# Sustainability "How-To Guide" Series

BEFORE AFTER

# No-Cost/Low-Cost Energy Savings Guide


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# ACKNOWLEDGEMENTS

This guide has been compiled from information provided by a collective of contributing writers to the BetterBricks Web site (www.BetterBricks.com). BetterBricks is the commercial building initiative of the Northwest Energy Efficiency Alliance (NEEA), which is supported by local electric utilities in the Northwest. Through the BetterBricks initiative, NEEA advocates for changes to energy-related business practices in the area's buildings, including a specific effort targeting building operations professionals in the use of best practices to maximize building performance. In this era of heightened appreciation for the impact climate change is having on our environment and our economy, energy efficiency is a crucial component to address global warming. The goal of the BetterBricks initiative is to provide building professionals with information, tools, training and resources to help them make energy efficiency a core strategy of building operations and the financial bottom line.

*—Christine Doonan, Alan Kakaley, Jim Volkman, Brad L. Weaver*

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# FORWARD

## IFMA Sustainability Committee (ISC)

The IFMA Association's ISC is charged with developing and implementing strategic and tactical sustainability initiatives. A current initiative involves working with the IFMA Foundation on the development of a series of "How-To Guides" that will help educate facility management professionals and others with similar interests in a wide variety of topics associated with sustainability and the built environment.

The general objectives of these "How-To Guides" are as follows:

1. To provide data associated with a wide range of subjects related to sustainability, energy savings and the built environment
2. To provide practical information associated with how to implement the steps being recommended
3. To present a business case and return-on-investment (ROI) analysis, wherever possible, justifying each green initiative being discussed
4. To provide information on how to sell management on the implementation of the sustainability technology under discussion
5. To provide case studies of successful examples of implementing each green initiative
6. To provide references and additional resources (e.g., Web sites, articles, glossary) where readers can go for additional information
7. To work with other associations for the purpose of sharing and promoting sustainability content

The guides are reviewed by an editorial board, an advisory board and, in most cases, by invited external reviewers. Once the guides are completed, they are distributed via the IFMA Foundation's Web site www.ifmafoundation.org free of charge.

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Established in 1990 as a nonprofit, 501(c)(3) corporation, the IFMA Foundation is supported by the generosity of a community of individuals—IFMA members, chapters, councils, corporate sponsors and private contributors—and is proud to be an instrument of information and opportunities for the profession and its representatives.

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'Expand knowledge of the built environment, in a changing world, through scholarships, education and research'

The Vision Statement of the IFMA Foundation

# 1 EXECUTIVE SUMMARY

This No-Cost/Low-Cost Energy Savings guide is principally derived from the BetterBricks article *Common Opportunities: The Top Four,* which can be found at the BetterBricks Web site, www.BetterBricks.com, under Building Operations. The goal of the guide is to provide facility operations personnel with a practical document that will provide the resources to initiate no-cost/low-cost energy-efficiency measures at their sites. This is not a theoretical piece, but aims to present specific maintenance targets in a "here's where to go, here's what to look for" format. The Web site articles from which this guide was derived have several bullet lists that can be translated to spreadsheet templates and used as checklists for facilities managers to reference. Many templates and software tools are also available for download, as noted in Appendix A: References in this guide (BetterBricks 2009a).

Another of the IFMA Foundation Sustainability "How-To Guides," *Getting Started: A Guide to Sustainability in Existing Buildings* by Chris Hodges (Hodges 2009) provides greater detail about planning to achieve sustainability in an existing facility and the associated cost benefits. The driving concept, and thus the difference, behind this manual is to provide facilities managers with the tools to get started on identifying problem areas and implementing no-cost/low-cost solutions. While there is an investment of time taken to explore the possibilities, the payoff/payback will be significant in terms of savings in energy usage and, therefore, in energy costs.

Targeting four specific areas as the best sources of potential problems, and thus potential efficiency gains, the guide provides lists that can essentially be used as checklists for facilities personnel, giving them starting points to gradually chip away at various efficiency projects. The top four areas of potential efficiency improvements discussed include:

***Equipment scheduling***: This section details the process of determining where energy is being wasted in areas that are not in use. Specific areas for examination are: lighting, plug and process loads, fan systems, chiller and boiler availability, and pumps. The section answers the question: Are these service items reflective of a facility's occupancy?

***Sensor error:*** The use of sensors has increased over the years, but often the settings are out of synch with what they are supposed to be monitoring. This can be caused by incorrect placement, failed sensors, errors in set up or even changes in usage patterns that have not been recalibrated as needed. This section demonstrates what to look for, how to make the changes and also how to set up a logical schedule to monitor settings.

***Simultaneous heating and cooling:*** Most heating, ventilating and air conditioning (HVAC) systems use some form of reheat, but if the settings are off for the air handler that pulls in the primary supply air, it can mean excessive reheating, using unneeded energy. A setting off by just 1 degree on a system with 20,000 cfm (cubic feet per minute) (9,400 liters per second) operating 10 hours a day, five days a week would cost an extra $1,000/year (US dollars) in electric reheat (using $0.06 per kWh). This section targets problems in various HVAC systems: VAV with reheat, constant-volume with reheat and dual duct, multizone fan and central air conditioner (AC) with perimeter heating.

***Outside air usage:*** To provide proper indoor air quality (IAQ) requires efficient ventilation, which in turn requires that the outdoor air be treated. Ventilation systems can experience many problems such as dampers stuck open or closed or improper sensor calibration. This section outlines the potential issues and details the various symptoms to look for to achieve optimum IAQ, while lowering energy use.

While these four areas offer immediate benefits to energy efficiency, the manual concludes by offering information on energy unit indexing (EUI), benchmarking and the benefits of developing a strategic energy management plan (SEMP), for which many tools and templates are available.

# 2 INTRODUCTION

To save energy through improved building operation first requires determining frequent problems that have the largest savings. Most operations and maintenance (O&M) related energy waste falls into four major categories:

***Equipment scheduling:*** Equipment runs when it is not needed.

***Sensor error:*** Erroneous sensor data causes increased heating, cooling or equipment operation, which can affect occupant comfort.

***Simultaneous heating and cooling:*** The same air gets heated and cooled, or hot and cold air streams get mixed together to make warm air.

***Outside air usage:*** Economizer does not function optimally, or excessive outside air causes increased heating and/or mechanical cooling, and sometimes too little outdoor air compromises indoor air quality.

This guide provides a roadmap for attacking these issues, providing checklists of where to look, what questions to ask, where to find solutions and how to implement energy saving measures.

**Figure 1: A "fat," energy wasting building**

### 2.1 Key Practice to Start: Develop a Building Systems Operations Map

Uncovering problems requires a thorough understanding of how a building is used, operated and maintained. One way to obtain that understanding is to develop a building systems operations map.

A building systems operations map documents current conditions, focusing on scheduling and on targeting heating, ventilating and air conditioning (HVAC) systems and equipment where common opportunities are found in similar buildings and systems. 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 targeting HVAC systems and equipment for potential energy savings. The map should clearly identify areas for immediate improvement, such as changing thermostat set points or equipment schedules, and provides the basis for additional evaluation.

**OUTLINE OF A TYPICAL BUILDING SYSTEMS OPERATIONS MAP FOR BOILERS, CHILLERS AND COOLING TOWERS**

- **Operating schedules and sequences of operation**
- **Large pumps and circulation loops served**
- **Fan systems served, including terminal units and air handling units**
- **Major energy systems served, such as water heaters and sterilizers**
- **General maintenance practices and equipment condition**

### OUTLINE FOR A TYPICAL BUILDING SYSTEMS OPERATIONS MAP FOR A MAJOR FAN SYSTEM

- The operating schedule and set points
- Occupancy schedule of the area(s) supplied, noting areas with extended operating hours
- Any capability of terminal units or baseboards to run independently of a major fan
- Sequence of operations for terminal units and/or baseboards
- Sequence of operations for air handling units, with a focus on the control of the outside air damper mixed-air temperature and supply air temperature
- General maintenance practices and equipment condition

### OUTLINE TO DOCUMENT ONGOING PROBLEMS AND WHAT BUILDING OPERATORS COMPENSATE FOR

- Undersized equipment
- Oversized equipment
- Spaces that cannot maintain temperature settings
- Building pressurization problems
- Major HVAC equipment with higher than typical failure rate

### OUTLINE FOR A TYPICAL BUILDING SYSTEMS OPERATIONS MAP FOR EACH MAJOR OCCUPANCY

- Occupancy schedule
- Lighting schedule and methods of control
- Equipment schedule and methods of control

### 2.2 Sample Templates

The four sample templates of building systems operations maps illustrate how spreadsheets can be constructed and modified to reflect different facility types. Obviously not all buildings will have the same equipment setup, but there are basics that can be outlined. Figures 2 through 5 illustrate general, plant, air system and pump spreadsheet templates.

**GENERAL INFO**

**Buiding Name:_____________________________________________ Date:_____________**

**Year Constructed_________ Building Size:_____________ Age of Chiller_______**

**Age of HVAC System__________ Number of Stories:_________ Age of Boiler_______**

**Describe HVAC System Type________________________________________________**

| Occupancy Schedules | | | | | | |
|---|---|---|---|---|---|---|
| | % of Building | Total Hours | | Wks Per | # | |
| Area | | Wkdy | Wknd | Year | Occ | Notes: |
| | | | | | | |

| Lighting System | | | | |
|---|---|---|---|---|
| | System | Est. | | |
| Area | Type | W/Sq.Ft. | % of Bldg | Notes: |
| | | | | |
| | | | | |
| | | | | |

| Misc. Office Equipment | | |
|---|---|---|
| | Load Density | |
| Area | (High, Med, Low) | Notes: |
| | | |
| | | |
| | | |

| Other (e.g. Cafeteria, Data Centers) | | | | | |
|---|---|---|---|---|---|
| | | HVAC | Est. Elec. | Est. Other | |
| Area | Desription | Service | W/Sq.ft. | kBtu/sq.ft. | Notes: |
| | | | | | |
| | | | | | |
| | | | | | |

**Comments:**

**Figure 2: General building operations map template**

**Building Name:** ______________________ **PLANT** **Date:**____________

| | | | | | | Control System "M" Manual "S" Self Contained "X" Control System | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Service ID | No. Units | Est. Size Tons | Est. Motor HP | Est. Annual Oper Hours | Start /Stop | Temp Reset | Temp Lckout | Stage Comp | Control Sequence Parameters/Notes |
| Chillers | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |

| | | | | | | Control System "M" Manual "S" Self Contained "X" Control System | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Service ID | No. Units | Capcity Control (Pony / Damper/ VFD) | Est. Motor HP / Cell | Est. Annual Oper Hours | Temp Reset | O.S.A Temp Lckout | Cap Control | Other | Control Sequence Parameters/Notes |
| Cooling Tower | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |

| | | | | | Control System | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Availablity Stand-by or On-Demand | "M" Manual "X" Control System | | | | |
| | Service ID | No. Units | Est. Size Mmbtu | Est. Annual Oper Hours | | Start /Stop | Temp Reset | Temp Lockout | Staging | Control Sequence Parameters/Notes |
| Boilers | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
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| | | | | | | | | | | |

**Figure 3: Central plant operations map template**

Building Name: ______________________________ **AIR SYSTEMS** Date: ____________

| | | | Ctrls Disch. | | Fans | | Est. Oper. Hours | | Control System "S" Self Contained "X" Control System | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Service ID | No. Units | Sensor Read | Est. Size (CFM) | Supply Est. HP | Return Est. HP | Wkdys | Wknd | Start /Stop | Temp Reset | Econo | Stage Comp | Control Sequence Parameters / Notes Comments |
| Air Handlers/Packaged Units | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
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| | | | | | | | | | | | | | |

Actual Outside Air Temperature: ____________ Controls O.S.A. Sensor Temp Reading: ________________

| | | | | | | | Control System "S" Self Contained "X" Control System | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Service ID | | Type | Htg Source | Clg Source | | | Night Stbk | Temp Ctrl | Warm Up | Occup Ctrl | Control Sequence Parameters / Notes Comments |
| Terminal Units | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |

| | | | | | | | | Control System "S" Self Contained "X" Control System | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Service ID | | | | | | | | | | | Control Sequence Parameters / Notes Comments |
| Other | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
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**Figure 4: Air system operations map template**

**Building Name:______________________________** **PUMPS** **Date:____________**

| | Service ID | No. Units | Capcity Control (Pony / Damper/ VFD) | Est. Motor HP | Est. Annual Oper Hours | Condition Comments |
|---|---|---|---|---|---|---|
| Chilled Water | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| Condenser Water | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| Hot Water | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| Domestic | | | | | | |
| | | | | | | |
| | | | | | | |

**Figure 5: Pump operations map template**

# 3 DETAILED FINDINGS: THE TOP FOUR SAVINGS OPPORTUNITIES

After the initial step of developing a building systems operations map, it is necessary to determine where energy efficiencies can be affected. The information in this section outlines what to look for in the "Top Four" areas of no-cost/low-cost energy efficiency: equipment scheduling, sensor error, simultaneous heating and cooling, and outside air usage.

### 3.1 Equipment Scheduling

**The easiest way to save energy from equipment operation is to shut it off.**

Occupants rarely complain when equipment runs longer than needed, so it is 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 regularly. Typically, the plan 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.
- Ventilation or exhaust fans usually use more energy at night because the ventilation or makeup air is colder.
- Staging equipment to reduce demand charges can actually increase energy costs. For example, some facilities may stage equipment over an hour or two to avoid demand spikes. The spike in current required to start motors does not last long enough to affect billing demand, typically measured over 15- or 30-minute intervals. The equipment comes online earlier than necessary, increasing consumption and having no effect on the demand charge.
- Longer operating hours result in shorter equipment life and more frequent replacement of lamps, ballasts, filters, belts, electric heating coils, contactors, relays, motors, pumps, chillers, boilers, compressors and other equipment.
- Increased operating hours of a building increases the cleaning frequency for 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, look for a reason. It is usually obvious that a lamp or printer should be off, but HVAC equipment may be running to supply a computer room that needs continuous conditioning, or to condition a process load (BetterBricks 2009b, BetterBricks 2009c).

Systems that often experience scheduling problems include:

- Lighting
- Plug and process loads
- Fan systems
- Chillers and boilers
- Pumps

#### 3.1.1 Lighting

Manually controlled wall switch lights are usually turned on by occupants as they arrive, but not always turned off as they leave. Occupants may not hesitate to turn off lights in a small room, but are reluctant to turn off large banks of lights if they think someone else might still be in the space.

Things to look for include:

- Is a specific person responsible for turning off the lights?
- Does the custodial staff turn off lights after hours as they go through the building?
- Do the light switches have turn off labels?

If lighting is controlled by a time clock, things to look for include:

- Does the programming match the occupant schedule?
- Does the schedule account for holidays and weekends?
- Is someone responsible for checking the programming regularly to make sure it meets current occupancy requirements?
- Do the lights actually turn off as programmed?
- Have temporary, special event schedules been reprogrammed back to normal schedules?

If there are motion sensors, things to look for include:

- Are they properly oriented to sense occupants?
- Has the time interval to switch the lights off after occupancy been properly set?

If there are daylight controls, things to look for include:

- Are the sensors situated properly?
- Are the appropriate light levels set?

If problems are suspected, you can attach a data logger to the lighting circuit and take readings at 15-minute intervals to identify the extent of the problem.

### 3.1.2 Plug and Process Loads

Plug and process loads are generally manually controlled by occupants. Like manually controlled lighting, these loads are normally turned on by occupants, but are often left on longer than necessary. Unlike lighting, custodial staff is not usually empowered to turn off plug loads like computers or medical equipment as they go through a building each evening. Some equipment such as servers, fax machines and medical equipment may need to run continuously.

Typical scheduling problems to look for include:

- Does the tenant or IT department have a policy or system in place to make sure computers with an ENERGY STAR power saving mode have it enabled?
- Does the tenant have a policy to encourage employees to turn off their equipment when leaving?
- Are computer monitors turned off when not in use?
- Are printers and scanners turned off when not in use?

### 3.1.3 Fan Systems

Most fan systems are controlled by a building automation system (BAS) or time clock. Typical scheduling problems to look for include:

- Do the programmed schedules match occupancy requirements?
- Do programmed schedules accommodate holidays and weekends?
- Are systems checked to make sure fans actually turn off when programming indicates they are off?
- Are the fans running after hours for minimal tenant occupancy?
- Is optimum start and stop utilized?
- If optimum start/stop is not available, are start times adjusted seasonally by the building operator?
- Can fan-powered variable air volume (VAV) boxes operate independently of the air handling unit? If so, are they programmed to match occupancy?
- Are exhaust fans interlocked with the air handling unit or controlled separately?
- Can baseboards operate independently from the fan system? If so, are they programmed to match occupancy?

### 3.1.4 Chiller and Boiler Availability

Typical scheduling issues with chillers and boilers include:

- Are chillers locked out when the outside air temperature is low?
- Are boilers locked out when the outside air temperature is high?

- Are chillers and boilers prevented from operating at the same time?
- Are there controls to shut off the boiler or chiller when there is no load?

### 3.1.5 Pumps

Typical scheduling issues for pumps include:

- Are domestic hot water circulating pumps scheduled off when the building is unoccupied?
- Are hot water pumps scheduled off when the building is unoccupied and the boiler is off?
- Are chilled water pumps scheduled off when the building is unoccupied and the chiller is off?
- Are condenser pumps scheduled off when the building is unoccupied and the chiller is off?
- Are hot water pumps controlled to run only when there is a demand for hot water or when the outside air is cool?
- Are chilled water pumps controlled to run only when there is a demand for chilled water or when the outside air is warm?
- Are condenser pumps interlocked to run only when there is a coil or process demand for chilled water?

## 3.2 Sensor Error

Sensor error can increase energy use, compromise occupant comfort, and prevent plant and system loads from being met (BetterBricks 2009b, BetterBricks 2009d). This is most often caused by calibrated sensors that have not been calibrated. However, it can also be due to incorrectly placed sensors, failed sensors or mistakes in control setup.

While building systems use many sensors, critical control sensors are the most likely to cause severe energy penalties. For example, while space temperature sensors result in energy waste and comfort problems, the effect on energy is usually minor and restricted to one zone. On the other hand, errors from a critical control sensor, such as the temperature of return air at the air handling unit, can cause large energy penalties affecting many zones, yet may not cause comfort issues. Sensor error is hard to detect unless the sensors are calibrated regularly.

A wide variety of sensor types are available for HVAC use. Many can be calibrated and others need to be replaced periodically. It is important to know the specifications of the specific sensor in order to maintain it. Older carbon dioxide sensors need to be calibrated as often as every two months, and some newer sensors are guaranteed to be accurate for the service life of the sensor, between 5 and 15 years.

Control sensors with the most potential to have a significant effect on energy use are generally those used to implement resets and control outside air at air handling units and central plants. While the impacts can be huge, the fix is simple — regular calibration.

Critical control sensors include:

- 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 include:

- 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 the end of the service life is approached?

Many sensor problems can appear to be other issues, for example:

- 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

### 3.3 Simultaneous Heating and Cooling

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. To meet the conditioning requirement of each zone, most central HVAC fan systems use some form of reheat. At the zone level, the quantity of air is usually modulated to satisfy the cooling load or may be reheated to meet a heating load. A typical office building floor will have electric or hydronic coils installed in the ductwork or in the fan boxes serving the perimeter areas, while the central area is cooled only (BetterBricks 2009b, BetterBricks 2009e). The temperature of the cool air leaving the air handler at the primary supply determines the amount of reheat required in the various zones. Control strategies optimize the supply air temperature and reduce reheat. Usually the supply air is reset to the highest temperature that can still meet the largest cooling load. If the control strategy is not optimized, the supply air will be cooler than necessary and reheating it will use more energy than necessary.

For example, if the primary air temperature was off by just 1 degree from optimum, it would cost approximately $1,000 per year (US dollars) in electric reheat at $0.06/kWh (US dollars) on a system with 20,000 cfm (9,400 L/s) of primary air operating 10 hours per day, five days per week.

There are many variations of central HVAC fan systems that have similar problems of simultaneous heating and cooling. The following are systems that should be targeted for energy saving O&M opportunities:

- VAV systems with reheat
- Constant volume systems with reheat
- Dual duct systems
- Multizone fans
- Central air conditioning systems with perimeter heating

To determine if there are problems, generate a trend log for the system. Trend the following:

- Outside air temperature (OAT)
- Return air temperature (RAT)
- Mixed air temperature (MAT)
- Supply air temperature (SAT)
- Economizer damper position, if positive feedback is available

Also graph the temperatures and see how the MAT varies with respect to the SAT, the RAT and the OAT. Then, see if the MAT curve changes slope when the dampers go to minimum position.

#### 3.3.1 Example of Normal Operation: Temperature

Figure 6 shows that MAT tracks RAT closely, as the outside air damper is set at 20 percent when the OAT is warmer. When the OAT is cooler than RAT, the MAT should equal the OAT because the system is completely (100 percent) in economizer cooling mode. This illustrates normal, efficient operation of the system. If your graph looks like this, the problem should be solved.

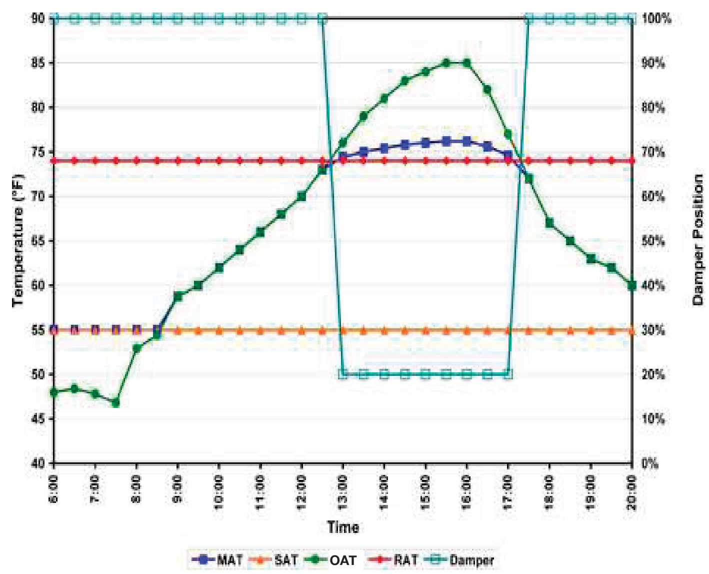



**Figure 6: Graph of normal system operation (Courtesy of BetterBricks)**

#### 3.3.2 Example of Abnormal Operation: Temperature Problem

Figure 7 shows that MAT tracks OAT closely, with the outside air damper set at 80 percent when the OAT is warmer than the RAT. If your graph looks like this, you could be drawing in too much outside air. You will need to start the process over. If the graph profile changes over time, another fan system may be affecting the space with the problem. It could also be caused by external wind pressure, which is discussed below.

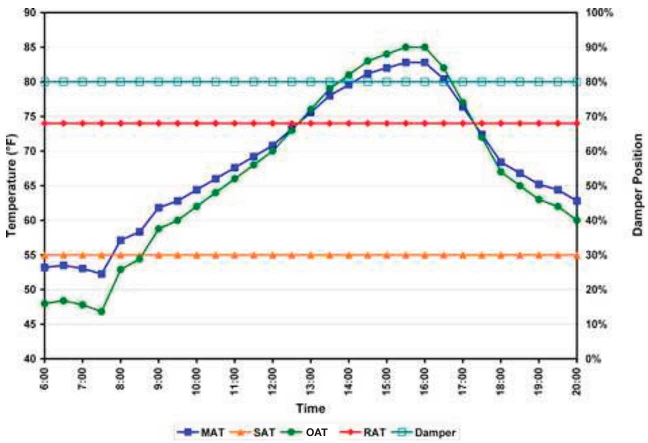



Figure 7: Example of high MAT (Courtesy of BetterBricks)

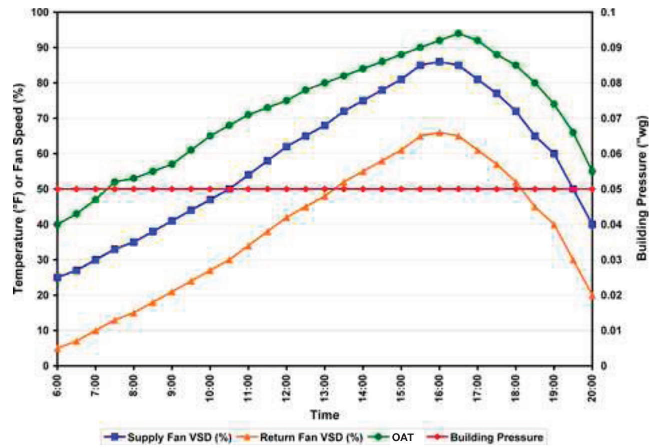



Figure 8: Normal operation with controlled building pressure (Courtesy of BetterBricks)

Trend the following additional points:

- Supply and return air fan status
- Supply and return fan speed, if on a variable-speed drive (VSD)
- Make sure to trend the VSD output, not the building automation system (BAS) output signal to the VSD
- The same points on adjacent air handling units, if they serve the same area
- Building static pressure with respect to the exterior

Graph the additional points and see how the building pressure varies with respect to the operation of each fan. Look for variations in the building differential pressure with respect to OAT, fan operation and general wind conditions. A pressure problem can be caused by an HVAC fan, wind or temperature differential between the lobby and top floor. This pressure differential is known as stack effect.

### 3.3.3 Example of Normal Operation: Controlled Building Pressure

Figure 8 shows normal operation of the building system with controlled building pressure under all conditions. If your graph looks similar to this, the problem has been resolved. Consider adding alarm set points for the building pressure so that you will be notified in the future of the problem before it affects energy usage.

### 3.3.4 Example of Abnormal Operation: Pressure Problem

Figure 9 shows how the building pressure becomes negative due to the stack effect as the OAT increases. Excessive air will be pulled through the outside air damper, increasing the MAT. Outside air can also be pulled in through perimeter doors, and even through curtain walls. If this occurs, you either have a fan control problem or a large break in the building envelope at the roof. Inspect the roof area for open doors, or for high-rise buildings inspect open isolation dampers in pressurization fans.

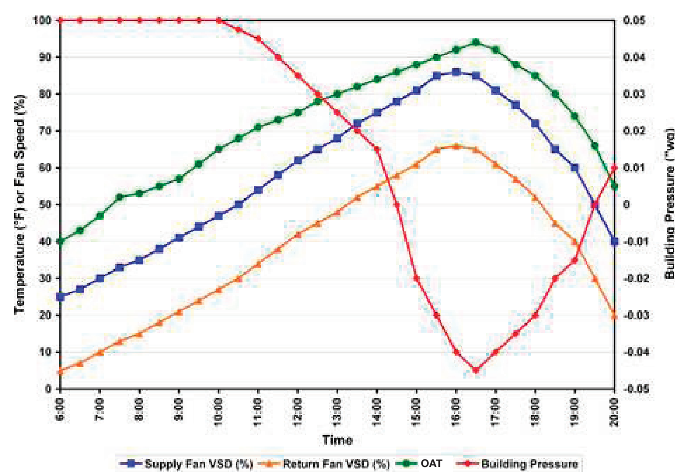



Figure 9: Abnormal operation with negative pressure (Courtesy of BetterBricks)

In addition to increased energy costs, simultaneous heating and cooling increases operational costs. When the central system delivers cooler air than required, the zone reheat coils must temper the air before it is delivered to the space causing the heating and cooling systems to work against each other. This creates additional wear on electric heating coils, contactors, hot water pumps, chilled water pumps, boilers, chillers and auxiliaries.

Chillers and boilers may run when none are needed, or a larger chiller or boiler may be sequenced on when a smaller one could have met the load. Electric reheat coils are turned on when they could have been left off. Variable flow chilled water and hot water systems operate at higher flow rates than necessary. Equipment capacity is reduced because the heating and cooling systems are working against each other. This can lead to underheated or undercooled areas and occupant discomfort when capacity is exceeded. Maintenance costs and equipment reliability are both affected.

### 3.4 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 (BetterBricks 2009b, BetterBricks 2009f). Proper ventilation rates are needed to maintain indoor air quality. Building codes require a minimum ventilation rate, usually based on ASHRAE Standard 62: Ventilation for Acceptable Indoor Air Quality. While buildings are only required to meet the ventilation code in effect at the time of construction or major remodel, it is good practice to provide ventilation that matches the most current codes and standards — if your HVAC system is capable. Requirements change from state to state and can usually be found by doing a search at the appropriate state Web site on air quality building codes.

#### 3.4.1 Economizers

Many buildings use an outdoor air economizer, which uses outside air for free cooling when its temperature is below the return air temperature. The economizer varies the outside air quantity from the minimum ventilation rate up to 100 percent outside air as needed to cool the building.

#### 3.4.2 Scheduling

Energy codes generally require that outside air dampers be closed when the building is unoccupied, and open to the minimum ventilation rate when it is occupied and being heated. When the building requires cooling, the economizer activates and allows additional outside air when the outside air is cooler than the return air.

#### 3.4.3 Demand Controlled Ventilation

Demand controlled ventilation adjusts the amount of outside air based on the number of occupants in the space. It is best applied to areas with large variations in occupancy such as auditoriums, gymnasiums and large conference rooms. By adjusting the ventilation rate to meet actual, rather than peak occupancy, requirements, energy is saved while maintaining indoor air quality.

Carbon dioxide ($CO_2$) is an easily measured by-product of humans. Demand controlled ventilation typically uses $CO_2$ sensors to control the minimum ventilation rate based on the difference between ambient outdoor air $CO_2$ levels and indoor space $CO_2$ levels. The latest ASHRAE standard 62.1-2004 does not specify a specific $CO_2$ difference that must be maintained. However, older versions of the standard recommended 700 parts per million (ppm) as an adequate differential for controlling odor.

#### 3.4.4 Fixed Air Systems

In some cases, the fan system is designed to provide outside air at a fixed rate any time the fan runs.

This is used either in very small systems or in special cases that require 100 percent ventilation for hazardous processes. Many current codes require heat recovery on systems that use 70 percent or more outside air.

#### 3.4.5 Energy Impacts

Heating outdoor air is an energy intensive and expensive process. Heating 20 cfm of outside air (9 L/s), typical for one person for 14 hours per day, five days per week, using electric resistance heat at $0.06/kWh costs about $28 (US dollars) a year in a typical Seattle, Washington, year. If an air handling unit supplies an extra 1,000 cfm (470 L/s) of outside air it would cost approximately $1,400 (US dollars) per year.

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. Ventilation systems can experience many problems. Some typical problems include:

- Minimum ventilation rate is never adjusted for a change in occupancy
- Minimum ventilation rate is set by damper position, rather than a measured airflow
- Damper leaks when in unoccupied mode
- Damper does not close when in unoccupied mode
- Damper stuck in one position
- Temperature sensors used when system is in economizer mode are out of calibration or have failed
- $CO_2$ sensor is improperly located

### 3.5 No-Cost and Low-Cost Energy Saving Strategies

This guide is designed to help facilities personnel implement the top four energy efficiency possibilities. Some recommendations for starting to implement no- or low-cost energy saving activities that can be easily performed are summarized below (BetterBricks 2009b, BetterBricks 2009h).

#### 3.5.1 Using the Energy Use Index (EUI) and Benchmarking

The energy use index (EUI) is the amount of energy used by a building per unit area of building floor area. By normalizing energy use to floor area, buildings can be benchmarked and compared for relative energy performance. The EUI can be based on whole building energy use or on specific end uses such as lighting or heating. A whole building EUI is a good measure of overall energy savings potential. Much data is available on whole building EUI for many building types. A building with a higher EUI than the average similar building is more likely to have energy-saving opportunities and the magnitude of the difference hints at the magnitude of potential savings.

Comparing the past performance of a building to current energy performance can provide further insight and might lead to additional energy savings. Questions to ask include:

- Has the EUI increased over time?
- Can the increase be correlated to a change in hours of occupancy, a decrease in vacant space, equipment additions or equipment changes?

If not, it probably indicates an opportunity to reduce energy use.

#### 3.5.2 The Benefits of Developing a Strategic Energy Management Plan (SEMP)

A strategic energy management plan (SEMP) involves six steps:

- Assess: Take a look at where you are
- Commit: Obtain executive buy-in for a plan
- Plan: Understand staffing and funding requirements and develop a plan
- Secure: Obtain executive approval
- Implement: Get it done
- Recognize: Track progress and reward efforts (BetterBricks 2009b, BetterBricks 2009g)

To develop your SEMP, here is a partial list of what is available:

- Energy practice checklist: Gets you started with a list of information you will need to gather: www.betterbricks.com/track.aspx?link=graphics/assets/documents/EnergyPracticeChecklist%28Step1%29v2%282%29.xls
- ENERGY STAR Portfolio Manager: An interactive energy management tool to track and analyze consumption: www.energystar.gov/index.cfm?c=evaluate_performance.bus_portfoliomanager
- SEMP templates: For forming an energy management plan: www.betterbricks.com/DetailPage.aspx?ID=943
- Financial tools: To assess life cycle cost analysis
- Sample SEMP PowerPoint presentation: To help you sell your plan to management: www.betterbricks.com/DetailPage.aspx?ID=943

Energy efficiency has become a major part of what facilities management entails. It is no longer just the good and responsible thing to do — it is necessary.

# 4 MAKING THE BUSINESS CASE

In a recent article from Foreign Policy magazine entitled "The Seven Myths About Alternative Energy" (September/October 2009), environmental journalist Michael Grunwald breaks down the viability of the various methods put forth as potential means of energy production, from nuclear energy to biofuels to wind and solar power. Grunwald highlights the problems with some alternatives, such as being years away from economic viability or the inefficient use of farmland for energy production, instead of food production. While some ideas show promise, in the near term he concludes that the two most effective means to lower energy consumption that can be accomplished are efficiency and behavioral changes.

"Efficiency isn't sexy," writes Grunwald (2009), so it does not get the attention the more exotic solutions receive. But it works. He continues, "'Negawatts' saved by efficiency initiatives generally cost 1 to 5 cents per kilowatt-hour versus projections ranging from 12 to 30 cents per kilowatt-hour from new nukes." (Grunwald 2009). So not only can you get cost-saving results for less money, you can get them soon.

Energy management delivers bottom line results so that money saved can be used in other critical business areas, such as new textbooks for children in schools or additional personnel in understaffed hospitals.

Here is what you can expect to accomplish:

- Lower operations and maintenance expenses
- Increased occupant comfort and satisfaction
- Reduced pollution and emissions generated via energy production
- Positive public relations and marketing for your company
- Shared community values with the public and elected officials
- Increased productivity, reduced absenteeism and increased morale through improved comfort and indoor air quality
- A reputation of innovation
- A legacy of achievement

# 5 CASE STUDIES

Three case studies are presented. The first, Kaiser Permanente, discusses a successful building tune-up and enhanced operations and maintenance pilot project. The second, the Boston Edison Building, demonstrates how lighting codes can have a very large impact on building energy consumption. The third case study, the Joe Serna Jr. Building, briefly discusses how daytime cleaning can reduce energy consumption and improve tenant satisfaction.

## 5.1 Kaiser Permanente

**KAISER PERMANENTE**

| | |
|---|---|
| Location: | Portland, Oregon |
| Building type: | Urgent care medical office building |
| Size: | 51,000 square feet (4,700 square meters) |
| Project: | Building tune-up |
| Electric utility: | Portland General Electric |

When Tony Moiso took over as facilities maintenance manager at Kaiser Permanente, he inherited 43 buildings in a region that stretches from Longview, Washington, to Salem, Oregon. Managing such far-flung facilities presents a significant challenge. He decided to upgrade the building controls to provide remote access and a centralized view of the building systems. He also wanted to maximize the investment by making sure the buildings were operating as efficiently as possible.

Karl Friesen, senior account executive at Control Contractors, Inc., a West Coast control system installation and integration contractor, suggested using the building performance services (BPS) approach to identify the most cost-effective opportunities for building improvements. This combination of a building tune-up with ongoing enhanced operations and maintenance efforts usually results in significant savings for building owners. Mr. Friesen presented a proposal to bundle the BPS services with the control system upgrade. The 30-year-old Kaiser Permanente East Interstate Medical Office was selected for the pilot project as it offered a host of HVAC energy-efficiency opportunities.

### 5.1.1 Building Tune-Up

The BPS approach included a building tune-up: a systematic examination of the building's mechanical system to find opportunities for energy savings and improved performance. The project included the following:

- Checking the air handling units for mechanical failures
- Documenting the sequences of operations
- Examining schedules and set points
- Verifying connectivity of equipment
- Evaluating sensor functioning
- Establishing trend data

During the tune-up, the team identified and fixed several problems: stuck dampers, disconnected reheat coils and miscellaneous issues with the variable air volume (VAV) boxes.

### 5.1.2 Enhanced Operations and Maintenance

Kaiser Permanente's strategy for maintaining building performance over time was to appoint Marty Zapp, chief engineer at the East Interstate Medical Office, as the HVAC system and controls champion. As champion, Mr. Zapp is in charge of:

- Proactively identifying and solving system-related problems
- Educating himself and his team about proper system maintenance
- Tracking and managing system performance
- Communicating system performance to management

Mr. Zapp and his team use the upgraded interface to the control systems to complete these tasks. With remote access, a visual overview and graphical controls, Mr. Zapp and his team very proactively maintain the building systems.

### 5.1.3 Results

***Improved quality of care:*** Since the BPS process was implemented, Kaiser Permanente has reduced its occupant complaints by nearly 23 percent. With a comfortable building, both staff and patients can relax and focus on the important work of getting well.

***Cost and energy savings:*** The building tune-up identified several opportunities for Kaiser Permanente to save both money and energy. Such savings could allow Kaiser to purchase new medical equipment related to patient care. Yet the success of this project does not just benefit Kaiser Permanente and its patients. The energy Kaiser saves is enough to power 46 average Oregon homes.

***Continuous improvement:*** The facilities team and the control systems contractor are now better equipped to identify and track down problems. They have already identified and fixed a number of additional issues. With the systems in better working order and a graphical overview of the building, the team can respond to complaints more quickly and even anticipate problems before someone calls.

### 5.1.4 Future Plans

The pilot project was such a success that Kaiser Permanente is performing the same process to nine more buildings. Over the next three to four years, Kaiser plans to extend this approach to all 43 buildings. To maintain the performance, they will conduct building tune-ups on each building every three to five years.

The implications of the pilot are significant — especially in the energy-intensive, not-for-profit health care industry. Every dollar saved can be channeled directly into patient care and mission critical goals. The energy saved becomes available to the rest of the community. With better building performance, these hospitals and clinics are not only supporting the health of their patients, they are supporting the health of their communities on both a local and global scale.

**KAISER PERMANENTE ENERGY AND COST SAVINGS FINANCIAL ANALYSIS**

**Cost of building tune-up: $18,000 (US dollars)**

**Cost to implement opportunities: $26,060 (US dollars)**

**Cost share: $9,750 (US dollars)**

**Potential annual savings: $32,906 (US dollars), 548,440 kWh**

**Simple return on investment (ROI): 75%**

**Simple ROI (after cost share): 96%**

*Note: The upgraded controls interface was an additional investment of $31,523 (US dollars)*

### 5.2 Boston Edison Building

**BOSTON EDISON BUILDING**

| | |
|---|---|
| Location: | Boston, Massachusetts |
| Building type: | Office building |
| Size: | 230,000 square feet (21,000 square meters) |
| Project: | Lighting system study to correct a system already in place |

The Boston Edison corporate office in Boston, Massachusetts, had an efficient system in place to allow tenants to activate lighting during off hours in specific locations. Unfortunately, the tenants lost their codes to enable the system, requiring security to turn the lights on for an entire floor, in some cases for just one person. During an off hours walk through, it was discovered that all lights in 216,000 square feet (20,000 square meters) of the 230,000 square foot (21,000 square meters) building were on – in this case, for just 5 people. More alarmingly, over 70 percent of total energy use was consumed during unoccupied periods.

The solution to this discovery was to redistribute the codes and post the codes in the applicable zones.

***Lesson learned***: Energy-efficiency equipment is only useful when used. Checking that it is being used properly is an essential part of an O&M scheduling plan (BOMA 2009).

**Boston Edison Corporate Office**

Over 70% of total energy use was consumed during non-occupied periods!

Tenants lost their dial-in codes to activate lighting during off hours. Upon request, security would turn on entire floors of lighting for one person.

| Cost | Cost / sf | Annual Savings | Annual Savings / sf | Payback | ROI Increase | Asset Value Increase | Annual Energy Savings |
|---|---|---|---|---|---|---|---|
| $2,000 | 1¢ | $121,200 | 53¢ | 2 mos. | 6,050% | $1.5 mil | 6.5% |

BOMA Energy Efficiency Program

**Figure 10: Summary of Boston Edison corporate office case study (Courtesy of the Building Owners and Managers Association (BOMA) International)**

### 5.3 Joe Serna Jr. Building

**JOE SERNA JR. BUILDING**

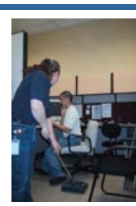
| | |
|---|---|
| Location: | Sacramento, California |
| Building type: | Office building |
| Size: | 950,000 square feet (88,000 square meters) |
| Project: | Personnel scheduling: a no-cost efficiency move for janitorial scheduling |

The Joe Serna Jr. Building houses the California Environmental Protection Agency. Building management implemented daytime cleaning hours as a means to saving energy. In addition to having no cost associated with the change, there were additional benefits.

Rather than after hours cleaning, building management instituted day shifts from 11 a.m. to 8 p.m. The result was an immediate 8 percent reduction in energy use, which translated to an annual estimated savings of $100,000 (US dollars) for the 950,000 square feet (88,000 square meters) of building space.

On top of the energy savings, a 70 percent reduction in tenant complaints was equivalent to saving an additional $110,000 (US dollars) in labor hours. Under the new setup, tenants can communicate their preferences directly to janitorial staff. Additionally, the potential for unwanted moving of paper, equipment and furniture was reduced.

**Joe Serna Jr. Building**



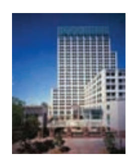
**Day Cleaning**

Janitorial Hours
11:00 am – 8:00 pm

Instituted during 2001 energy crisis

Immediate energy saving of 8%

70% reduction in tenant complaints



Managed by Thomas Properties Group

*ENERGY STAR Energy Performance Rating = 94*

| Cost | Cost / sf | Annual Savings | Annual Savings / sf | Payback | Asset Value Increase | Annual Energy Savings |
|---|---|---|---|---|---|---|
| $0 | 0¢ | $100,000 | 11¢ | Immediate | $1.25 mil | 8% |

**Figure 11: Summary of Joe Serna Jr. Building case study (Courtesy of the Building Owners and Managers Association (BOMA) International)**

### 5.4 Conclusion

While there are numerous innovative technological options that can increase energy efficiency, in an environment of tight budgets and escalating energy costs, as well as a heightened awareness of the importance of energy conservation, the no-cost/low-cost approach is more than appropriate for the majority of facilities managers — it is essential. Energy management is a key aspect of a building's day-to-day operations. Energy management must be viewed with a wider eye that examines many aspects of usage — occupant patterns, equipment efficiency and weather patterns. This guide is intended to help make the process of implementing an energy plan accessible to all facilities managers.

# 6 APPENDICES

## 6.1 Appendix A: References


ASHRAE (2007). *ASHRAE Standard 62: Ventilation for Acceptable Indoor Air Quality.*

BetterBricks (2009a). BetterBricks Web site, see Tools & Resources section under each main heading: www.BetterBricks.com

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Hodges (2009). Getting Started, IFMA Foundation Sustainability "How-To Guide" Series: www.ifmafoundation.org/files/sustain_wp/GettingStarted.pdf

## 6.2 Appendix B: ADDITIONAL RESOURCES

ENERGY STAR: www.energystar.gov home page provides energy management guidelines, tools, a resources library, expert help sources and much more.

United States Department of Energy Federal Energy Management Program (FEMP): www1.eere.energy.gov/femp includes the *O&M Best Practices Guide* for free download.

American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE): www.ashrae.org provides links to many resources as well as operations and performance management certification.

Database of State Incentives for Renewables and Energy Efficiency: www.dsireusa.org can be used to find local utility resources for operations and maintenance topics.

## 6.3 Appendix C: GLOSSARY

**Benchmarking:** Comparing the energy performance of one building with the performance of: (1) the same building from a previous time period, (2) the performance of other buildings in the same campus or management portfolio, or (3) the average performance of buildings in a broad regional or national database.

**Bullhead tee:** The name given to the installation of a tee fitting where the primary supply water flow enters the side tap and exits through the ends.

**Cavitation:** A condition occurring when the inlet pressure at the pump is less than the vapor pressure of the liquid being pumped, causing the liquid to vaporize into bubbles in the suction stream. The bubbles collapse upon entering the pump housing with the rotating impeller, preventing the pump from effectively moving the liquid. This creates a very distinct sound, like marbles being shaken in a tin can. Each pump has its own characteristic net positive suction head required (NPSHR) to prevent this condition.

**Cell:** The smallest cooling tower subdivision with independent air and water flow. It is enclosed by exterior walls or partition walls. Each cell may have one or more fans and one or more distribution systems.

**Chilled water reset schedule:** Automated control logic that raises or lowers the supply temperature of the chilled water leaving the chiller in response to another variable such as outside air temperature.

**Coil:** Used to heat and cool an air stream by transferring heat to or from another medium. Coils can be bare tube type or have an extended fin surface. Coils may use water, steam, refrigerant or electricity as a source for heat transfer.

**Compressor:** A mechanical device used to compress a gas.

**Condenser:** A portion of a refrigeration system in which hot refrigerant vapor is cooled by water or air, allowing the refrigerant vapor to condense back to liquid form.

**Evaporator:** A device in which a liquid refrigerant draws heat from chilled water and vaporizes it into a gaseous state.

**Expansion valve:** A component of the refrigeration system that regulates the rate of flow of liquid refrigerant into the evaporator.

**Fan coil unit:** A small terminal air handling unit with a fan and coil(s) to heat and/or cool the airstream.

**Fill:** The portion of a cooling tower that provides a large air-water interface area for heat transfer allowing a small amount of water to evaporate into the airstream, cooling the remaining water.

**Impeller:** The rotating part of a centrifugal pump, compressor or fan designed to move a fluid by rotational force. It is usually made up of a disc with multiple vanes attached to it.

**Magnetic bearing technology:** A centrifugal compressor with a rotor shaft and impeller that levitates during rotation while suspended in a magnetic field.

**Makeup water:** Water added to a circulating water system to replace water lost by evaporation, blowdown or leakage.

**Notched belt:** A belt with teeth (notches) used to mechanically link two or more rotating pulleys. The notches increase grip, help cool the belt and relieve stress as the belt bends around small diameter pulleys. This belt type improves drive efficiency.

**Pony motor:** A small secondary cooling tower fan motor that operates instead of the primary cooling tower fan motor in light load conditions.

**Predictive maintenance:** Maintenance practices using specialized diagnostic equipment at regular intervals to detect the onset of deterioration of machinery. The aim of predictive maintenance is to extend service life by reducing degradation.

**Preventive maintenance:** A maintenance activity performed at a regular time period or run-hours interval to prevent systems from failing.

**Process load:** A cooling or heating load not related to maintaining occupant comfort, such as file server rooms and specialized diagnostic equipment in the health care sector. The loads may be intermittent or continuous.

**Pump head:** The differential pressure of a fluid generated by a pump between the inlet and outlet. This pressure may be expressed in feet of water or pounds per square inch (psi) in English units or kilopascals (kPa).

**Refrigerant:** A substance producing a refrigerating effect by expanding or vaporizing.

**Subcooling:** The process of cooling a liquid to a temperature at which it will condense at a constant pressure.

**Superheat:** Energy removed from the refrigerant in the condenser to make the vapor 100 percent saturated.

**Terminal unit:** The final piece of HVAC equipment in a distribution system capable of modifying the temperature in a conditioned space.

**Trend logging/trend log:** Recording system variables, such as temperature, volume, pressure or power, at time intervals to monitor equipment operation and help identify and/or diagnose problems. Logging is accomplished using portable data loggers, electrical meters or a direct digital control (DDC) system.

**Ton of cooling:** The amount of energy necessary to melt one ton of 32°F (0°C) ice into 32°F (0°C) water in 24 hours. One ton of cooling equals 12,000 Btu/hour (3,516 watts).

**Two-way valve:** A valve regulating flow between no flow (closed) and full flow (open). It can either modulate or operate as a two-position valve in response to an external input signal. A two-way valve does not have a bypass, like a three-way valve.

**Variable-speed drive (VSD):** An electronic device that controls the rotational speed of an alternating current (AC) electric motor by controlling the frequency of the electrical power supplied to the motor.

**V-belt:** A belt used to mechanically link two or more rotating pulleys. The “V” shape of the belt tracks in a mating groove in the pulley or sheave.

**Water-to-air heat pump:** A heat pump that heats or cools air by either taking heat from or rejecting heat to a closed circulating water loop and then transfers the conditioned air to the space.

**Waterside economizer:** An economizer added to a standard chilled water system to provide air conditioning without operating a chiller. The system includes chiller bypass piping, associated valves and a heat exchanger. Under certain outside air conditions and internal load conditions, water from the cooling tower bypasses the chiller to a heat exchanger connected to the chilled water supply loop.

**Wet bulb temperature:** A measurement of air temperature relative to the water content of the air. The bulb of a wet bulb thermometer is covered with a wetted wick. The water on the wick evaporates less in humid conditions and more in drier conditions. At 100 percent relative humidity, the wet bulb temperature is equal to the dry bulb temperature. At dry bulb temperatures where humidity is less than 100 percent, the wet bulb temperature is less than the dry bulb temperature. At any given dry bulb temperature, lower relative humidity will result in a greater difference between the two temperatures.

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