/cold calls) logged for the building or certain areas of a building.
2. Perform a comfort survey of all building occupants.
3. Conduct building walk-throughs.

When using the building control system to monitor comfort complaints, trends or reports can be set up for continually monitoring targets.

When determining what type of comfort survey to administer, it is important to consider the building type, the work done in the building and if the occupants regularly use computers. Successful survey methods differ, depending on building and occupant characteristics. A comfort survey can be administered as a paper-based form or phone interview or as an electronic web-based survey. Dahl (2008) found that paper-based surveys administered during a class of college students received a very high response rate. However, paper-based surveys disturbed to faculty, staff and professors outside of an organized class setting provided a low response rate, even when e-mails were sent to the potential survey participants to explain the importance of the survey. Using a phone interview method for a large government facility, Dahl (2008) received a 52 percent response rate.

A comfort survey can also be web-based. The Center for the Built Environment (CBE) at the University of California-Berkeley has developed such a survey that has been used in over 170 offices buildings within North America and Europe to assess thermal comfort and perceived productivity for office buildings. This survey consists of self-assessment questions, as opposed to objective questions based on physical measurements. The survey took less than one minute to complete and was administered once in the morning and once in the afternoon, to detect possible differences during the day. Between 20 to 40 percent of the building occupants responded to the surveys.

A third method to assess occupant comfort is to perform building walkthroughs. During the walkthrough ask building occupants if they are too hot or cold. Building walkthroughs with occupant interaction can help build rapport between the team and building occupants.

When developing a comfort survey to assess the comfort and mechanical system performance, the following should be kept in mind:

1. Explain the purpose of the survey to participants.
2. Collect information to identify where the survey participant works within the building.
3. Provide a scale or rating system to help occupants state their satisfaction with temperature conditions of their work space.
4. Keep the survey short.

D.1 Indoor Environmental Quality (IEQ)

It should be understood that comfort, as provided by the HVAC system, is only one element of overall Indoor Environmental Quality (IEQ). Beyond thermal conditions, IEQ encompasses qualities and comfort-related factors for air (IAQ), lighting, and acoustics. Survey instruments and on-line data collection, sometimes called Post-Occupancy Evaluations (POE) are available covering all these areas.

An important reference source for this area is the ASHRAE publication Performance Measurement Protocols for Commercial Buildings, 2010.

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INFORMATIVE ANNEX E: TRAINING NEEDS ASSESSMENT

SOURCE: National Employee Development Center (NEDC) Instructional Systems Design Guide

This informational Annex provides an overview of the training needs assessment process and references worksheets and job aids available for needs assessment purposes. The source of this material is the National Employee Development Center (NEDC) Instructional Systems Design Guide. NEDC is the focal point for training for the USDA Natural Resources Conservation Service (NRCS). The Center maintains a staff of instructional systems specialists, an audio-visual specialist, a public affairs specialist, and training technicians.

Another excellent resource for training needs assessment is the American Society for Training & Development(ASTD). ASTD is the world's largest association dedicated to workplace learning and performance professionals.

Human performance problems are not always solved via instruction. Instruction should only be used when the performance problem stems from a lack of knowledge, skills or attitudes and when instruction is the most cost-effective solution. Instruction should not be used as the solution when a performance problem stems from lack of motivation, feedback, incentives, or some other cause. Needs assessment, the first step in the instructional design process, serves as an objective way of uncovering human performance problems or potential problems. Needs assessment begins with a simple analysis of the performance problem to determine if training is the solution or if a more comprehensive needs assessment is warranted.

The following definitions are useful.

Need - A gap separating what people know, do or feel from what they should know, do or feel to perform competently.

Training Need - A gap that can be closed by training.

Performance Problem Analysis - A simple, quick assessment to determine if training is the solution to a performance problem or potential problem. It can lead to the conclusion that a comprehensive needs assessment is warranted.

Comprehensive Needs Assessment/Analysis - The process of identifying causes of performance problems in order to select methods, means, tactics, tools and approaches for solving the problems.

E.1 Step Formal Process.

NEDC’s Instructional Systems Design Guide is built around the job of designing formal, typically classroom training for groups of people. Each of the 10 steps in the instructional design process are linked on the left navigation bar. For each step there is a brief discussion along with worksheets and job aids in PDF format.

E.2 Five Step “Fast Track” Process. While the principles and concepts are the same for any type of training, the formality represented in the ISD guide is not practical for the design and delivery of on-the-job training. A quick reference guide for designing and delivering OJT is provided in the table below.

Worksheets and Job Aids for Needs Assessment

Guide or Worksheet	URL for download	Description
NEDC Instructional Systems Design Guide	http://www.nedc.nrcs.usda.gov/isd/index.html	Full guide addresses ten instructional design areas and provides worksheets and job aids.
Performance Problem Analysis Model: Is Training Really Needed?	ftp://ftp-fc.sc.egov.usda.gov/NEDC/isd/app.pdf	A simple, quick assessment to determine if training is the solution to a performance problem or potential problem. It can lead to the conclusion that a comprehensive needs assessment is warranted.
Performance Problem Analysis Worksheet	ftp://ftp-fc.sc.egov.usda.gov/NEDC/isd/performance_problem_analysis_worksheet.pdf	
Task Analysis Worksheet	ftp://ftp-fc.sc.egov.usda.gov/NEDC/isd/task_analysis_worksheet.pdf	Task analysis is an intensive examination of how people perform work activities. A task is a series of actions or behaviors that accomplishes a goal. Typically a task analysis deals with observable steps.
Goal Analysis Worksheet	ftp://ftp-fc.sc.egov.usda.gov/NEDC/isd/goal_analysis_worksheet.pdf	When organizational or other constraints prohibit a task or content analysis, instructional designers need an objective means of transforming laudable but otherwise vague desires into specific targets for learner accomplishments. This is the function of goal analysis.
Designing and Delivering On-the-Job Training	ftp://ftp-fc.sc.egov.usda.gov/NEDC/isd/ojt.pdf	Less formal 5-step process for designing OJT.

E.3 Training and Credential Programs for Facilities Professionals

Training and Certificate Programs

- Federal Energy Management Program (FEMP), U.S. Department of Energy (DOE)
- International Training Institute (ITI)
- International Union of Operating Engineers (IUOE)
- Northwest Energy Education Institute (NEEI)
- U.S. EPA Energy Star
- University of Washington (UW) Certificate in Facility Management

Training and Credential Programs

- American Society for Healthcare Engineering (ASHE) – Certified Healthcare Facility Manager (CHFMTM)
- Association of Energy Engineers (AEE) – Certified Energy Manager (CEM®)
- Association of Facilities Engineers (AFE) – Certified Plant Engineer (CPE); Certified Plant Maintenance Manager (CPMM); Certified Plant Supervisor (CPS)
- American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE) – Operations and Performance Management Professional Certification (OPMP®)
- Building Commissioning Association (BCA) – Certified Commissioning Professional (CCPTM)
- Building Operator Certification (BOC) – Certified Building Operator (BOC®)
- Building Owners and Managers Institute (BOMI) – Facility Maintenance Administrator (FMA®); Systems Maintenance Technician (SMT®)
- International Facility Management Association (IFMA) – Certified Facility Manager (CFM®); Facility Management Professional (FMP®)
- National Air Filtration Association (NAFA) Certified Technician
- National Sustainable Building Advisor Program (NaSBAP) – Certified Sustainable Building Advisor (CSBA)
- U.S. Green Building Council/Green Building Certification Institute (GBCI) – LEED® Accredited Professional; LEED® Green Associate

E.4 Checklist for On-Site Facility Training Programs

(Source: Washington State Energy Office, Hospital On-Site Training Demonstration, 1994. Reprinted with permission from the Washington State University Extension Energy Program.)

The purpose of WSEO's on-site training demonstration was to gain experience with on-site training design and delivery that could be applied to future training programs. Ultimately, on-site training should be one component of an effective training program at a facility. The lessons learned in this demonstration emphasize some of the needs of an overall training program for facility staff.

- Limit the amount of information and the length of classroom sessions. Participants can only absorb so much information. Focus on critical topics and develop this information in greater detail.
- Develop site specific training information and materials. Participants react more favorably to training that addresses specific topics like HVAC systems relative to courses covering a range of general energy conservation topics.
- Target the training to action takers. Identify individuals that have responsibility for particular facility operations. Provide training at a high enough level for these critical individuals to take action
- Provide greater amounts of hands-on training. Staff preferred this part of the training. The ability to provide hands-on training is a key advantage of on-site training.
- Provide a dynamic training style. Rather than just presenting information from overheads in the classroom, develop activities to make the participants more involved and active learners.
- It is important for the trainer to take time to establish a relationship with participants to gain an understanding of their needs and capability. Training will be more effective if there is a rapport between the trainer and participants.
- Facility managers and staff leads need to participate in the training. It is critical for the hospital to show a strong commitment to the training and support staff efforts to apply the training to their jobs.
- Identify action items early in the training process. This allows the training to more effectively address specific actions.
- Limit the amount of time lag between the various phases of the training demonstration. Training needs to take place over several months so that staff enthusiasm is maintained throughout the process.
- Emphasize the importance of the action plans and communicate this to all the participants. The action plans need to be an integral part of the training, rather than an afterthought.

- ❑ Training cannot address all the problems in a building. Some needs and problems may require more technical assistance than can be provided in a training program. Organizational dynamics can create barriers to training by not empowering individuals to take action. Other priorities (major remodels, new construction) can divert attention away from the training.

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INFORMATIONAL ANNEX F BUILDING INFORMATION MODELING (BIM)

Building information modeling (BIM) can be used to share knowledge and information about a facility to make decisions during the entire life cycle of the building (Fallon 2008). The most common uses of BIM in practice today are within the planning, design and construction phases of a project. The use of BIM for facility management is still emerging. As a result, few facilities are currently using BIM for operations and maintenance. One of the limitations of using BIM for O&M is the availability of software that can import and export the .ifc or .ifcxml file formats.

To understand how to apply BIM within O&M, there are several terms that are important.

COBie, Construction Operations Building Information Exchange: A structured data exchange format that looks like a spreadsheet. COBie can be used to collect project information and transfer the information from one application to another, such as between a BIM software product and a CMMS software product. At this time, BIM software vendors are working to export information to the COBie data format. Some CMMS vendors are also working to import information from the COBie data format.

COBie2: A refinement of COBie with the goal of internationalizing and consolidating COBie. Several of the spreadsheets tabs from COBie have been merged together in COBie2. For more information see: http://www.buildingsmart.com/content/fm_aquarium_cobie2_description

Industry Foundation Class (IFC): A data model structure to allow the exchange of information between different software packages. Most simply put, IFCs are a vendor neutral file format used within software (ASHRAE 2009). IFCs are of concern to software developers and software programmers.

OmniClass: OmniClass tables are intended to be a standard for classifying information for the North American architectural, engineering and construction (AEC) industry over the entire life cycle of a facility. OmniClass tables are intended to be the means to organize, sort and retrieve information and derive information from relational computer applications. By classifying this information, the OmniClass tables are a means to organize, sort, and retrieve information and develop relational database computer software. For example, OmniClass tables are used to define and refine IFCs, xml metadata and data exchanges. OmniClass tables are also used by COBie. The tables can also be used to organize library materials, organize product literature, organize project information, and to provide a classification structure for electronic databases (OmniClass 2006).

Information Delivery Manuals (IDM) are an integrated reference to describe specific processes needed for information exchange within the BIM environment. IDMs include process maps, exchange requirements, and functional parts (IDM 2006). For BIM users, an IDM includes a plain language description about the building construction process, information exchange requirements, information that may be provided by the user, and the expected end results of the process.

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INFORMATIVE ANNEX G: PREDICTIVE MAINTENANCE TECHNIQUES

Several different nondestructive condition measurements can be used for HVAC equipment, including, but not limited to, vibration analysis, thermography, pressure measurements, motor current analysis, oil analysis and refrigerant analysis. Each of these techniques is briefly described below. When using predictive maintenance techniques, it is important to select the types of tests that will have the largest benefits to the organization, such as reduced downtime, reduced maintenance costs, and/or reduced impact on building occupants.

G.1 Vibration analysis

Vibration analysis is used to determine the condition of rotating equipment. It can be used to detect a wide range of equipment problems before a failure occurs and can be used to forecast the most appropriate time to schedule maintenance, preventing unscheduled downtime.

Vibrations analysis can be used to detect the following problems:

- Misalignment and imbalance (which account for 60-80% of fan and pump problems)
- Resonance and bearing defects
- Gear and belt problems
- Sheave and impeller problems
- Looseness and bent shafts
- Flow-related problems (cavitation and recirculation)
- Electrical problems (rotor bar problems)

When analyzing vibrations data, it should be collected and tracked over time. A single vibration measurement will give the operator an indication of current operating conditions, but the data is more valuable if trended over time (ASHRAE 2003).

G.2 Thermography

Thermography, also called infrared thermographic inspection, is a process that uses electromagnetic radiation to measure heat transfer. Infrared thermographic inspection uses an infrared scanner to systematically scan temperature profiles to find problems before they arise. Infrared thermographic inspections of exterior envelope of roofs, entrances, wall and fenestration can quickly define areas of poor insulation, thermal leaks, thermal bridges and other areas of concern. Problems are detected when hot and cold spots are found. Infrared thermographic inspection is a quick and accurate technique that can be used to prevent equipment failures by collecting and analyzing thermal performance data. However, it does not ensure proper equipment operation. Other maintenance practices should be employed to ensure performance reliability (ASHRAE 2003).

G.3 Pressure Measurements Pressure gages can be used to measure the difference between atmospheric pressure and across closed systems. Pressure readings can be used to check the following pressure differences:

Across a heat exchanger outlet vs. inlet tubes to determine when the tubes need to be cleaned

- Across a filter to determine when the filter should be changed
- To determine if there is a flow restriction within a hydraulic system
- To determine when oil should be added to a gas engine

G.4 Motor current analysis.

Motor current analysis is used to diagnose rotor problems, including:

- Broken or cracked rotor bars
- Broken or cracked shorting rings
- Bad high-resistance joints between rotor bars and shorting rings
- Shortened rotor lamination
- Loose or open rotor bars preventing good contact with edge rings

Motor current analysis uses a multi-meter and motor current clamp to measure current draw on the motor. Motor current analysis can generally be performed while the equipment is running.

G.5 Oil Analysis.

Oil current analysis is one of the oldest and most common predictive techniques. Motor current analysis determines the wear metal count and types of contaminants in the oil. The wear metal count determines if the equipment is wearing in an unusual manner. The type of contaminants in the oil allows decisions to be made regarding the time interval between oil changes. Oil analysis can be completed by spectrochemical analysis, physical tests and ferrography.

G.6 Refrigeration Analysis.

Refrigerant analysis checks for vapor-phase and liquid-phase contaminants within the refrigerant and the physical properties of the refrigerant. The technique can also be used to determine that the refrigerant within the system meets acceptable standards, typically ARI Standard 700-99: Specifications for Fluorocarbon Refrigerants. Refrigerant analysis should be performed after repairing leaks, adding refrigerant to a system or after performing major repairs that have a high potential for moisture contamination. High moisture levels are undesirable in refrigeration systems because it can increase the acid level of the refrigerant, which can cause motor insulation to deteriorate or tube metal to corrode.

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INFORMATIVE APPENDIX H GUIDANCE FOR HVAC ENERGY SAVINGS

H.1 Source: Northwest Energy Efficiency Alliance Better Bricks <http://www.betterbricks.org>

Any HVAC system can be targeted for opportunities to improve scheduling, outside air use and calibration of sensors. The following HVAC system types have inherent design issues that make them prone to excessive energy use in certain areas.

System Type	Where Found	Opportunities for Savings
Dual Duct Fan Systems	Hospitals, pre 1980 offices & other	Simultaneous heat/cooling, Zone scheduling
Multi-zone Fan Systems	Hospitals, pre 1980 offices & other	Simultaneous heat/cooling, Zone scheduling
Constant Volume Reheat Systems	Hospitals, pre 1980 offices & other	Reheat
VAV fan systems	Hospitals, offices, other	Reheat /Recool, Zone scheduling
Heat Recovery or Energy Recovery	Hospitals & other with high minimum outside air	Dirty coils, coil bypass not optimized, non operational
Boilers	Hospitals & other with central HVAC	Inefficient combustion, poor staging, steam/steam trap leaks
Chillers	Hospitals, large office, other with central HVAC	Poor staging, dirty/corroded tubes, increase chilled water temperature
Compressed Air System	Hospitals, shops, older buildings	Poor Staging, leaks
Heat Pumps	Small buildings	Control of auxiliary heat
Water Loop Heat Pumps	Most building types.	Control of loop temperature and outside air, zone scheduling

H.2 The Top Four HVAC Savings Opportunities

To be *sustainable*, a facility should use only as much energy as necessary to meet operational requirements. Most buildings can reduce their energy consumption 10-30 percent by taking steps to eliminate excess energy use. Saving energy through improved building operation starts by finding opportunities in four areas that have been found to have the most frequent problems

and the potential for the greatest benefits. Most O&M related energy waste falls into four major categories:

- (1) Equipment scheduling: Equipment runs when it is not needed.
- (2) Sensor error: Erroneous sensor data causes increased heating, cooling, or equipment operation which can also affect occupant comfort.
- (3) Simultaneous heating and cooling: The same air gets heated and cooled, or hot and cold airstreams get mixed together to make warm air.
- (4) Outside air usage: Economizer does not functioning optimally or excessive outside air causes increased heating and/or mechanical cooling; sometimes too little air compromises indoor air quality. Lack of energy recovery and excessive outside air during periods of no or low occupancy.

(1) Equipment Scheduling: The easiest way, in most cases, to save equipment energy is to “shut it off”.

Letting equipment run longer than needed almost never generates occupant complaints , so it's easy for this problem to go unnoticed. A plan or procedure should be put in place to check occupant requirements and re-evaluate equipment operating schedules on a regular basis. Typically this should be performed twice a year and whenever there is a major tenant change.

Poor equipment scheduling has many negative impacts:

- Energy use increases proportionally to operating hours for most non-modulating equipment such as lighting, plug loads, and constant volume fans.
- For fan systems with ventilation or exhaust, nighttime operation almost always uses energy at a higher rate due to the colder ventilation or make-up air.
- Equipment staging intended to reduce demand charge can actually increase energy costs.. For example, some facilities may stage in equipment over an hour or two to avoid demand spikes. Motor starting currents are too short in duration to have an effect on billing demand (usually measured over 15 or 30 minute intervals), The equipment is coming on line earlier than necessary and increasing consumption while having no effect on the demand charge.
- Longer operating hours results in shorter equipment life and more frequent replacement of lamps, ballasts, filters, belts, electric heating coils, contactors, relays, motors, pumps, chillers, boilers, compressors and numerous other equipment.
- Increased operating hours leads to the need for more frequent cleaning of chiller bundles, boiler tubes, fan coils, evaporator coils, and condenser coils.

Walking through the building when it is unoccupied is a good first step in identifying unnecessary equipment operation. If equipment is running the reason will need to be investigated further. It is usually obvious that a light or printer should be off, but HVAC equipment may be running to supply a computer room that needs 24/7 conditioning or some other process load.

(2) Sensor Error: Sensor error can increase energy use, create occupant comfort issues and prevent plant and system loads from being met. While there are many sensors used in building systems, critical controls sensors are the most likely to cause severe energy penalties. For example, while space temperature sensors cause both energy waste and comfort problems, the effect on energy is usually minor and restricted to one zone. On the other hand, errors of critical control sensor such as the temperature of return air at the air handler can cause large energy penalties affecting many zones, yet may not cause comfort issues. Sensor error is hard to detect the error unless calibration is performed regularly.

There are a wide variety of sensor types available for HVAC use. Many can be calibrated and others need to be replaced periodically. It's important to know the specifications of the specific sensor in order to maintain it. Older CO₂ sensors need to be calibrated as often as every 2 months and newer sensors are available guaranteed accurate for the service life of the sensor - ranging from 5 to 15 years.

Critical control sensors with potential for large energy impacts, are generally those that are used at air handlers and central plants to implement resets and control outside air. While the impacts can be huge, the fix is quite simple – Regular calibration.

Critical control sensors include the:

- Mixed air temperature sensor
- Return air temperature sensor
- Outside air temperature sensor
- Supply air temperature sensor
- Chilled water temperature sensor
- Hot water temperature sensor
- Carbon dioxide sensor
- Carbon monoxide sensor

Some questions to ask:

- Are sensors calibrated at least annually?
- Are critical control sensors calibrated at least twice a year?
- Are critical control sensors replaced on a regular schedule as they approach end of service life?

Many sensor problems can appear to be other issues, such as:

- Plant and system loads not met
- Reset schedule not working
- Outside air economizer not functioning properly
- Boilers and chillers on when not needed
- Equipment not modulating as expected
- Simultaneous heating and cooling

(3) Simultaneous Heating and Cooling: Most central HVAC fan systems use some form of reheat. Central fan systems are designed to supply space conditioning to multiple areas in a building. Each area has its own space conditioning needs. Typically a central fan supplies cool air to one or more zones. At the zone level the quantity of air is usually modulated to satisfy the cooling load or may need to be reheated to meet a call for

heating. A typical office floor will have electric or hydronic coils installed in the duct work or the fan boxes serving the perimeter areas, while the central area is only cooled.

The temperature of the cool air leaving the air handler (primary supply air temperature) is critical to the amount of reheat required in the various zones. Control strategies are used to optimize the supply air temperature and reduce reheat. Usually the supply air is reset to the highest temperature that can still meet the cooling load. If the control strategy is not optimized, the supply air will be cooler than it needs to be and it will take more energy to bring it up to the reheat temperature.

In addition to obvious energy costs, Simultaneous Heating and Cooling adds to operational costs. When the central system delivers cooler air than required, the zone reheat coils must temper the air prior to delivery to the space. The heating and cooling systems work against each other. The impacts are greater than just energy e.g. additional wear on electric heating coils, contactors, hot water pumps, chilled water pumps, boilers, chillers and auxiliaries.

(4) Outside Air Usage: Outside air is supplied to a building by the ventilation system in order to displace indoor air pollutants and provide adequate ventilation for the building occupants. Proper ventilation rates are needed to maintain indoor air quality. Building codes require a minimum ventilation rate, usually based on ASHRAE Standard 62.

While buildings are only required to meet the ventilation code current at the time of construction or major remodel, it's good practice to provide ventilation that matches the latest codes and standards – if your HVAC system is capable

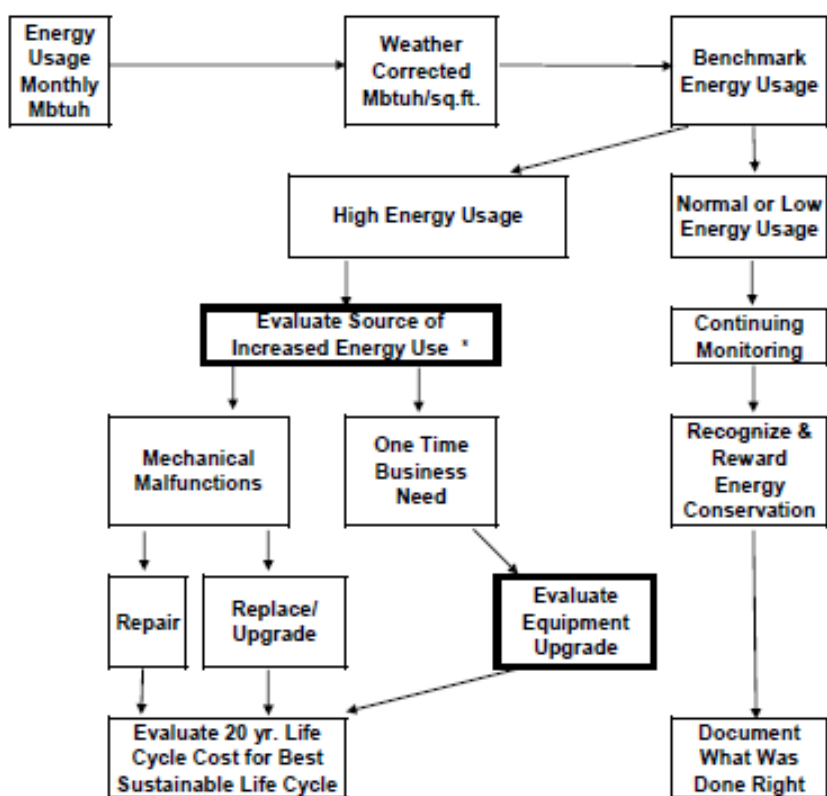
Heating outdoor air is an energy intensive and expensive process. Ideally a building's ventilation system will provide only the minimum outside air to meet occupant air quality needs, except when it can be used for cooling. There are numerous ways the ventilation system may operate that are less than optimum. Some typical problems include:

- Minimum ventilation rate never adjusted for a change in occupancy.
- Minimum ventilation rate set wrong by damper % rather than a measured airflow
- Damper leaks when in the unoccupied position
- Damper does not close when in unoccupied mode
- Damper stuck in one position
- Temperature sensors used by economizer out of calibration or failed
- Bad CO2 sensor location
- Bad or mis-calibrated CO2 sensor

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INFORMATIVE ANNEX I: ENERGY PERFORMANCE DIAGNOSTIC PROCEDURE

A sample procedure for Energy Performance Diagnostics is provided here. This procedure shows an overall logic model for assessing performance based on normalized energy data, which may be monthly bills or shorter interval data. Various approaches to energy performance diagnostics, for use in on-going monitoring programs, are under development.



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INFORMATIVE ANNEX J: HIGH-PERFORMANCE SYSTEMS SAMPLE CHECKLISTS

This Informative Annex contains sample checklists for equipment and systems likely to be found in high performance buildings. The Annex is not intended to be all inclusive or exhaustive of all possible system and equipment types. Additional checklists can be added as the Guideline is updated.

J.1 Water Efficiency

J.1.1 Reclaimed Water Systems Maintenance

The design of reclaimed (gray water and rainwater) systems varies tremendously. Reclaimed water systems can range from gray water systems that collect only water from lavatories to flush toilets, black water reclamation systems and rainwater systems. Therefore, it is very important to clearly understand the components of the system, source(s) and use(s) of water within the building under consideration. Sources of reclaimed water can include, but are not limited to: lavatories, showers, water closets, cooling towers, rain water and storm water. Uses of reclaimed water can include, but are not limited to: toilet flushing, washing clothing and irrigation. Special consideration should be given to what system components require specialized training to operate and maintain.

Within a reclaimed water system, the maintenance of the filtration and disinfection components is the most critical aspect. If the filtration and disinfection components are not properly maintained, the required water quality is unlikely to be achieved. Additionally, it is possible that poor water quality could negatively impact the health of the building occupants.

As the system components of reclaimed water systems varies tremendously, it is beyond the scope of this guideline to create a comprehensive list operations and maintenance requirements and guidelines. A few tips are provided:

- Systems with biological processes: Only trained, preferably licensed, wastewater operators should perform maintenance on systems that include biological processes, such as membrane bioreactors
- UV lamps: Transmittance levels of the lamps should be periodically checked, as the transmittance degrades over time
- Ozone disinfection: Periodically check the components to ensure there are no leaks.
- Pumps: Maintenance of pumps is similar to pumps used for central plant applications, such as chilled water pumps

J.1.2 Sample Checklist for Reclaimed Water Maintenance:

- Determine sources of reclaimed water in the building
 - Lavatories
 - Showers
 - Water closets
 - Cooling towers
 - Rain water
 - Other
- Determine how the reclaimed water is used in the building
 - Flushing toilet
 - Irrigation of outdoor plants
 - Other
- Determine system components
- Determine system components requiring specialized training and request training or hire a third party to perform necessary maintenance
- Perform required proactive maintenance at required intervals and/or ensure that third party service provider performs required maintenance

J.1.3 Sample Checklist for Waterless Urinals Maintenance

Waterless urinals are similar to traditional urinals. These attach to the wall and should be cleaned and disinfected daily. The main difference between a waterless and traditional urinal is that the waterless urinal is not connected to the existing water line, as only a connection to the existing gravity line is needed (Yon and Cosaboon 2009).

If waterless urinals are installed, a few things to be aware of include:

- If replacing traditional urinals, cap the water supply line.
- If the urinal has a liquid-sealant cartridge it should be replaced either after a specified time period or number of flushes. If the urinal has a replacement cartridge, the replacement range can vary from three to six months, or 1,500 to 7,000 uses.
- If the urinal does not have a liquid-sealant cartridge, it should be manually flushed out bi-weekly by purging the urinal with water to remove any remaining waste and liquid sealant and clean the waste pipe.
- A log to track sealant and cartridge changes or manual flush outs should be kept (Yon and Cosaboon 2009).

J.2 Building Envelope

J.2.1 Sample Checklist for *High Performance Building Envelope* Maintenance

- Look for water spots, water stains and dirt streaks near doors or windows during regular building walkthroughs. Identify and log locations of potential areas of damage.

- Investigate water leaks and damage promptly. Ascertain if the moisture is due to leakage or condensation from equipment. Repair leaks and remove water damaged materials.
- Perform visual inspections of the roof drainage systems monthly and after significant weather events. Look for clogged drains, damaged gutters or downspouts. Repair and clean as required.
- Perform seasonal inspections of the building façade looking for damage or problems. Focus on wall penetrations, window openings, weep holes, flashing and copings. Take pictures to document problems. Log problems and areas for future review.
- Budget for and perform thermography surveys (infra-red scans) (ASHRAE 2003) of the building façade to look for areas of insulation breakdown or thermal breaks.
 - Survey areas experiencing water damage first.
 - Prioritize areas to be scanned if the budget will not allow for a full building survey.
 - Perform surveys when there is the greatest contrast between the ambient conditions and the building temperature. For example, perform a roof scan at dusk when the roof temperature is warm and it has its greatest contrast when compared to the evening sky.
 - As most modern thermography equipment take digital images of the scans, the images should be printed and cataloged for future reference.
- In buildings that have experienced excessive humidity problems, slab on grade floors concealed by flooring should be scanned with thermography equipment to look for potential mold locations. Evaluate entrances, roofs and exterior walls and fenestration with infrared imaging and address areas of greater than normal heat loss in a systematic and ongoing program to improve overall envelope performance.

J.3 Indoor Environmental Quality (IEQ)

J.3.1 Sample Checklist for Indoor Environmental Quality (IEQ)

- Outside Air Usage and Ventilation System Control
 - Trend or measure and log RAT, OAT and MAT to check ventilation rates. Calculate the percentage of outside air based using the following simple formula
Percentage Outside Air = $(TRA - TMA) / (TRA - TOA)$
- Use CO₂ sensors to monitor and control ventilation
 - Weekly verify ventilation system match occupant schedules
 - Weekly log of RAT, OAT and MAT to check ventilation rates
 - Semi-annually check calibration of CO₂ sensors
- Trend of space temperatures with alarms for high and low temperatures

- Periodic verification that building ventilation systems are functioning properly including:
 - Visually inspect of outside air intake components every three months and verify all dampers operate without binding and through their full range of motion.
 - Keep air handling systems clean, including mechanical equipment rooms being used as return air plenums.
 - Perform ASHRAE Standard 62.1 Table 8-1 Activities
- Annual physical verification of ventilation airflows using a certified testing and balancing firm
- Identify and control sources of indoor air pollutions