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## ENERGY STAR Buildings Manual

# A Guide for Implementing the ENERGY STAR Buildings Program

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# Preface

The *ENERGY STAR BUILDINGS MANUAL* is a guide for ENERGY STAR Buildings Partners to use in planning and implementing profitable energy-efficiency upgrades in their facilities. Its purpose is to provide a concise overview of each of the five recommended stages of the ENERGY STAR Buildings Program: Green Lights, Building Tune-Up, Load Reductions, HVAC Distribution System Upgrades, and HVAC Plant Upgrades. The energy-efficiency improvements made in each of these stages build upon the upgrades made in previous stages.

This manual is only one of several technical resources that EPA is making available for ENERGY STAR Buildings Partners. It provides a roadmap to guide participants through the steps that need to be completed during each stage of the program.

Following an introductory chapter, the manual is organized according to each of the program's five stages. Each chapter provides information on upgrade opportunities, including project management considerations and additional points to consider when preparing specifications. Appendices discuss building environmental quality issues and provide supplemental information on program management.

This is the second edition of the *ENERGY STAR BUILDINGS MANUAL*. As we prepare future editions, we welcome the reader's specific suggestions for improvements. Please call 202–775–6650 or send a fax to 202–775–6680.

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# Before You Begin

# Before You Begin

EPA's ENERGY STAR Buildings Program is here to help building owners and managers make profitable investments in energy-efficient equipment and operations.

Investments in energy efficiency benefit the Nation by reducing pollution and creating jobs. The profitability of those investments provides benefits to building owners by improving their bottom lines.

To gain maximum energy savings and profits, ENERGY STAR Buildings Partners are encouraged to use a comprehensive five-stage strategy for their building upgrades. Before learning about the specifics of the stages, however, spend some time with this introductory chapter. Here you will become familiar with the ENERGY STAR Buildings Program and some of its key elements.

This chapter contains the following sections:

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# Program Overview

SECTION 0.1

Each year, the energy required to operate office buildings in the United States:

- Consumes approximately $71 billion from the Nation's economy.
- Costs the owner of a typical building between $1 and $3 per square foot.
- Adds significantly to the amount of pollution released into the atmosphere:

  —16 percent of the carbon dioxide.

  —12 percent of the nitrogen oxides.

  —22 percent of the sulfur dioxides.

The goal of EPA's ENERGY STAR Buildings Program is to reduce that pollution by encouraging building owners to voluntarily implement profitable energy-efficiency improvements in their buildings.

## The Program

A typical large office building consumes energy (primarily electricity) in four main areas:

- Lighting systems (29 percent).
- Air-handling systems (28 percent).
- Cooling systems (24 percent).
- Office equipment, elevators, auxiliary heating, and other (19 percent).

The five stages of the ENERGY STAR Buildings Program (Figure 1) include plans for energy-efficiency tune-ups and upgrades in each of these areas. Through these actions, ENERGY STAR Buildings Partners can expect to reduce total building energy consumption by 30 percent, on average.

The five-stage strategy developed by EPA takes into account load-reducing upgrades at the beginning of the program to provide maximum savings when the heating and cooling systems are upgraded at the end. Although following this strategy is not required of ENERGY STAR Buildings Partners, it is highly recommended. The chapters of this manual are organized to follow this strategy.

Each stage of the ENERGY STAR Buildings Program provides opportunities for profitable upgrades throughout your building (Figure 2) and corresponding reductions in your energy costs. Each stage is briefly described below.

**Figure 1. ENERGY STAR Buildings Program Stages and Activities**

**Stage 1: Green Lights**
- Implement Green Lights upgrades.

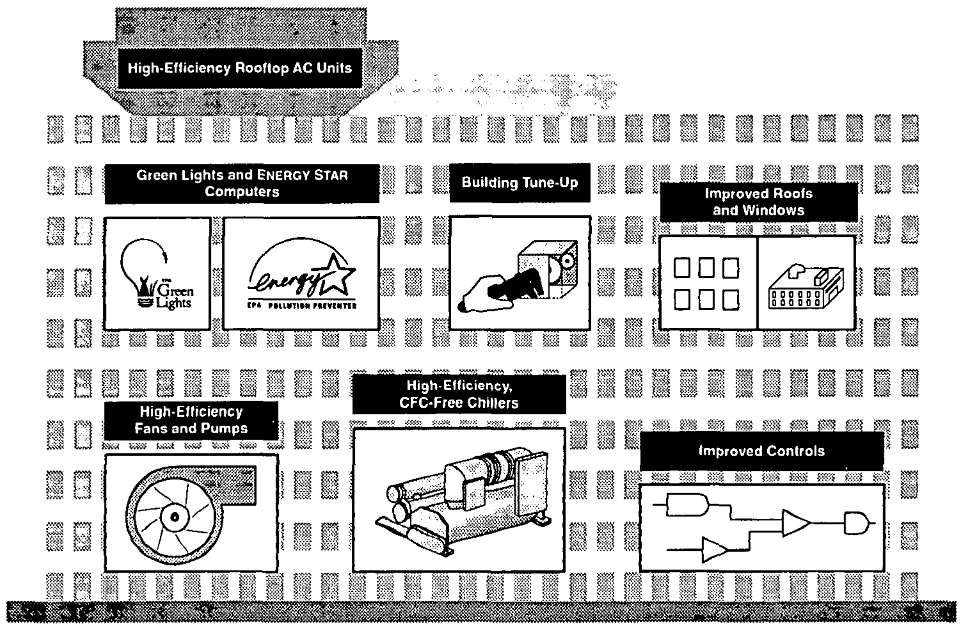
**Stage 2: Building Tune-Up**
- Perform building tune-up.
- Implement preventive maintenance and training programs.

**Stage 3: Load Reductions**
- Install profitable window and roofing upgrades.

**Stage 4: HVAC Distribution System Upgrades**
- Install energy-efficient motors and variable-speed drives downsized to new loads (with appropriate safety margins).
- Install and calibrate controls.

**Stage 5: HVAC Plant Upgrades**
- Upgrade or replace plant with downsized, high-efficiency equipment.

Figure 2. Opportunities for Profitable Energy-Efficiency Improvements Through the ENERGY STAR Buildings Program




- ***Stage 1—Green Lights***
  Get your building upgrades off and running by installing energy-efficient lighting systems that will provide immediate, profitable reductions in overall energy consumption.

- ***Stage 2—Building Tune-Up***
  Be certain that building systems are operating efficiently by performing a comprehensive energy-efficiency tune-up of your entire facility, including preventive maintenance and staff training programs. The tune-up provides the additional benefits of improved levels of occupant comfort and indoor air quality.

- ***Stage 3—Load Reductions***
  Complete the foundation for the heating, ventilating, and air conditioning (HVAC) system upgrades in Stages 4 and 5 by reducing heating and cooling loads. For example, energy-efficient lighting implemented through the Green Lights Program gives off much less heat. Therefore, new cooling equipment would not need to provide as much peak capacity as the equipment it replaces. Other ways to reduce heating and cooling loads include energy-efficient office equipment, such as computers and printers with the ENERGY STAR label; reflective coatings for windows; and improved insulation or reflective coverings for roofs.

- ***Stage 4—HVAC Distribution System Upgrades***
  Downsize your air-handling system to match newly reduced loads by installing smaller energy-efficient motors and larger pulleys; converting constant air volume systems to variable air volume systems (where applicable); and installing variable-speed drives to control fan motors and provide maximum efficiency at reduced airflow.

- ***Stage 5—HVAC Plant Upgrades***
  Reduced loads achieved in Stages 1 through 4 create the opportunity for substantial equipment cost savings on new, high-efficiency heating and cooling equipment—for example, a smaller, high-efficiency, CFC-free chiller (an upgrade

that should be seriously considered as new laws mandating reductions in chlorofluorocarbons come into effect). You will also be installing variable-speed drives to control chilled water pumps and condenser water pumps and improving boilers, cooling towers, and direct-expansion space-conditioning equipment.

Each stage of the ENERGY STAR Buildings Program includes a comprehensive survey related to the area that is to be upgraded. These surveys will help you determine where energy-saving modifications and upgrades will be most effective.

### *Flexibility To Meet Your Needs*

The five stages of the ENERGY STAR Buildings program provide you with flexibility to accomplish the entire program at one time or in sequence. However, performing the upgrades in stages will enhance the return on your investments because you can closely match equipment to reduced loads, thus building on the success of previous stages.

## *In This Manual*

Your *ENERGY STAR BUILDINGS MANUAL* contains the following information:

- The remaining sections in this introductory chapter tell how EPA is prepared to support your efforts, provide advice on how to organize and manage your ENERGY STAR Buildings effort, and describe the roles of energy monitoring and building surveys.
- Chapters 1 through 5 explain how you can obtain energy savings through profitable energy-efficiency upgrades in each of the five stages of the program.
- Chapter 6 provides information on additional areas where you may be able to make energy-efficiency improvements.
- Appendix A contains the building survey forms and instructions.
- Appendix B discusses indoor air quality issues associated with your building upgrades.
- Appendix C contains supplemental program management information on financing and preparing requests for proposals and quotations.
- Appendix D is a glossary of terms and abbreviations used in this manual.

Comments on the *ENERGY STAR BUILDINGS MANUAL* are welcome at any time.

| To Comment on the ENERGY STAR BUILDINGS MANUAL |
|---|
| **Phone 202-775-6650** |
| **Fax 202-775-6680** |

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# Partner Support

SECTION 0.2

The following support is available to all ENERGY STAR Buildings Partners:

- ***Planning and Implementation***

  —Partner Visits.

  —Telephone Support.

  —Communications.

- ***Information and Analysis***

  —*ENERGY STAR BUILDINGS MANUAL.*

  —Software for Economic Analysis.

  —Green Lights Database of Financing Programs.

  —Case Studies Documenting Savings for Specific Technologies.

  —Results of Building Energy Usage Computer Simulations.

  —Technology Briefs.

  —Technical Advisory Support.

These support activities are described in the following paragraphs.

## Planning and Implementation Support

EPA stands ready to provide the following types of planning and implementation support as your participation in the ENERGY STAR Buildings Program begins.

### Partner Visits

In some cases, representatives of EPA or EPA contract personnel may be available to visit ENERGY STAR Buildings Partners' facilities to address specific upgrades or implementation issues. Implementation issues can include the following:

- Organizing the ENERGY STAR Buildings team, establishing team leadership, and designating management roles.
- Establishing lines of communication and coordination, both within the team and between your organization and EPA.
- Identifying financing needs and resources.
- Conducting the ENERGY STAR Buildings surveys.
- Planning trial installations and evaluating new technologies.
- Setting goals and developing action plans.
- Determining an approach to use in deciding which upgrades to implement.
- Developing strategies for submitting progress reports.

EPA or EPA contract personnel can also help you use the ENERGY STAR Buildings analysis tools that are available and provide brief technical reviews of completed surveys for specific facilities or program stages. They can help you conduct preliminary surveys and define trial installation projects for immediate implementation at your facility. In some cases, they can visit upgraded facilities to gather information for case studies or to provide assistance in determining opportunities for additional energy savings.

### Telephone Support

EPA and its contract personnel will maintain regular contact with all ENERGY STAR Buildings Partners. Periodic calls provide a convenient opportunity to discuss project specifics, methodologies, and difficulties and to answer technical or programmatic questions. The objective of this support is to help Partners get the most out of their participation in the program.

Of course, you certainly do not need to wait for the ENERGY STAR Buildings Program to call you; any time you have a question, problem, or comment you can call or fax us.

| ENERGY STAR Hotline |
|---|
| **Phone 202-775-6650** |
| **Fax 202-775-6680** |

### Communications

Because saving energy and preventing pollution is good news, one important goal of the ENERGY STAR Buildings Program is to help Partners inform employees, customers, shareholders, and the business community about their participation in the program.

***Corporate Communications.*** EPA has developed a variety of communications materials and publications to facilitate participation in the ENERGY STAR Buildings Program. These materials include the *Green Lights Update* newsletter, slide presentations, and *ENERGY STAR Buildings Marketing Briefs*.

***Case Studies.*** One of the most successful ways to promote energy efficiency is through the use of case studies. These "success stories" can be used for corporate recognition, program promotion, education, and developing confidence in the profitability of building upgrades. ENERGY STAR Buildings Program staff will work with you to develop a case study that may ultimately be publicized in ENERGY STAR Buildings Program materials, industry publications, local newspapers, or even national media.

***Progress Reporting.*** Compliance with the project documentation requirement in the ENERGY STAR Buildings Memorandum of Understanding can be easily met by submitting an ENERGY STAR Buildings Annual Report for each facility once each year.

EPA analyzes each implementation report form submitted and follows up as needed to obtain complete information, assist in selecting future upgrades, or coordinate case study development. The information is also entered into an EPA database that is used to determine the overall impact of the program and to analyze trends in upgrade choices, costs, methods, acceptance, and profitability. These analyses will provide valuable input for future energy-efficiency products and services.

## Information and Analysis

One of the major obstacles to successful implementation of energy-efficiency upgrades is the scarcity of objective information to use in deciding which upgrades provide the proper mix of energy efficiency and profitability. The ENERGY STAR Buildings Program has developed the following information resources to help Partners obtain the information they need.

### Software

The QuikFan analysis program, which runs under Microsoft Windows 3.0, is an easy-to-use software tool designed to assist in calculating the profitability of implementing fan system upgrades, including the interactive effects of cooling load reductions and installation of variable-speed drives on fan motors in a building. After you enter engineering and financial data, QuikFan calculates the cost of the upgrade, the simple payback period (in years), and the internal rate of return for a number of different scenarios.

| QuikFan Software |
|---|
| **EPA Atmospheric Pollution Prevention Division**<br>**USEPA/OAR (6202-J)**<br>**401 M Street SW**<br>**Washington, DC 20460** |
| **Or call the ENERGY STAR Hotline: 202-775-6650**<br>**Fax: 202-775-6680** |

EPA is developing additional software tools that will help Partners calculate profitable chiller upgrades and prioritize their buildings for upgrading.

### Database of Financing Programs

This directory, developed for the Green Lights Program, consists of two indexed databases. ***Utility Financing*** contains information on utility incentive programs (rebates, direct assistance, and loans) that encourage energy-efficiency upgrades. ***Non-Utility Financing*** contains information on companies that provide financing services, either financing companies or energy services companies that coordinate with banks, leasing firms, or investment groups. The financing options offered by these firms include conventional loans, guaranteed savings insurance, capital leases, and shared savings.

The Financing databases run on IBM PC or compatible computers.

**Financing Database Software**

**EPA Atmospheric Pollution Prevention Division**
**USEPA/OAR (6202-J)**
**401 M Street SW**
**Washington, DC 20460**
**Or call the ENERGY STAR Hotline: 202-775-6650**
**Fax: 202-775-6680**

Appendix C contains more information on financing options for building energy-efficiency upgrades.

### Technology Studies

EPA will maintain a number of technology studies documenting energy savings and internal rate of return for specific upgrades in specific types of buildings. ENERGY STAR Buildings Partners can use these studies as a starting point in determining the type of energy savings and profits expected from a particular energy-efficiency upgrade.

### Computer Simulations

EPA will offer the results of building energy usage computer simulations that ENERGY STAR Buildings Partners can use as a starting point in determining the type of energy savings and profits expected from a particular energy-efficiency upgrade. Comparing the results for upgrades and building types in locations similar to yours can help you determine if you are moving in the right direction.

### Technology Briefs

EPA is developing a series of Technology Briefs summarizing various technologies and implementation issues of interest to ENERGY STAR Buildings Partners. These publications are intended to serve as introductions to these technologies and issues.

### Technical Advisory Support

ENERGY STAR Buildings Partners can receive technical advisory support from EPA contract personnel as they implement their pilot ENERGY STAR Buildings upgrades. This support includes design reviews, technical analysis, and site visits.

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# Implementation Planning

SECTION 0.3

This section provides some advice on how to organize the ENERGY STAR Buildings effort within your company.

## Assembling the ENERGY STAR Buildings Team

The first step in organizing the ENERGY STAR Buildings program in your company is to assemble the team that will oversee the program—that is, set goals, establish timetables, and assign responsibilities. Such a team typically includes the following members:

- The **ENERGY STAR Buildings Project Director** serves as the ENERGY STAR Buildings "champion," ensuring that your company successfully meets the upgrade commitments established in the Memorandum of Understanding and acting as the primary program liaison between EPA and your company. This individual conducts the kickoff meeting, coordinates ENERGY STAR Buildings team activities, and establishes and oversees the implementation plan. The project director also directs your company's upgrades. Therefore, this role requires a motivated person who can engage participation, using either direct authority or personal influence, and can influence or communicate with all corporate functions affected by ENERGY STAR Buildings.
- **Facility Managers** are the primary contacts for each of your company's facilities and should be the main contacts for specific upgrade projects.
- A **Financial Analyst** decides how to secure funding for upgrade projects and identifies the most advantageous financing options. This individual performs a variety of financial tasks, such as projecting cash flows, calculating after-tax internal rates of return for upgrades, and interpreting reports. The analyst also evaluates financing sources and produces in-house documents for use in project approval and procurement.
- A **Purchasing Specialist** researches and identifies the most cost-effective purchasing options. The specialist also negotiates national purchasing agreements to provide a means of reducing costs and improving service, ultimately increasing the profitability of your upgrades. National agreements can enable your company to streamline purchases of equipment and ensure competitive prices.
- **Decision Facilitator.** Decisions related to upgrade projects require approval from various decision makers at many levels (for example, building owners, executives, legal counsel, and comptroller). At least one team member needs to understand your company's approval process for ENERGY STAR Buildings investments. This team member will use this knowledge to scrutinize the process and determine the appropriate places for streamlining or proposing changes. This review should precede the kickoff meeting, because it can help ensure that no organizational conflicts arise during the meeting. The review also helps get the internal approval process moving and can provide helpful information. For example, the facilitator may know that pre-approved funds are available if appropriate paperwork is submitted.
- The **Communications Director** focuses your company's communications efforts to ensure that your achievements in

protecting the environment are recognized. For example, this person coordinates effective uses of the ENERGY STAR Buildings logo in advertising, newsletters and public areas and develops media tools such as press releases. The communications director also works with EPA to publish case studies of upgrades in trade journals or the general media. In addition, this person educates employees, stockholders, and customers about the program.

- For large firms with many facilities, **Regional or Division Coordinators** can play a significant role. In some cases, a coordinator may also serve in the role of facility manager, as described above, providing building-specific information and overseeing surveys and upgrades. In other cases, an organization will select a team leader to coordinate the upgrade activities for a group of facility managers in a region or division.

## The Kickoff Meeting and Ongoing Progress Meetings

The kickoff meeting begins your company's participation in the ENERGY STAR Buildings Program. This meeting is important because it helps you make the initial planning, scheduling, and budgeting decisions needed to get your program under way.

Experience with current ENERGY STAR Buildings Partners indicates that the participation of senior management at the kickoff meeting will help ensure that these key decisions are made. For this reason, it is important that participants at the kickoff meeting include the person in your company who signed the ENERGY STAR Buildings Memorandum of Understanding with EPA; the members of the ENERGY STAR Buildings Project Team; decisionmakers representing the finance, facilities management, procurement, environmental affairs, and communications functions; and the facility manager and the building manager of the building selected for the initial upgrades.

An example agenda for a ENERGY STAR Buildings kickoff meeting is presented in Figure 3. Your EPA account manager will coordinate with you to help finalize the agenda for your kickoff meeting.

Regularly scheduled progress meetings should follow the kickoff meeting, once you begin to implement the ENERGY STAR upgrades. The purpose of these meetings is to measure and discuss progress, resolve implementation issues, communicate successes, and further develop the implementation plan.

## Develop a Technical Approach

In addition to the upgrades themselves, your technical approach involves three other important components

### Selecting the Necessary Expertise

The most critical step in carrying out successful upgrades is the survey and analysis process. Your company can use one of two technical approaches to getting the necessary expertise or combine these two.

- **In-house personnel.** An in-house survey and analysis process ensures employee involvement and provides maximum objectivity. However, it usually requires some training and time investment.

- **Outside expertise.** Outside expertise (i.e., consultants, energy management companies, product vendors) enables fast implementation using experienced personnel. However, the scope of products or services may not be comprehensive, and professional fees may be required to ensure objectivity.

### Identifying Facilities

One of the first technical planning activities you should undertake is developing a list of facilities to target for surveys and upgrades. Usually, it is not feasible to upgrade all facilities simultaneously, so the facility managers need to evaluate facilities whose upgrades will yield the highest internal rates of return. These facilities receive top

**Figure 3. Example Agenda for an ENERGY STAR Buildings Kickoff Meeting**

**Welcome and Introductions**

**Making ENERGY STAR Buildings a Strategic Part of Your Business**

- Facilities as Assets
- Potential for Savings with ENERGY STAR Buildings
- Organizing for Success

**Estimating Your Company's Profitability**

- Buildings To Be Included in the Program
- Capital Investment Requirements
- Expected Returns
- Timeline for the Program

**Pilot Building**

- Scheduling the Pilot Building
- Securing Funding
- Upgrade Opportunities

**Questions and Answers**

**Wrap-Up**

**Tour of the Pilot Building**

priority for immediate upgrade efforts. The savings generated from these upgrades can then finance subsequent upgrades.

In identifying high-priority facilities, facility managers should consider a variety of factors, including:

- Regional economic factors.
- Facility characteristics.
- Corporate priorities.

You should develop an initial list of priority facilities before the kickoff meeting. You can view it as a working list, and you should review and alter it as necessary. Upgrades should be scheduled so that the minimum requirements identified in the Memorandum of Understanding are met.

Companies with multiple facilities need to understand that prioritizing facilities can be time-consuming and difficult. You may need to consult with several departments within your organization and even review real-estate records as part of this process.

### *Reporting Progress*

To document your upgrade progress, complete the standard one-page ENERGY STAR Buildings Annual Report. This report establishes the credibility of your pollution-prevention efforts and shows the benefits of your energy-efficiency projects to management, customers, and stakeholders. In addition, submitting reports helps identify and publicize your success stories. Regular reporting also helps EPA evaluate program effectiveness and enhance technical support to participants.

## Identify Financing Needs and Resources

For your program to be successful, you need to allocate sufficient funds to meet your upgrade commitments. Your company can either allocate existing funds or secure third-party financing. Utility incentives and financing options can reduce or eliminate the need for capital, reduce risk, and improve cash flow. In fact, financed lighting upgrades routinely result in positive cash flow. Third-party financing also enables you to retain more of your own capital for use in your business and thus to begin gaining the benefits of energy-efficiency upgrades earlier than might be possible otherwise.

Although you do not have to make the decision regarding specific financing options at the outset, you should begin investigating them early on. Appendix C contains more information about financing options.

## Develop an Action Plan

At the close of the implementation planning process, you will have identified barriers to successful implementation of the ENERGY STAR Buildings Program. The number and severity of these barriers will vary from company to company. For instance, some companies will need creative financing plans, while others will have difficulty setting priorities among facilities. You should develop a written strategic action plan to help you overcome the barriers you identify. You can use this plan to clarify the tasks that need to be accomplished in specific timeframes and to assign responsibilities. EPA can provide assistance in developing the plan if necessary.

## Develop an Internal Communications Plan

Once you have assembled the ENERGY STAR Buildings team, project work begins. To help keep the project running smoothly, you should develop an internal plan to regularly communicate and distribute information. The cornerstone of this plan is the kickoff meeting, conducted in cooperation with EPA. However, ongoing employee involvement and education combined with external publicity will help maintain the momentum generated at the kickoff meeting.

## Employee Involvement and Education

Your company's employees are key participants in your efforts to prevent pollution. You should notify employees about your organization's participation in the ENERGY STAR Buildings Program as soon as possible after signing the Memorandum of Understanding. Emphasize the importance that ENERGY STAR Buildings places on occupant comfort and explain how high-quality improvements that save energy, protect the environment, and save money can be made.

Trial installations provide an excellent opportunity to demonstrate the efficiency and quality improvements resulting from the upgrade project under consideration. Publicize energy savings information along with a listing of the quality improvements.

Keeping employees aware of your organization's ongoing upgrade progress and resulting savings will maintain their support.

## Publicize Activities Externally

You should also publicize your activities externally to help raise awareness of the program and the benefits of your building upgrades. Several standard publicity avenues are available—press releases, advertisements, and case studies published in trade journals. In addition, networking with other ENERGY STAR Buildings participants may provide other creative publicity ideas.

# SECTION 04 The Importance of Energy Monitoring

Careful monitoring of building systems is important for maximizing energy saving measures. Once a baseline is established and energy consumption is broken down by end-use, you can develop a better understanding of how to most effectively improve the building. For example, if specific end-use power readings indicate that an unusually large amount of energy is being used for heating, the heating system is probably oversized or extremely inefficient. Post-retrofit monitoring is needed to quantify actual energy savings resulting from energy-efficiency measures.

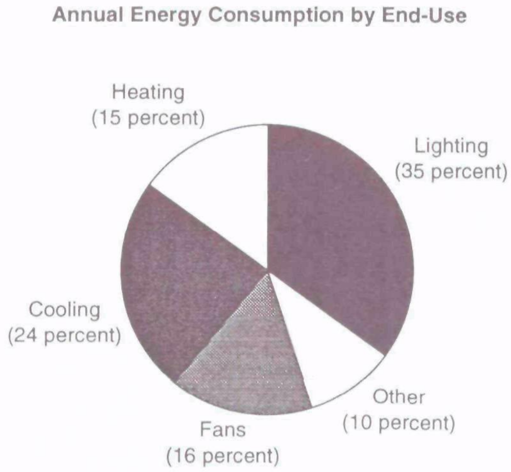
EPA recommends detailed monitoring at your facility as a way to determine where additional savings can be found and to ensure that the building is running as efficiently as possible. Table 1 contains a list of EPA's recommended monitoring points. This monitoring plan was successfully used by the ENERGY STAR Buildings Showcase Partners.

- **Phase I.** Recommended points should be monitored prior to the start of the upgrades. At a minimum, baseline energy consumption broken down by end-use (an

**Table 1. Recommended Monitoring Points**

| Monitoring Point | Phase | Units | Purpose |
|---|---|---|---|
| Lighting Load | I, II | kW | End-use breakdown |
| Light levels | I, II | fc | Light level comparison |
| Fan Electric Load | I, II, III | kW | End-use breakdown |
| Chiller Electric Load | I, II, III | kW | End-use breakdown |
| Cooling Tower Electric Load | I, II, III | kW | End-use breakdown |
| Office Equipment Electric Load | I, II | kW | End-use breakdown |
| Electric Reheat Load | I, II | kW | End-use breakdown |
| Misc. Plug Loads | I, II | kW | End-use breakdown |
| Pumps Electric Load | I, II, III | kW | End-use breakdown |
| Fan Output | I, II, III | cfm | Cooling/heating load |
| Supply Air Temperature | I, II, III | F | Cooling/heating load |
| Return Air Temperature | I, II, III | F | Cooling/heating load |
| Duct Static Pressure Setpoint | I, II | psi | Airflow requirements |
| Chilled Water Flowrate | I, II, III | gpm | Load changes |
| Condenser Water Flowrate | I, II, III | gpm | Load changes |
| Chilled Water Supply/Return Temperature | I, II, III | F | Load changes |
| Condenser Water Supply/Return Temperature | I, II, III | F | Load changes |
| Hot Water Flowrate | I, II, III | gpm | Load changes |
| Hot Water Supply/Return Temperature | I, II, III | F | Load changes |
| Steam Flowrate | I, II, III | lb/hr | Load changes |
| Steam Pressure | I, II, III | psi | Load changes |
| Heating Gas/Oil Flowrate | I,II,III | cfh | Load changes |

### Figure 4. Example End-Use Chart




example of which is shown in Figure 4) should be compiled.

- **Phase II.** Once the first three stages of the program have been completed, a new set of readings should be taken, including one-time readings and continuously monitored points. A new set of footcandle readings should be taken at the same locations as were taken before Stage 1 (the Green Lights upgrades). After completion of Stages 2 and 3 (the building tune-up and load reductions), it is important to recalculate the baseline energy consumption and end-use breakdown. This knowledge will help determine if fan or motor downsizing in Stages 4 and 5 is possible due to a reduction in load. Extensive monitoring in this phase will also confirm savings estimates and new system parameters due to earlier upgrades.

- **Phase III.** After completion of all five stages, monitoring of all recommended points should continue and the data should be analyzed on a regular basis. Building managers should adjust operating systems based on monitored information to improve building efficiency when applicable.

# Pre-Upgrade Building Surveys

SECTION 0.5

The purpose of the ENERGY STAR Buildings Program is to help you make profitable investments in energy efficiency. Each stage of the program requires an understanding of the type of system or equipment to be upgraded and the condition and energy efficiency of that system or equipment.

A comprehensive survey of your building and its systems will enable you to compile the information needed to determine where energy-saving modifications and upgrades can be implemented.

The survey forms in this manual have been designed to allow you to choose between conducting a one-time, building-wide survey or conducting individual, stage-by-stage surveys. The forms contain questions that will help you to determine the most profitable upgrades and to compile the information needed to calculate their economic benefits, prepare implementation plans, and manage installation. They require visual inspections of all building systems and a few specific measurements. The measurements are straightforward and can be conducted in a reasonably short period of time.

The surveys for each stage of the ENERGY STAR Buildings Program are described below.

***Stage 1—Green Lights.*** Surveys related to your lighting systems are completed as part of your participation in the Green Lights Program and are described in the *Lighting Upgrade Manual.*

***Stage 2—Building Tune-Up.*** Surveys for Stage 2 will help you determine the status of your building's systems. The goal is to become familiar with the overall condition of your building and the conditions under which its systems operate. This in turn will help you determine the tune-ups needed to improve operations and prepare your building for the energy-efficiency upgrades to follow, making those upgrades as profitable as possible.

***Stage 3—Load Reductions.*** Surveys for Stage 3 will help you determine if window or roofing upgrades can be profitable in your building. You will be inspecting your windows and roof and then answering some basic questions about each.

***Stage 4—HVAC Distribution Systems.*** Surveys conducted for Stage 4 will help you determine the types of air-distribution system upgrades that will be profitable in your building. You will be inspecting your air-handling systems and then answering some basic questions about each.
*Note: In this edition of the ENERGY STAR BUILDINGS MANUAL, the survey deals with variable volume air-handling systems only. Future editions will include surveys for constant volume air-handling systems and water-side systems.*

***Stage 5—HVAC Plant.*** Surveys conducted for Stage 5 will help you determine the types of HVAC plant upgrades that will be profitable in your building.
*Note: In this edition of the ENERGY STAR BUILDINGS MANUAL, the survey deals with water-cooled centrifugal chillers only. Future editions will include surveys for other types of HVAC plant upgrades, including boilers and packaged units.*

When you are ready to conduct a survey, look for people familiar with the following aspects of your facility:

***Building:*** Floor plans, architectural and engineering drawings, and location of equipment rooms and equipment; construction materials, insulation materials, and window types.

***Mechanical Equipment:*** Configuration and operation of air-handling units and heating and cooling systems; types and operation of the controls on these systems.

***Electrical Systems:*** Configuration of the power distribution system and electrical systems for air-handling units and heating and cooling systems; types and operation of motors; lighting systems.

A survey team might include the building engineer, an HVAC technician, a controls technician, and an electrician. If you cannot assemble the people or materials needed to conduct the surveys, you may want to turn to a qualified engineering consulting firm.

To conduct the surveys, you will need the following items:

- Copies of the survey forms.
  *Note: Be sure to copy the survey forms and retain the originals for later use or use at another building (if applicable).*
- Notepad to record additional information.
- Other tools and documents as specified on the survey questionnaire. For example:
  - —Ammeter, devices to record temperature and humidity, calculator
  - —Architectural, mechanical, and electrical drawings and as-built drawings
  - —Operations and maintenance manuals
  - —Maintenance records for each system
  - —Complaint logs.

If your building has an energy management system, the system can be used to compile operating schedules, current readings, and operational sequences for use in conducting the surveys.

Appendix A contains the survey forms and describes the information required for each survey, the materials needed to conduct the survey, and the personnel recommended for the survey team.

Stage 1:  Green Lights

# Stage 1: Green Lights

CHAPTER 1

Stage 1 of the ENERGY STAR Buildings Program involves your participation in an EPA program closely associated with the ENERGY STAR Buildings Program—Green Lights.

As an ENERGY STAR Buildings Partner, you are already committed to participation in the Green Lights Program. Implementing the energy-efficient Green Lights upgrades will get your ENERGY STAR Buildings upgrades off to a very good start.

ENERGY STAR Buildings Partners must already be participants in the Green Lights Program. However, for those who are not familiar with Green Lights, this chapter provides a brief description of the program and tells you who to contact for additional information. Comprehensive guidance for implementing a Green Lights upgrade is provided in your *Lighting Upgrade Manual*.

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# Green Lights Overview

SECTION 1.1

Green Lights is a voluntary program that encourages the widespread use of energy-efficient lighting systems. When you implement the Green Lights Program, you will be doing the following:

- Determining appropriate lighting levels.
- Improving the efficiency of components and luminaires.
- Implementing controls on operating hours.
- Maintaining or improving lighting quality.
- Maximizing energy savings.

Lighting efficiency can be improved without reducing lighting quality. In fact, many efficiency improvements will improve lighting quality. The following four categories of lighting upgrades should be implemented:

- ***Adjusting Lighting Levels and Quality.*** Put the correct amount of quality light where it is needed. Improve the effectiveness of the lighting by reducing glare and improving color rendering.
- ***Improving Fixture Component Efficiency.*** Upgrade with high-efficiency lamps and ballasts to increase the efficiency of converting electricity to light.

## Tackling the Barriers to Innovation—Common Problems and the Green Lights Solution

***Problem: Lighting Is a Low Priority.*** Few organizations focus on the opportunity to invest in their own lighting systems.

***The Green Lights Solution:*** Green Lights Partners see lighting as an investment—a source of profits. Signing the Memorandum of Understanding makes lighting an organizational priority.

***Problem: Lack of Information and Expertise.*** Lighting information travels slowly outside the world of the lighting industry.

***The Green Lights Solution:*** Green Lights provides informational tools to help lighting investors make informed upgrade decisions.

***Problem: Difficulty in Financing.*** Investments in energy-efficient lighting require up-front capital.

***The Green Lights Solution:*** Green Lights has developed a registry of financing resources and provides it to all Green Lights Partners.

***Problem: Restricted Markets.*** Low demand for energy-efficient lighting technologies results in lack of consumer understanding about potential cost savings and enhanced lighting. Prices remain high due to small production runs.

***The Green Lights Solution:*** Green Lights promotes energy-efficient lighting technologies as cost-effective and high-quality products to consumers and informs manufacturers about the benefits of investing in new technologies.

***Problem: Split Incentives Between Landlords and Tenants.*** To realize savings from a lighting upgrade, landlords and tenants must renegotiate leases. The landlord rarely installs energy-efficient lighting in new construction because utility charges are passed on to tenants.

***The Green Lights Solution:*** Green Lights is developing standard lease language that removes the split incentive barrier between landlord and tenant.

- ***Improving Luminaire Efficiency.*** Get more light from a fixture by retrofitting or replacing the fixture with more efficient reflector and shielding materials. Routine fixture cleaning also improves luminaire efficiency.
- ***Controlling Burning Hours.*** Use automatic or manual lighting controls to turn lights off when they are not needed.

EPA's Green Lights support system will help you select the best technologies to provide maximum energy savings for your building.

Refer to your *Lighting Upgrade Manual* for detailed guidance on implementing the Green Lights Program and profitably maximizing energy savings through lighting upgrades.

## Participating in the Green Lights Program

Green Lights Partners sign a Memorandum of Understanding with EPA, in which they agree to conduct a lighting survey of their facilities and, within 5 years, implement high-efficiency lighting upgrades in 90 percent of their square footage where it is profitable and where lighting quality is maintained or enhanced. Participants also agree to appoint an implementation manager to oversee participation in the program.

EPA also signs the Memorandum of Understanding and agrees to provide the following support to Green Lights Partners:

- ***Decision Support System.*** A state-of-the-art computer software package that enables Partners to survey lighting systems, assess lighting options, and select the most profitable lighting upgrades.
- ***Financing Registries.*** User-friendly computer databases that describe all available third-party financing programs.
- ***Ally Programs.*** Allies include lighting manufacturers, lighting management companies, and electric utilities that have agreed to educate customers about energy-efficient lighting.
- ***Endorser Program.*** Endorsers are membership associations and other organizations that promote Green Lights.
- ***Public Recognition.*** The Green Lights Program places public-service advertising in major magazines and provides newspaper articles, reports on new lighting technologies, a newsletter, and other materials. To encourage participants to promote their own Green Lights activities, EPA distributes ready-to-use promotional materials to all Partners.

In addition, EPA contracts and grants provide the following services:

- ***Lighting Services Group.*** Provides technical support, including a technical services hotline, workshops, and the comprehensive *Lighting Upgrade Manual.*
- ***National Lighting Product Information Program.*** Provides "consumer reports" with valuable product information on lighting.

For more information about Green Lights:

- Refer to your *Lighting Upgrade Manual.*
- Call the Green Lights Information Hotline at 202–775–6650 or fax at 202–775–6680.
- Call the Green Lights Technical Hotline at 202–862–1145 or fax at 202–862–1144.
- Access the Green Lights Electronic Bulletin Board from your modem at 202–775–6671.

## Stage 2. Building Tune-Up

# Stage 2: Building Tune-Up

CHAPTER 2

Stage 2 of the ENERGY STAR Buildings Program provides the opportunity to make your entire building more energy-efficient through maintenance activities and modifications to equipment and procedures. Many of these improvements are free or low-cost and thus are profitable on their own; however, they also lay a solid foundation that can make your investments in Stages 3, 4, and 5 even more profitable.

The first step in the tune-up process is to survey the building and document its overall condition and the conditions under which its various systems are operating. This information will help you determine which systems need to be tuned up and where energy-saving upgrades will be most profitable. As part of the tune-up, you will also be implementing a preventive maintenance program, and training the facilities staff on the new procedures.

This chapter contains the following sections:

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# SECTION 2.1 Introduction

Building tune-up involves maintenance activities and modifications to equipment and procedures—many of which are free or low-cost—that will enable your building's systems to operate at their designed efficiencies. This is also known as recommissioning. Energy consumption in many buildings can be reduced by 5 percent or more simply by correcting existing minor problems such as dirty filters and mis-calibrated controls.

Tune-ups are important at this point in the ENERGY STAR Buildings Program because they also lay the foundation for upgrades implemented later in the program, allowing those upgrades to provide the best return on money invested in energy savings. If the later upgrades are applied to malfunctioning systems, they not be as profitable. Furthermore, if a system is tuned up to operate at peak efficiency, substantial profits can be realized even before more comprehensive upgrades are undertaken.

The Case Study and the Simulation in this section show the type of energy savings that can be expected from building tune-ups.

Remember:

- Tune-ups increase the reliability of equipment and systems.
- Tune-ups save energy, making future energy-efficiency upgrades more profitable and providing profits of their own.

## Best Opportunities

Most building systems and equipment, as well as the facility's operations and maintenance program, can be tuned up to improve overall building performance and reduce energy consumption. Itemized checklists of these tune-up opportunities and actions are provided in Section 2.7. The checklist format is used because many tune-up actions need only to be pointed out and do not require explanation. Before turning to the checklists however, please take a few minutes to read the following discussions on reheat systems, energy management systems, testing and balancing, preventive maintenance, training, and project management.

### Case Study: Minneapolis-St. Paul

The University of Minnesota conducted a study of seven office buildings in Minneapolis-St. Paul and found the following types of problems:

- Excessive cycling of hot water boilers.
- Lights and office equipment left on during unoccupied hours.
- Air handling units left on during unoccupied hours.
- Simultaneous heating and cooling as a result of poor perimeter radiation controls.
- Heat pumps operating continuously.

The analysis led to operational changes that provided utility cost reductions of between 8 and 20 percent, averaging 15.4 percent, after subtracting the cost of the analysis ($0.10 to $0.12 per square foot). The simple payback period for these improvements was 0.67 years, with an EPA-calculated internal rate of return of 147 percent over 5 years.

Source: *Office Building Operations Case Study Reports*, Minnesota Building Research Center, University of Minnesota, 1991.

### Simulation: Washington, D.C.

EPA ran a simulation of an office building in Washington, D.C. (10 stories, 100,000 square feet) with the following typical conditions before the tune-up:

- Thermostats not calibrated, causing the summer setting to be 1 percent lower than the setpoint, the winter setting to be 1 percent higher than the setpoint, and the night-setback setting to be 3 percent higher than the setpoint.
- Humidity setting 10 percent higher than the setpoint.
- Supply fan input 15 percent higher than design conditions.
- Supply fan and return fan pressures 15 percent higher than design conditions.
- Chilled water pump input 15 percent higher than design conditions, condenser water pump input 8 percent higher than design conditions, and cooling tower fan input 8 percent higher than design conditions.
- Cooling design loads an average of 4 percent higher than design conditions across 10 zones.

In this building, annual HVAC energy consumption would be some 15 percent higher than building design conditions. The owner of this building could recover the costs of this unnecessary energy consumption by tuning up the building's systems.

## Building Tune-Up Survey

The Building Tune-Up Survey is an essential first step in Stage 2 of the ENERGY STAR Buildings Program. This survey will familiarize you with the condition of your building's systems and enable you to determine which systems need to be tuned up.

The survey has two main tasks: analysis and inspection. To complete it you will need to analyze some existing information and then obtain some additional information by conducting general inspections in various areas of the building. The Building Tune-Up Survey forms begin on page A–5.

# SECTION 2.2 Reheat Systems

To minimize reheat energy consumption (see box), you can:

- Monitor reheat year-round. Categorize usage into spring, summer, winter, and fall.
- Be sure thermostats controlling reheat are calibrated and operating properly.
- Consider turning reheat off in the spring, summer, and fall. A well designed reheat system should only use reheat in the winter months.
- If comfort cannot be maintained in summer without reheat, fix or redesign the system (as recommended in Stage 4 upgrades).
- When possible, increase supply air temperatures during the cooling season. Maximize savings without compromising occupant comfort.

Changes in reheat strategy can sometimes be accompanied by the HVAC distribution system upgrades associated with Stage 4. Upgrades that will maximize reheat efficiency include:

- Converting constant air volume systems to variable air volume. It is much more efficient to supply a small amount of cold air to a space than to supply a lot of cold air to supply ducts and have it reheated to a comfortable temperature.
- Transferring reheat controls from local thermostats to a central energy management system. This allows precise, custom control of reheat.

### What Is Reheat?

Reheat is the mechanical heating of an airflow which has been cooled to a pre-set minimum supply temperature. Air supply systems use reheat for local control of space temperature. In a constant air volume (CAV) system, the air leaving the supply fan is at a very cold temperature, and heating coils located at each specific inlet duct reheat the air to the locally desired temperature.

Reheat typically occurs inside ductwork, which is hidden behind walls and ceilings. As such, reheat is almost always overlooked as a source of energy waste or potential savings. Although you would never operate a fireplace during the summer in your own home, reheat in large HVAC systems during the cooling season is accepted as status quo.

Because reheat occurs simultaneously with cooling, it inherently wastes both heating and cooling energy. Typically, one cooling source will provide cooling over many or all spaces and reheat will be used locally for those areas which require less or no cooling at all. Even variable air volume (VAV) systems, which vary the cooling on a local level, require reheat for exterior spaces that need heating in the winter.

The design decision to incorporate reheat is a compromise between higher energy use and increased zoning of the cooling system. Reheat is often the result of insufficient zoning of the heating and cooling system. Therefore, as part of the design of many cooling systems, reheat cannot always be eliminated. If this is the case, one must be sure that the reheat used is minimized.

- If reheat is used to control humidity, considering the use of alternate dehumidification methods, such as a desiccant wheel or a heat pipe.

## Economic Benefits

The accompanying box on Reheat Savings shows the types of energy savings that can result from changes in a reheat system.

**Reheat Savings**

A 7-story office building uses electric reheat year-round. Monitoring of the reheat coils on one floor shows that a total of 23,930 kilowatthours was used for reheat during August 1994. With reheat controls, this consumption would have been cut to about 7,180 kilowatthours, for a savings of $1,340 at $0.08 per kilowatthour.

Improving the reheat system provides energy savings at the reheat coils and potential energy savings at the air handler and cooling coils. If the air is universally cooled to 55 degrees and then reheated to a local temperature of 65 degrees, removing reheat and cooling the air to 65 degrees initially not only cuts out reheat energy, it also saves the energy needed to cool the supply air that extra 10 degrees. Although certain zones sometimes need to be cooled more than others due to solar gain or conduction through windows, improving controls can cut reheat energy by about 70 percent during the cooling months.

# Controls and Testing and Balancing

SECTION 2.3

## Controls

An Energy Management System (EMS) can greatly improve the performance of a building. A typical EMS includes a main computer that receives information from sensors monitoring performance throughout the building and sends information to related mechanical and electrical equipment. The sensors record temperatures, pressures, humidity levels, water or air flows, power consumption, and other specific parameters (known as *points*). The output information controls equipment run time or setpoints based on the input. Some uses for an EMS are outlined below.

- *7-Day Scheduling*—HVAC, lighting, and heating and cooling systems can be programmed to start and stop on a weekly schedule. Annual schedules can account for holidays and seasonal changes. Running systems on a schedule can eliminate waste caused by human error.
- *Night Setback*—Heating and cooling setpoints can be changed to allow for less cooling during the summer and less heating during the winter during unoccupied nighttime hours. Allowing a lower setpoint instead of complete system shutoff prevents conditioned spaces from becoming too cold or too warm at night.
- *Direct Digital Control*—Temperature and pressure sensors inside air supply ducts can be used to control valves and dampers. If sensors are connected to an EMS, air temperatures and humidity levels can be maintained closer to the setpoints, eliminating waste due to overshooting.
- *Duty Cycling*—Peak demand can be controlled by shutting off certain motors, fans, pumps, and other HVAC equipment for short periods of time (10 to 30 minutes as necessary). Short system interruptions generally have a minimal effect on space temperature, so peak demand charges can be reduced considerably.
- *Optimal Start and Stop*—In this version of night setback, heating and cooling setpoints are controlled not by a time clock, but by outside air temperatures. This strategy can be used in conjunction with, or even in place of, night setback.
- *Economic / Enthalpy Control*—The EMS can be used to track outside air temperature and relative humidity and open outside air dampers when use of outside air would be beneficial. For example, when cooling is needed during the summer and the outside temperature drops below 65 degrees, the EMS can open the dampers to allow outside air to mix with warm return air, thereby reducing the load on the cooling system. Enthalpy controls measure temperature and humidity (that is, the total heat content) of outside air and open outside air dampers

**Controls Prevent Conflict**

In some buildings, the heating and cooling systems (and sometimes the perimeter and interior systems as well) work against each other. For example, if the heating and cooling systems are not controlled by the same thermostat, the heating system may be overheating the space while the cooling system is operating at a high capacity to remove that heat. You can resolve this situation by installing controls that operate both systems together. These controls can then switch between heating and cooling as needed.

## Meters Help Save Energy

Installing meters will help you determine where energy is being wasted in your building systems. Meters should be installed on a system when the annual cost of energy exceeds five times the cost of the meter. They can point out conditions that can be corrected with little or no capital investment but result in energy savings of approximately 5 to 15 percent.

**Benefits of Metering**

- Identifies opportunities for energy-efficiency improvements.
- Ensures consistent system operations.
- Provides comparisons with previous or similar operations.
- Allocates energy costs to various cost centers.

**Submetering To Document Energy Savings**

Submetering enables you to evaluate the energy savings that can result from implementing various energy-saving options. Evaluating these savings will support your efforts to build organizational support for additional profitable investments in energy efficiency. In addition, once purchased, a meter can be used in all energy conservation projects to continue to evaluate their contributions.

**Selecting a Meter**

Many different types of electric meters are available. The appropriate type depends on the functions required. Newer meters use electronic technology and are capable of taking a variety of measurements, including cumulative energy consumption, instantaneous demand, volts, amperes, power factors, and harmonics. They can also interface with energy management systems.

if this level is below the total heat content of the return air.

- *Chilled Water Setpoint*—The temperature setpoint of chilled water can be adjusted based on part-load conditions. When the setpoint is raised to the temperature necessary for the cooling load, the energy consumption of the chiller is reduced.

  *Note: This strategy will not work on a system with variable-speed drives programmed to reduce flow rates for part-load conditions.*

## Balancing

**Air-Side Systems**

Air-side systems should be balanced when you notice any of the following conditions:

- A number of occupant complaints about temperature in the building.
- Hot or cold spaces in the building.
- The fan is unable to overcome the static pressure in the system or meet load requirements. In such cases, check the following first and make any necessary repairs before balancing:
  - — Clogged filter.
  - — Frozen dampers.
  - — Inoperable variable air volume boxes.

The system should be balanced by a qualified testing and balancing firm.

**Water-Side Systems**

Water-side systems should be balanced under the following conditions:

- The system is unable to meet temperature or pressure requirements in some areas. In such cases, check the air system first and make any necessary repairs before balancing.
- The system is modified, for example, by adding or deleting a coil or replacing any component that requires a substantial drop or increase in system pressure (that is, 5 feet of head or more).

The system should be balanced by a qualified testing and balancing firm.

# Testing and Balancing

A properly functioning HVAC system must be tested and balanced periodically to eliminate errors that can waste energy (see box).

# Preventive Maintenance

SECTION 2.4

A preventive maintenance program is an important part of the building tune-up.

- Preventive maintenance helps keep you aware of the condition of your building's systems at all times, thus eliminating many problems and equipment failures—and resulting downtime—before they occur.
- It is much more cost-effective than corrective maintenance.
- Without preventive maintenance, equipment performance can be expected to degrade, increasing the frequency and magnitude of repairs and shortening equipment life.
- Preventive maintenance more than pays for itself in terms of building life-cycle costs; without it, you pay more for energy, repairs, corrective maintenance, and equipment replacement.

## Building Management

- Keep an operations and maintenance log for major equipment and update it regularly to help identify opportunities for ongoing tune-ups.
- Keep a daily log of temperature and pressure levels as a way to determine when tubes, nozzles, and heat exchange areas need to be cleaned or adjusted.
- If you have an energy management system, be sure that system programming follows the designed sequence of operations.

The box on Preventive Maintenance Savings on this page shows the types of energy savings that can result from two illustrative preventive maintenance actions.

### Preventive Maintenance Savings

The following examples are based on a 25-horsepower, 20,000-cfm (cubic feet per minute) air-handling unit with 4-inch water column static pressure. The system operates 10 hours a day, 5.5 days per week, 52 weeks a year.

**Replacing Filters**

Replacing filters can save energy and improve indoor air quality. Pre-filters are replaced every 2 to 4 weeks, depending on conditions, and final filters are cleaned or replaced every 10 to 16 months, depending on the pre-filter's quality.

For the example system, 10 pre-filters (24" × 24" × 2", 30 percent efficient for 40 square feet at $4.47 each) cost $44.70 and 10 final filters (24" × 24" × 11.5", 65 percent efficient for 40 square feet at $28.95 each) cost $289.50. Labor costs $120 per year ($20 per hour × 0.5 hours × 12 times per year). The total installed cost of the filters is $946 per year.

Air-side energy consumption savings are $1,614 per year; internal rate of return is 71 percent.

**Calibrating Thermostats**

Thermostats should be calibrated every 6 months. A thermostat that varies by 1 degree above the heating setpoint relates to an increase of approximately 3 percent in energy costs; 1 degree below the cooling setpoint relates to an increase of approximately 5 percent in energy costs.

For the example system, the heating and cooling seasons are 6 months each. Yearly energy consumption is 112,100 kilowatthours per year. Labor costs $120 per year ($30 per hour × 2 hours × 2 times per year).

Air-side energy consumption savings are $364 per year; internal rate of return is 170 percent.

Remember:

- A preventive maintenance program extends equipment life (which correlates directly to capital costs), increases the reliability of equipment and systems, reduces downtime significantly, and saves energy.

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# SECTION 2.5 Training

Your building staff should fully understand and be well-trained on the operation of all building systems. Consider appointing a training coordinator to ensure that:

- The entire staff (all shifts) receives adequate training on new procedures related to the preventive maintenance program.
- The entire staff (all shifts) receives adequate training on new equipment. Vendors should always provide training on new equipment.
- The entire staff (all shifts) receives periodic training to keep them up to date on new procedures and equipment.
- New employees are trained on the functions, operating routine, and maintenance procedures for each piece of equipment in their areas of responsibility. In addition, new employees should understand operations and maintenance procedures for all building systems.

The training coordinator should maintain a log that outlines the training required for each type of equipment, a log that keeps track of what equipment each person has been trained on, and training schedules. The training coordinator should review this log regularly to ensure that all personnel have been properly trained.

To implement an effective preventive maintenance program, the staff must be an integral part of that program and understand all aspects of the program. A comprehensive training program on each type of equipment in each system includes the following:

- System fundamentals.
- How to use reference materials (operations and maintenance manuals, as-built drawings, and so forth).
- Functions, operational and control sequences, and maintenance procedures—including acceptable tolerances for system adjustments, which are crucial for maximum energy-efficiency savings.
- Warranty information.
- Service guidelines, including how to deal with unexpected conditions and emergencies.

The staff should be trained to keep the goal of maximum energy efficiency in mind at all times. A well-trained and responsive staff will ensure maximum energy savings.

If the building has an energy management system, training is essential for any staff member who will be working with that system. This training should include the following:

- Computer and programming fundamentals.
- How to operate the system.
- Programming in the system's language.
- System maintenance.
- Performing all system functions.

The staff should also be trained to be aware of indoor air quality issues. The goal is to obtain maximum energy efficiency while maintaining good indoor air quality standards. Appendix B provides more information on indoor air quality issues and how to implement air quality standards for your building.

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# Additional Considerations

SECTION 2.6

After you complete the Building Tune-Up Survey and analyze the results, you will have a good idea of the types of tune-ups that will be profitable in your building, making it more energy efficient and also reducing loads. This section contains some points to consider as you plan the tune-ups and implement a preventive maintenance program.

- Analyze your utility bills (see box) to help identify unusual patterns in energy consumption that may indicate the need for tune-ups.
- Organize the tune-ups according to the people needed to do the work. For example, an HVAC mechanic and a controls technician are needed for the air-side tune-ups in the equipment room.
- Complete all other tune-ups before balancing air-side and water-side systems. The other tune-ups may make balancing unnecessary. If balancing is still required, a better-tuned system will allow for more precise balancing.
- Be certain that all tune-ups related to a particular stage of the ENERGY STAR Buildings Program are done before determining the upgrades to implement in that stage.
- If your facility comprises more than one building, begin tune-ups in the building with the highest energy costs.
- Most tune-ups will not disturb occupants. Schedule tune-ups that may disturb occupants for hours when the building is unoccupied.
- Appoint preventive maintenance and training coordinators. These positions can be filled by the same person.
- Develop a preventive maintenance log and update it regularly. The log should contain:

  —Preventive maintenance procedures for each type of equipment (what work is to be done and how often it should be performed)

  —Preventive maintenance records for each piece of equipment to indicate work done, when, and by whom.

The preventive maintenance coordinator should review the log regularly to ensure

### Utility Bill Analysis

When you chart costs from your utility bills while conducting the Building Tune-Up Survey, you can gain some helpful insights into energy consumption in your building. The following list contains some areas to analyze.

1. Is energy consumption higher in the spring or fall than the winter or summer months? This could indicate a heating and cooling problem.
2. Are there significant peaks in any month or months? If so, what were the weather conditions? For example, if the weather was not unusually hot, but you notice a major increase in consumption in a summer month, it could indicate that all chillers were operating but were not needed or perhaps that some equipment was unnecessarily operating 24 hours a day.
3. Is energy consumption in any one period consistently and unexpectedly higher than the others? For example, if October usage is always high, central heating and central cooling may be running simultaneously.

You can also look at your utility bills to see when maximum demand charges are incurred. If, for example, maximum demand occurred in August and the weather was not unusually hot, there could be problems with equipment or operations.

that the preventive maintenance program is running smoothly.
*Note: Consider buying a computer software package for use in setting up and tracking your preventive maintenance program.*

- Consider establishing a bonus system to reward building management personnel for sustained building efficiency.
- The preventive maintenance coordinator should periodically inspect equipment to ensure that proper maintenance procedures are being followed.

It is important to have a complete set of operations and maintenance documentation, including the following:

- All operations and maintenance manuals for each type of equipment.
- Up-to-date versions of the building drawings (architectural, mechanical, and electrical).
- A complete set of specifications, including addenda and all approved changes.
- Up-to-date versions of as-built drawings for each system.
- Air and water balancing reports.
- All energy management system manuals.

Each staff member should be able to extract information on the building and its systems from any of these sources.

### Asbestos Concerns

When doing any cleaning or maintenance in buildings more than 20 years old, be aware of the possible presence of asbestos-containing materials, particularly in ductwork and boiler and mechanical rooms. While intact and undisturbed asbestos materials do not pose a health risk, damaged or disturbed asbestos materials can release asbestos fibers into the air and pose a health risk, particularly for service and maintenance workers. However, removing asbestos materials is often not a building owner's best course of action; instead, a proactive management program is recommended.

A number of Federal standards and regulations govern asbestos exposure. For guidance, building owners and managers should be familiar with two EPA documents: *Managing Asbestos in Place* (the "Green Book") and *Guidance for Controlling Asbestos-Containing Materials in Buildings* (the "Purple Book"). To obtain these publications or other materials related to asbestos or to get additional information on technical issues, call or write the Environmental Assistance Division, Office of Toxic Substances, U.S. EPA (TS–799), 401 M Street SW, Washington, D.C. 20460 (202–554–1404).

Many States and localities also have established standards and regulations related to asbestos. EPA's *Directory of State Indoor Air Contacts*, available from the Public Information Center, U.S. EPA (PM–211B), 401 M Street SW, Washington, D.C. 20460 (202–260–2080), can help you find the appropriate contact.

# Tune-Up Actions and Checklists

SECTION 2.7

The following pages contain checklists that you can use as you plan your building tune-up and preventive maintenance programs. The tune-up checklist is organized by area of concentration, while separate preventive maintenance checklists are included for actions that should be performed daily, weekly, monthly, every 6 months, and annually.

*Note: Some of the actions listed may not apply to your building or some of its systems. Refer to your survey results and notes when considering each item on the checklists.*

When performing any tune-up or preventive maintenance activity, it is important to follow manufacturers' specifications for service, maintenance, and replacement parts. Failure to do so may void warranties and could damage equipment or cause improper equipment operation.

## Building Tune-Up Actions – Building Management

__ Keep an operations and maintenance log for major equipment and update it regularly. A daily log of temperature and pressure levels will help indicate when tubes, nozzles, and heat-exchange areas need to be cleaned or adjusted.

__ If you have an energy management system, be sure that system programming follows the designed sequence of operations.

## Building Tune-Up Actions – Building Envelope

__ Install weatherstripping, caulking, and seals on doors, windows, penetrations, and other openings.

__ Replace worn weatherstripping and missing putty or caulking around door and window frames.

__ Seal openings in walls for piping, electrical conduit, through-wall units, and so forth.

__ Replace or repair latches on doors that do not close tightly. Adjust uneven doors.

__ Seal exterior joints such as foundation-to-wall.

__ Maintain adequate insulation in walls, ceilings, and roofing.

__ Replace wet insulation.

## Building Tune-Up Actions – Lighting Systems

__ Implement Green Lights upgrades.

__ Adjust schedules so that lights are on only when necessary.

__ Take advantage of natural lighting where possible.

__ Schedule cleaning tasks for daylight hours. If this is not possible, instruct the custodial staff to use only necessary lighting, one room at a time, and to turn lights out after a room is cleaned.

__ Clean lamps, luminaries, and interior surfaces of lighting fixtures on a regular schedule.

## Building Tune-Up Actions – Office Equipment Operation

__ Purchase Energy Star computers, printers, fax machines, and copiers when you need to buy new equipment.

__ Adjust schedules so that office equipment is on only when necessary.

__ Install timing devices on equipment whenever possible.

## Building Tune-Up Actions – Interior Space Conditions

__ Locate temperature and humidity sensing devices away from drafts, supply air diffusers, outside walls, and direct sunlight, where this can be done with minimal reconstruction and rewiring. Consider purchasing wireless temperature sensors.

__ Install locks on temperature and humidity sensing devices in areas where tampering is a problem.

__ Calibrate temperature and humidity sensing devices.

__ Adjust temperature and humidity setpoints within comfort zones seasonally--higher in summer and lower in winter.

__ Be sure that radiators and convectors are unobstructed and that air is flowing freely.

__ Close off and seal unused areas and reduce heating and cooling in little-used areas.

## Building Tune-Up Actions – HVAC Equipment

__ Check heating and cooling season setpoints to be sure that they are at design values.

__ Use night setback temperatures during unoccupied hours.

__ Install meters where cost-effective to monitor trouble areas and document energy savings.

__ Adjust controls to prevent simultaneous operation of heating and cooling.

__ Operate one boiler, chiller, or compressor at 90 percent capacity instead of two at 45 percent capacity.

## Building Tune-Up Actions – Air-Side Equipment

__ Clean all system components (for example, ducts, humidifiers, condenser coil faces, fan blades, and motors) regularly.

__ Clean or replace filters regularly.

__ Insulate supply ductwork, particularly where ducts run through unconditioned space).

__ Be sure that dampers are tightly closed and repair dampers with loose or frozen linkages.

__ Recalibrate controls and be sure that they operate as specified in the sequence of operation.

__ Replace inaccurate gauges and thermometers.

__ Replace worn belts and bearings on fans and motors.

__ Maintain proper shaft alignment on motors to reduce noise and vibration.

__ Keep linkages and bearings lubricated.

__ Maintain tight seals on dampers and air-handling equipment.

__ Be sure that pneumatic lines are not leaking and that water never enters the pneumatic lines.

__ Be sure that the compressed air system is maintained and operating properly.

## Building Tune-Up Actions – Water-Side Equipment

- __ Repair leaks in and maintain pipes, steam traps, pumping glands, packet glands, valves, rings, orifices, gaskets, couplings, and impellers.
- __ Insulate pipes and tanks.
- __ Recalibrate controls and be sure that they operate as specified in the sequence of operation.
- __ Clean or replace strainer screens in pumping systems periodically.
- __ Be sure that air separators are operating properly and that no air is entering the system.
- __ Isolate offline boilers and chillers.
- __ Reduce domestic hot water temperature setpoints to the minimum required (for example, by reducing a 180-degree setpoint to 120 degrees).
- __ Flush water systems periodically.
- __ Use proper water treatment procedures to reduce fouling of transfer surfaces and the potential for biological growth. Check cooling tower bleed-off periodically to ensure that water and chemicals are not being wasted.
- __ Replace inaccurate gauges and thermometers.
- __ Clean coils, chillers, tubes, tanks, drain pans, heat-exchange surfaces, and boilers or furnaces regularly.

## Daily Preventive Maintenance Checklist

**All Systems**

__ Inspect generally. Look at gauges to ensure that the equipment is operating normally, perform a visual inspection for obvious problems such as leaks, and check for unusual noises.

**Lint Screens**

__ Clean or replace.

**Chiller**

__ Check oil level.

__ Check oil pressure.

__ Check operating pressures.

**Cooling Tower**

__ Check water level.

__ Check PH value of water.

## Weekly Preventive Maintenance Checklist

**Air Compressor**

__ Blow out drip pockets and eliminators.

__ Check oil level.

**Equipment Room**

__ Clean.

**Chiller**

__ Check refrigerant level.

__ Check refrigerant piping for leaks.

**Controls**

__ Check settings and calibration.

**Fans**

__ Check belt tension.

**Humidifiers and Dehumidifiers**

__ Check operating pressures.

**Pumps**

__ Clean screens, strainers and tanks.

**Water Treatment**

__ Check controls.

__ Check PH value of water.

## Monthly Preventive Maintenance Checklist

**Air Compressor**

__ Check belt tension and alignment.

__ Clean screens, strainers, and tanks.

**Controls**

__ Test protective devices.

**Cooling Tower**

__ Lubricate bearings.

__ Check operating pressures.

**Dampers**

__ Lubricate bearings.

__ Check for effective operation.

**Distribution System**

__ Clean air intake.

**Fans**

__ Check for blade balance.

**Humidifiers and Dehumidifiers**

__ Clean strainers and tanks.

__ Clean sprays.

__ Check for spray erosion.

**Motors**

__ Check shaft alignment.

__ Lubricate bearings.

__ Check belt tension and alignment.

__ Check oil level.

**Pumps**

__ Lubricate bearings.

__ Check oil level.

**Chiller**

__ Check controls.

__ Check tension and alignment of compressor belts.

__ Lubricate bearings.

__ Check PH value of water.

__ Check compressor rotation and seals.

**Drain Pans**

__ Clean.

**Pre-Filters**

__ Clean or replace.

## 6-Month Preventive Maintenance Checklist

**Air Compressor**

__ Clean or replace filters.

**Coils**

__ Remove dust.

__ Check drainage.

__ Pump down.

**Controls**

__ Test freeze protection on all equipment.

**Chiller**

__ Check drainage.

__ Pump down.

__ Check compressor shaft alignment.

**Cooling Tower**

__ Clean sprays.

__ Check for spray erosion.

**Outdoor Air Intake Grills and Screens**

__ Clean or replace.

**Dampers**

__ Check alignment.

__ Check controls.

**Humidifiers and Dehumidifiers**

__ Check controls.

**Motors**

__ Check for overheating.

__ Remove dust.

**Operating Schedules**

__ Analyze to ensure equipment is running only when needed.

**Pumps**

__ Check for overheating.

__ Test standby equipment.

**Steam and Water Piping**

__ Blow out drip pockets and eliminators.

__ Check drainage.

## Annual Preventive Maintenance Checklist

**Air Compressor**

__ Lubricate bearings.

__ Clean air intake.

__ Check oil chambers.

__ Check alignment.

__ Check controls.

__ Pressure test.

__ Check valves and rings for wear and leaks.

**Air Washer**

__ Check thoroughly for leaks.

**Coils**

__ Check thoroughly for leaks.

**Cooling Tower**

__ Check thoroughly for leaks.

**Motors**

__ Check rotation.

**Dampers**

__ Lubricate bearings.

__ Check seals for leaks.

**Humidifiers and Dehumidifiers**

__ Check thoroughly for leaks.

**Filters and Final Filters**

__ Clean or replace.

**Pumps**

__ Check alignment.

__ Check oil chambers.

__ Check seals.

**Steam and Water Piping**

__ Check strainers and tanks.

__ Check thoroughly for leaks.

__ Check traps.

**Fans**

__ Check shaft alignment.

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# Stage 3: Load Reductions

CHAPTER 3

In Stage 3 of the ENERGY STAR Buildings Program, you will be reducing the energy loads in your building. By participating in the Green Lights Program and purchasing ENERGY STAR office equipment, you may already have implemented some highly profitable load reductions such as energy-efficient lighting. However, load reductions also include upgrades to your building's exterior systems—its windows and roofs. Window upgrades are profitable for application to many office buildings. They save energy, improve building appearance, and increase occupant comfort and productivity. Roofing upgrades lessen the overall cost of a new or recovered roof by improving energy efficiency.

This chapter contains the following sections:

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# Introduction

SECTION 3.1

Thus far in the ENERGY STAR Buildings Program, you have taken three major steps toward reducing building energy loads:

- EPA Green Lights lighting upgrades.
- Building tune-up and preventive maintenance actions.
- ENERGY STAR office equipment purchases (see Chapter 6).

The reduced loads achieved through these upgrades can make the subsequent HVAC system upgrades in Stages 4 and 5 even more profitable by creating the opportunity to downsize (that is, reduce the size and capacity of equipment—see Chapters 4 and 5) those systems to match the reduced loads.

In this stage of the program, by considering the building's exterior "systems," that is, windows and roofs, you should be able to find excellent opportunities for further energy savings, additional downsizing, and even more profits.

## Best Opportunities

To save energy and decrease heating and cooling loads, consider the following building exterior upgrades:

- *Window films* that limit the amount of solar heat passing through windows and the amount of internal heat escaping through windows.
- *Reflective roof coverings* that reflect summer heat away from the building.
- *Additional roofing insulation* that will keep heat out during the summer and keep heat in during the winter.

### Illustrative Savings

A building in the northeastern United States has the following attributes:

- Gross area = 30,650 sq. ft.
- Roof area = 7,860 sq. ft.
- Four floors
- Glass to exterior wall ratio = 40 percent

The owner of this building implemented Green Lights upgrades and purchased ENERGY STAR office equipment as old equipment was scheduled for replacement.

The building, located in an industrial park, receives direct sunlight throughout most of the day, and occupants are complaining about the added heat from the sunlight and the glare on computer screens. In addition, occupants are using window ledges to store books and papers, which is making the building look bad from the outside. Thus the owner decided to install window films.

The building's roof was scheduled for replacement, so the owner decided to upgrade insulation as part of the replacement.

These combined upgrades provided the following changes in energy consumption:

| | Before | After |
|---|---|---|
| Lighting (watts/sq. ft.) | 2.6 | 0.8 |
| Equipment (watts/sq. ft.) | 1.0 | 0.5 |
| Shading coefficient | 0.9 | 0.3 |
| Insulation R-Value | 12 | 20 |

The upgrades reduced total energy consumption in this building by 43 percent, providing $43,957 per year in total energy savings with an internal rate of return of 91 percent.

You can implement building exterior upgrades individually, or combine them to provide maximum savings. As you develop your strategy:

- Always consider window films, which provide the best opportunity for low-cost fenestration upgrades.

- If the roof on your building is in need of replacement, increase the R-value[1] of the original insulation or add a reflective roof covering as part of the replacement.
- If the roof needs to be recovered, use a reflective roof covering.
- If your building is a low-rise building with a large roof area, consider a roofing upgrade (added insulation in northern climates, reflective coverings in southern), even if the roof does not need replacement or recovering.

## Window and Roofing Survey

The Window and Roofing Survey is an essential first step in Stage 3 of the ENERGY STAR Buildings Program. This survey will familiarize you with the condition of your building's exterior shell and enable you to determine if window and roofing upgrades can be profitable in your building. You will be inspecting your windows and roof and then answering some basic questions about each.

The survey contains questions that will help you to determine the most profitable upgrades and to compile the information needed to calculate their economic benefits, prepare implementation plans, and manage installation.

To complete the survey, you will need to visually inspect your building's windows, roofing, and insulation. You will also need to analyze some existing information and perform a few simple calculations. The Window and Roofing Survey forms begin on page A–19.

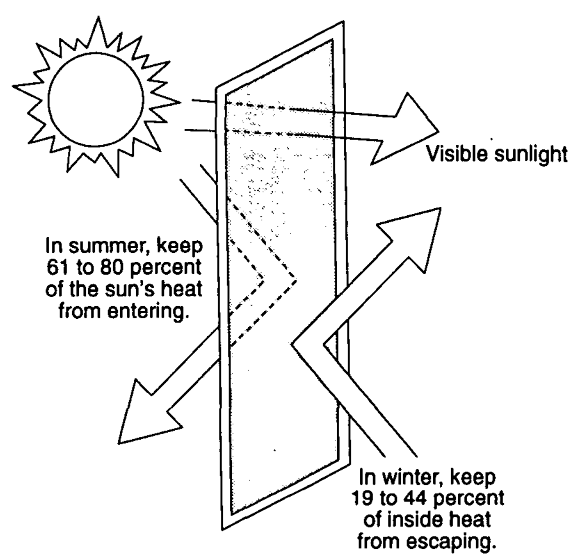
[1] R-value measures the thermal resistance of insulation. A higher R-value means more resistance to heat transfer.

# SECTION 3.2 Window Films

Window films save energy by reducing heat loss and heat transfer through windows (Figure 3.2–1), by allowing better balance in heating and cooling systems, and by providing opportunities for HVAC system downsizing. These thin layers of polyester, metallic coatings, and adhesives limit both the amount of solar heat passing through windows and the amount of internal heat escaping through windows. They can be applied directly to the interior surfaces of all types of glass and generally last from 7 to 12 years.

In the heating season, more heat escapes from a window than comes in from the sun (on a 24-hour basis), the extent depending on the local climate. Window films can help reduce this costly heat loss by reflecting indoor radiant heat back into the room. In the cooling season, even when drapes and blinds are closed, most of the sun's heat passes through the glass into the room. Window films stop the heat of the sun at the window.

**Figure 3.2–1. What Window Films Do**




Most of the energy savings from window films are a result of solar heat rejection, which is measured by the window's shading coefficient[1]. The remaining savings are a result of reduced heat transfer, measured in the window's U-value[2].

*Note: The shading coefficient and U-value of your windows should be in the window manufacturer's data with the building's as-built drawings or specifications. If they are not, a manufacturer's representative should be able to determine these values.*

Window films provide additional benefits by doing the following:

- Increasing productivity by providing a more comfortable environment.
- Reducing glare caused by sunlight on computer screens.
- Increasing the value of the building by improving its appearance and providing architectural unity and distinction to windows.
- Reducing fading of carpets, furniture, and other fabrics by filtering out harmful ultraviolet rays.
- Increasing privacy by restricting visibility from the outside.

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[1] Shading coefficient is a ratio comparing, under the same conditions, solar heat gain through a window system to solar heat gain through a single pane of clear glass. A lower shading coefficient means less heat gain through the window.

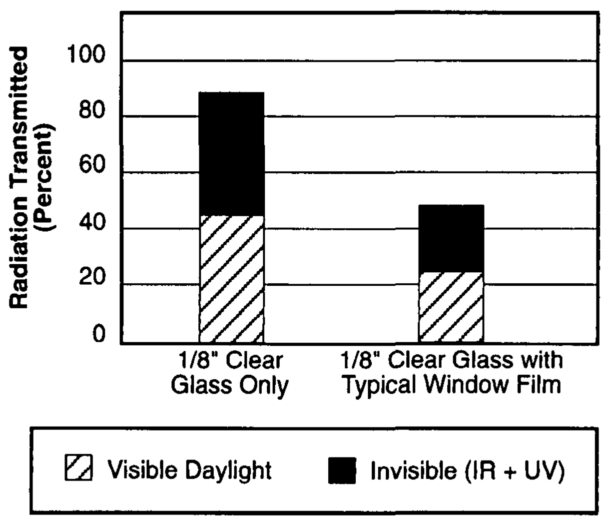
[2] U-value measures a window's rate of heat conductivity, independent of solar radiation. It is a measure of the heat transfer that occurs between the inner and outer surfaces of the window. A lower U-value means better insulation is provided by the window. Because U-values increase greatly with greater temperature differences, it is important to use glass with a U-value appropriate for conditions in your area.

### Why Window Films Save Energy

Window films reduce the amount of radiation passing through glass (Figure 3.2–2). A pane of clear glass 1/8-inch thick transmits about 88 percent of the solar radiation that strikes it, in approximately equal parts of visible daylight and radiated heat. A window film on the pane reduces the transmitted energy by approximately 50 percent.

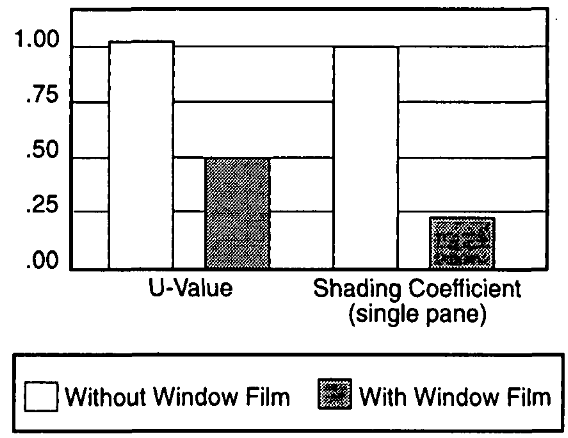
Window films also reduce heat loss in winter and heat gain in summer. Shading coefficients can go from 0.94 to as little as 0.23 and U-values from between 1.09 and 1.03 to less than 0.5, depending on your area of the country (Figure 3.2–3).

**Figure 3.2–2. Films Block Substantially More Solar Radiation Than Clear Glass**




Source: E Source, Inc.

**Figure 3.2–3. Window Films Reduce Effective U-Value and Shading Coefficient**




Source: ASHRAE.

- Protecting employees and property from potential harm from shattered glass.

## Economic Benefits

The greatest opportunity to profit from window upgrades is brought about by the fact that window films result in lower utility bill demand charges. Additional energy and capital cost savings can be achieved through downsizing, which may be possible because of reduced loads. However, it is important to remember that window films increase profits through means other than energy savings. Profits can be realized through factors such as increased worker productivity, increased property value, improved building marketability, and longer lifetimes for furniture and other fabrics.

For example, the owner of a building in Washington, D.C., with a variable air volume inlet vane HVAC system and single-pane windows installed window films that reduced the shading coefficient from 0.75 to 0.25. This upgrade reduced energy consumption by 1.2 percent and reduced energy costs by 3.3 percent. The internal rate of return on the window film investment alone was negligible. However, because of the reduced loads realized from these energy savings, the building owner was able to install a larger pulley on the HVAC system's fan (see Section 4.1.1 for more information on fan downsizing). The addition of this upgrade provided total reductions in energy consumption of 4.7 percent and total energy cost reductions of 9.5 percent. The combined internal rate of return was 23.9 percent.

You can determine if window films can be profitable for your building by applying the following criteria. The more criteria your building meets, the more profitable window films can be.

- Window space on the building is more than 25 percent of the building's surface area.

- The building is in a sunny location (that is, there is little natural shade).
- Windows on the south and west sides of the building receive direct sunlight.
- Windows have single-pane glass. Single-pane glass is found in 68 percent of the commercial space and 52 percent of the office space in the United States. (Note, however, that even buildings with better-insulated double-pane windows may profit from window films.)
- Windows have no existing tint, color, or reflective coating.
- The building is in an area of the country that has a great number of sunny days.
- Fan systems and cooling equipment are downsized due to peak cooling load reductions.

## Project Management Considerations

- If existing windows are of poor quality (for example, they contain single-pane glass or are prone to leakage), you should consider options such as glass replacement, double glazing, or full window replacement. These options are more expensive than window films.
- It may be more cost-effective to install window films only on the south and west sides of the building in places where sun exposure is more significant.
- Typical window films cost between $1.35 and $3.00 per square foot, installed. Of that, 80 to 90 percent is for labor.
- Window films must be installed properly. Improperly installed films can bubble, crack, peel off, or even cause glass to crack. Most manufacturers guarantee films and installation for 5 to 10 years.
- Have several manufacturers install sample films on one or two windows to compare their look and effectiveness and to obtain feedback from building occupants. Films look different when on the glass, and their look on the glass depends on the window type.
- Installation should not disrupt building operations. However, if existing films must be removed, it must be done when the building is unoccupied.
- Always follow the manufacturer's instructions for cleaning and maintaining window films.
- Window films deteriorate over time. As soon as you notice that the film is flaking or peeling, it should be replaced.
- Some utilities offer rebates for installing window films.

## Preparing Specifications

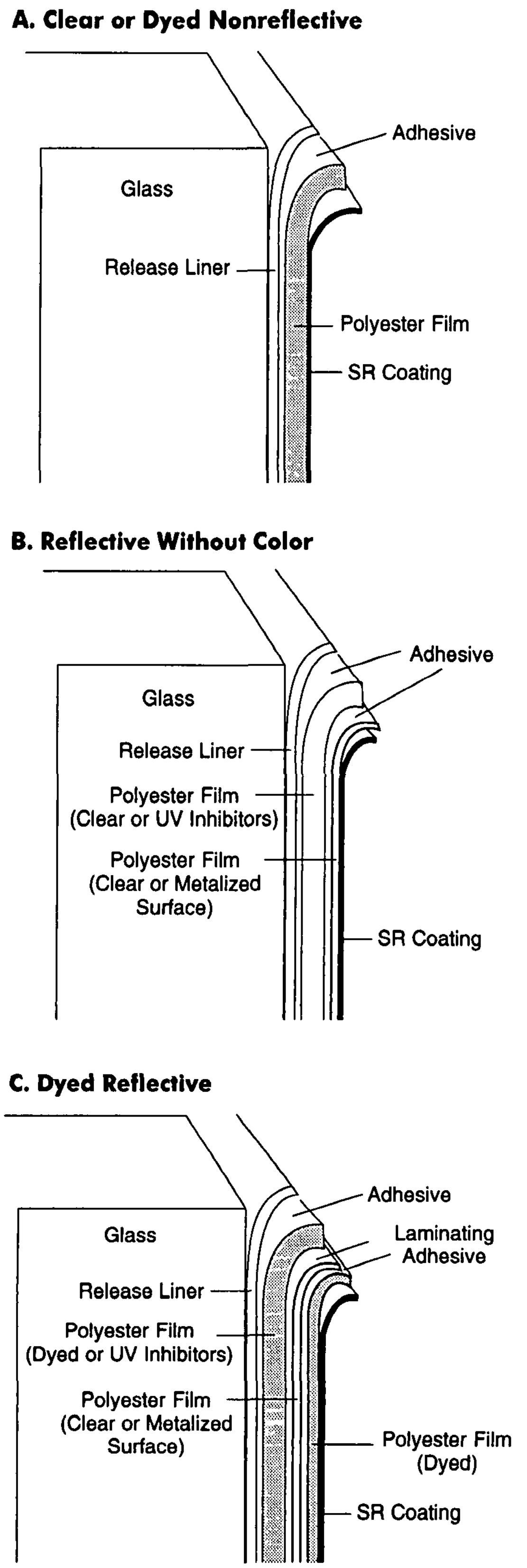
In consultation with an engineer or manufacturer, choose the window film that is most appropriate for your building. The three general categories of window films, shown in Figure 3.2–4, are described below. Scratch-resistance and shatter-resistance are common on all three.

***Clear or Dyed Nonreflective.*** Clear nonreflective films are often used solely for safety, security, or fade control. Dyes or colored adhesive coatings can be added where glare control and privacy are desired. In either case, energy savings are minimal because this type of film is nonreflective.

***Reflective Without Color.*** Clear polyester film is laminated to a second layer of metallized polyester to protect the metallized surface from exposure to corrosives. While referred to as reflective without color, they can appear to be colored (typically silver, gray, or bronze) because the metal itself is visible through the clear layers.

***Dyed Reflective.*** The protective layer laminated over the metallic surface is a dyed film that gives a colored reflection to that side of the product (usually the exterior). For colored reflection visible from either direction, another dyed layer can be added to the film side of the original metallic layer.

Figure 3.2–4. Types of Window Films




When working with the engineer or manufacturer to decide on the product for your building, use the following specifications:

- ***Solar Heat Reflection and Absorption Control.*** Choose a film with the lowest possible shading coefficient. Typical shading coefficients range between 0.23 and 0.94, where 0.23 is the most reflective, usually the darkest, and generally saves the most energy. However, be sure that the film does not reduce lighting excessively.
- ***Degree of Visible Light Transmission.*** All window films reduce light transmission. Therefore, a demonstration installation is recommended. This will enable you to consider the net light transmission of films after application. This is a subjective decision to some extent; however, if window films restrict light excessively, energy costs may increase because of the need for additional lighting and heating. This could negate the energy savings realized from reduced cooling loads.
- ***Heat Transfer.*** Select the lowest possible U-value.
- ***Absorption of Ultraviolet Radiation.*** Be sure to attain the maximum protection from fading.
- ***Color.*** Choose a color that looks good on your building.
- ***Shatter Protection and Scratch Resistance.*** Shatter protection is inherent in all window films. Scratch resistance is an option common on most types of window film. Be sure yours provides both.

Your choice should be the window film that provides the greatest energy savings at the lowest cost; however, you want to be sure that the window film selected looks good on your building and does not interfere with lighting requirements. If the window films cause a need for additional lighting, energy savings may be offset.

# Roofing Upgrades SECTION 3.3

If the flat roof on your building is at or near the end of its useful life, combining energy-saving upgrades with the repairs will enhance the profitability of your investment. The upgrades will also provide more opportunities for HVAC system downsizing.

The best opportunities for roofing upgrades are:

- Improving the R-value of insulation when you are replacing the roof
- Using a reflective material if you are recovering a roof.

## Roof Replacement

If an inspection determines the need for roof replacement, increasing the R-value of the original insulation as part of the project will save energy by restricting heat transfer through the roof. The insulation in most older buildings has an R-value between 4 and 10. The American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE) recommends a minimum R-value of 17. For highest energy efficiency, ASHRAE recommends an R-value between 25 and 30. As long as you are replacing the roof, you should upgrade to insulation with the highest R-value that is profitable for your building.

**Why Roof Upgrades Save Energy**

Insulation with high R-values provides greater resistance against winter heat loss and summer heat gain. For example, increasing R-value from 2 to 16 reduces summer heat gain by 85 percent and winter heat loss by 80 percent.

Light-colored roofs reflect more sunlight than dark colored roofs, decreasing summer heat gain. A dark roof reflects only 10 to 25 percent of solar heat, while light roofs reflect 65 to 75 percent.

## Roof Recovering

If an inspection determines the need for roof recovering, either now or in the future, you should first look into the feasibility of increasing the R-value of the insulation as part of the project. If you cannot profitably increase the R-value of the insulation, you can recover the roof with a light-colored material, whether stone, coating, or membrane, that will reflect sunlight (Figure 3.3–1). This upgrade is most effective on buildings with low R-value insulation in warm climates. In addition to saving energy, light-colored roofs typically last longer than dark-colored roofs.

New coverings, where profitable, offer the following advantages:

- Retaining the investment in existing insulation.
- Minimizing the cost of the retrofit.
- Reducing the amount of debris to dispose.
- Minimizing the risk of water or dust damage while the work is being done.

The most cost-effective roofing upgrades are those applied to low buildings, which typically have high roof-to-building envelope ratios[1] (Figure 3.3–2). In a high-rise building, the roof represents a small percentage of the above-ground building shell, but in low-rise buildings, the roof area can easily be 50 to 75 percent of the above-ground shell. Thus, the roof can be a major contributor to heat gain and loss, and savings from roofing upgrades can significantly reduce the building's total energy bill. Similarly, roofing upgrades are more effec-

[1] A comparison of the square footage of the roof to the total square footage on the exterior of the building.

Figure 3.3–1. What Reflective Roof Coverings Do

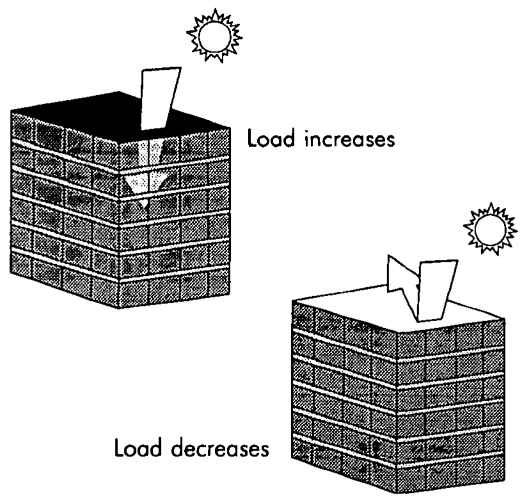
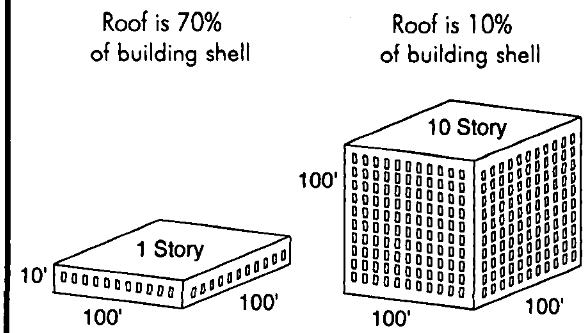



Figure 3.3–2. Low Buildings Have Higher Roof-to-Building Envelope Ratios Than Tall Buildings




Source: U.S. Department of Energy.

tive in areas that experience extreme heat in summer or extreme cold in winter.

## Economic Benefits

Energy savings from roofing upgrades vary with climate, the R-value of existing insulation, and building type and shape. For example, buildings with large roof areas in sunny climates may see significant energy savings from reflective roof coverings, while buildings in cold or rainy areas may not benefit from this type of upgrade at all. Buildings with large roof areas in cold climates see greater energy savings from increasing the R-value of roof insulation.

Table 3.3–1 shows the types of energy savings, payback, and internal rate of return that can be achieved from roof insulation upgrades on two types of office buildings. For example, improving insulation from an R-value of 7 to an R-value of 13 for a small office building reduces energy consumption by 5.3 percent, with an internal rate of return of 2.87 percent. Similarly, improving wet or deteriorating insulation (effective R-value of 0) to an R-value of 26 for a small office building provides energy savings of 30.3 percent, with an internal rate of return of 13 percent.

## Project Management Considerations

- Although replacing a roof is expensive, a new roof will last longer than a recovered roof. A new roof also provides the best opportunity to increase the R-value of insulation.
- Light-colored materials used in recovering will increase roof life anywhere, and reduce energy costs especially in warm climates and on buildings with low R-value insulation.
- To retain its effectiveness, light-colored reflective material on a roof needs to be cleaned periodically.
- Have a contractor or an independent inspector use an infrared scan to look for areas with heat loss or cut a small section out of the roof to test insulation for moisture (wet insulation has lost its effectiveness). Determining the condition of the roof will help you decide the type of work that needs to be done.
- Be sure the new roof or covering has a warranty (typically 7 to 10 years) and that the contractor is available to make any repairs that may be necessary.
- Look into applicable building codes before planning a roofing upgrade or

## Table 3.3–1. Energy Savings and Internal Rate of Return From Roofing Upgrades

| Building Type and Improvement in R-Value | Energy Savings (percent) | Simple Payback (years) | Internal Rate of Return (percent) |
|---|---|---|---|
| **Small Office Building** | | | |
| 0 (wet or deteriorating) to 7 | 21.2 | 2 | 53.89 |
| 7 to 13 | 5.3 | 15 | 2.87 |
| 13 to 26 | 3.8 | 33 | none |
| **Large Office Building** | | | |
| 0 (wet or deteriorating) to 7 | 0.50 | 4 | 28.82 |
| 7 to 13 | 0.10 | 21 | none |
| 13 to 26 | 0.10 | 39 | none |

Source: Simulations run on Department of Energy DOE 2.1E program, with the following assumptions:

Building Located in Washington, D.C.—Small Office Building: Total floor area: 2,250 sq. ft.; Roof area: 2,172 sq. ft.; System type: RTU VAV with gas hot water. Large Office Building: Total floor area: 797,124 sq. ft.; Roof area: 19,340 sq. ft.; System type: VAV with gas hot water.

Roofing Upgrade Costs (1993 Means R&R Cost Data)—None or wet to R-Value of 7: $0.77/sq. ft.; R-Value of 7 to R-Value of 13: $1.23/sq. ft.; R-Value of 13 to R-Value of 26: $1.82/sq. ft.

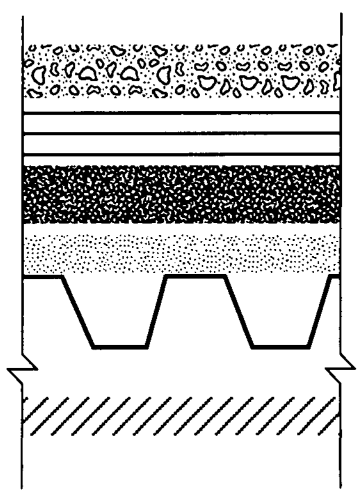
Cost of Energy in Washington, D.C.—Electricity: $0.086 per kilowatthour; Gas: $0.60 per therm.

replacement. Because of roof weight and firefighting concerns, some codes limit roofs to no more than two layers, thereby restricting the potential for recovering a roof. Removing existing layers may not be cost-effective.

- Recovering a roof will have minimal effect on building occupants. However, replacing a roof and adding insulation probably will affect people working on the top floor. Here you will need to decide between providing alternate workspace or having the work done during off hours or on the weekend.
- The time required for the project depends on the square footage of the building and the type of upgrade and material used.
- Be aware of indoor air quality considerations associated with roofing upgrades, particularly dust and fibers from removal of insulation and dirt and emissions from roofing repairs or covering. Appendix B contains more information about indoor air quality.
- Removal of existing roofing may involve disposal of materials with asbestos. In such cases, recovering may be a better alternative.

The type of deck on the roof is a factor in whether a new roof covering can be attached to the existing roof or through the existing roof to the underlying framework. Figure 3.3–3 shows the components of a typical roof.

**Figure 3.3–3. A Typical Roof Has Several Layers**

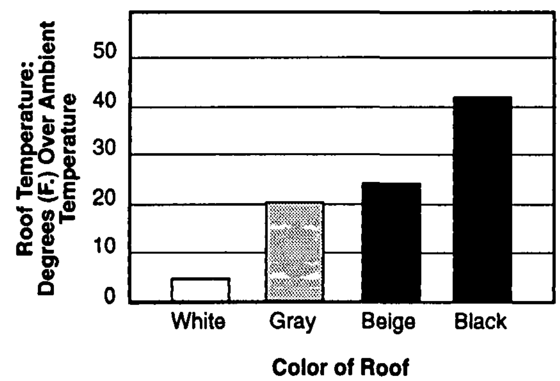


Protecting the roof from tearing off in high-wind conditions is also a consideration. The existing roof must be strong enough to support the new covering as well as anticipated loads and should drain well.

Select the R-value for insulation and the color and the level of reflectance needed in a roof covering based on the climate in your area, the type of building, the type of existing roof (or the new roof if you are reroofing), and existing insulation. Figure 3.3–4 shows the effectiveness of various colors of roof coverings.

It is important to work closely with the roofing materials manufacturer or representative to ensure compatibility among the various roof system components. Many manufacturers will assist in preparing the drawings and specifications.

**Figure 3.3–4. Light-Colored Roof Coverings Are More Effective in Reflecting Solar Radiation**




Source: Du Pont Company.

**Stage 4:** HVAC Distribution System

# Stage 4: HVAC Distribution System

CHAPTER 4

In Stage 4 of the ENERGY STAR Buildings Program, you will be upgrading the energy efficiency and cost-effectiveness of the distribution equipment associated with the HVAC systems in your building, both air-side and water-side. Each section in this chapter explains opportunities for profitable upgrades to a particular type of distribution system.

This chapter contains the following sections:

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# Variable Air Volume System Upgrades

SECTION 4.1

As you begin Stage 4 of the ENERGY STAR Buildings program, you have reduced overall loads in your building through a combination of Green Lights upgrades, building tune-ups, ENERGY STAR office equipment, and window and roofing upgrades. As a result, fans and motors on the variable air volume system's air-handling units in your building are probably oversized—that is, they are no longer required to operate at previous capacities. Oversized fans and motors waste energy. They are rarely required to run at full capacity, but still use the same amount of energy that full-capacity operation requires. Therefore, you can save a significant amount of money by ensuring that fans and motors operate efficiently at your newly reduced loads.

| Potential Savings | |
|---|---|
| Potential Air-Side Energy Savings From Downsizing, Smaller Energy-Efficient Motors, and Variable-Speed Drives | 50–85% |
| Internal Rate of Return | 25–55% |

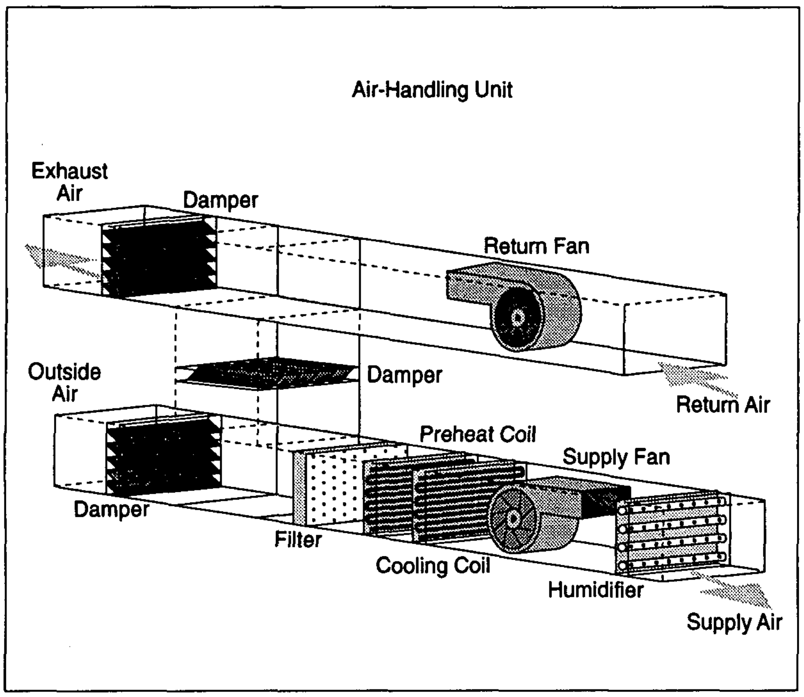
Figure 4.1–1 shows a typical variable air volume system and air-handling unit.

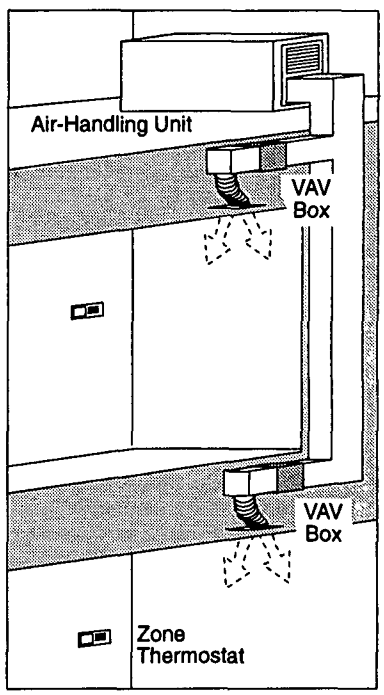
## Best Opportunities

The best opportunities for variable air volume system upgrades are:

- Fan system downsizing.
- Energy-efficient motors.

**Figure 4.1–1. Variable Air Volume System**



- Variable-speed drives.

These upgrades are discussed in the subsections that follow.

*Note: This edition of the ENERGY STAR BUILDINGS MANUAL deals with variable volume air-handling systems only. Future editions will include surveys for constant volume air-handling systems and direct expansion, unitary air-conditioning systems.*

**Illustrative Savings**

A building in the northeastern United States has the following attributes:

- Gross area = 30,650 square feet
- Four floors
- One central air-handling unit that serves 26,000 square feet. The air-handling system is a multizone variable volume inlet-vane system.

In Stage 4, the building owner decided to downsize the fan, install a smaller energy-efficient motor, and install a variable-speed drive sized for the decreased load.

These upgrades provided a 73-percent decrease in the building's fan energy consumption and saved $4,770 per year in total energy costs, with an internal rate of return of 54 percent.

## Variable Air Volume System Survey

The Variable Air Volume System Survey is an essential first step in Stage 4 of the ENERGY STAR Buildings Program. This survey will familiarize you with the condition of your building's air-handling systems and can be used in determining which system upgrades can be profitable in your building.

Much of the information gathered during the Variable Air Volume System Survey is used as input to the QuikFan computer program that calculates the economic benefits of the Stage 4 upgrades. The Variable Air Volume System Survey forms begin on page A–31.

# Fan System Downsizing

SECTION 4.1.1

Fan downsizing can be profitable in most buildings and can be implemented separately or in combination with energy-efficient motors and variable-speed drives.

## Finding the Oversized Fans

You can determine if variable air volume system fans are oversized by measuring the amperage, checking vanes and dampers, or measuring static pressure. These methods are described below.

### Measuring Amperage

1. When the variable air volume system is operating at its maximum level (for example, on a hot summer day), use an ammeter to measure the amperage of the fan motor (see Figure 4.1.1–1).
2. Look at the motor's nameplate to find its full-load amperage.
3. Compare the full-load amperage to the measured amperage. If the measured amperage is 25 percent or more lower than the full-load amperage, the motor is oversized.

### Checking Vanes and Dampers

When the variable air volume system is operating at its maximum level (for example, on a hot summer day), measure the position of the vanes or dampers. The position can be found on the actuator's pressure gauge, or (if there is one) on the actuator's pilot positioner (Figure 4.1.1–1). If you have an energy management system, the position also may be listed on the computer screen or a printout.

If the vanes or dampers are closed more than 20 percent, the fan is oversized.

### Measuring Static Pressure

1. When the variable air volume system is operating at its maximum level (for example, on a hot summer day), the inlet vanes or dampers probably are already open to 100 percent of their design value. If they are not, open them to that position.
2. Open all of the variable air volume boxes associated with the air-handling unit to 100 percent of their design values. One way to do this is to set the zone thermostats to a very low setting.
3. A gauge attached to a static pressure probe in the ductwork (Figure 4.1.1–1) indicates the static pressure controlling the vanes or dampers. This reading may also be available from an energy management system. Compare the static pressure reading with the static pressure setpoint. If the static pressure reading is less than the setpoint, the setpoint can be adjusted to the lower static pressure.

## Three Ways To Downsize

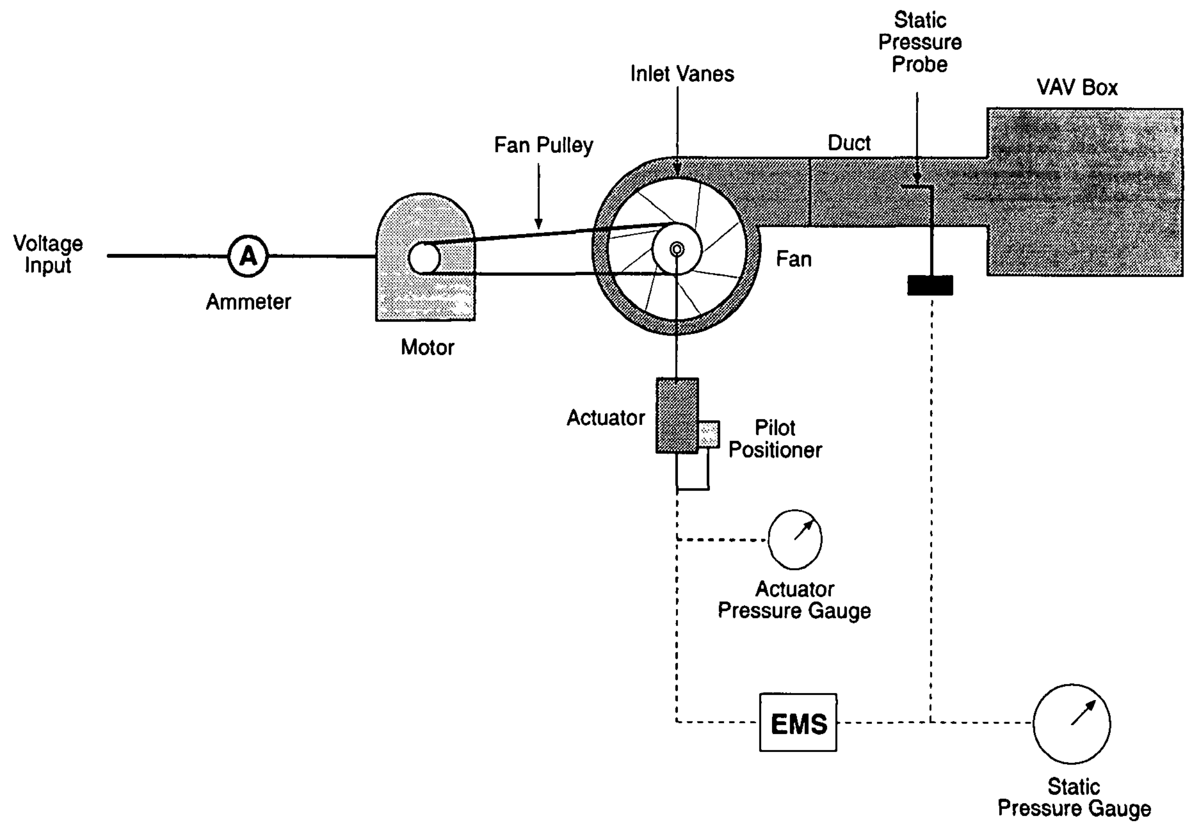
You can downsize fans by installing larger pulleys, adjusting static pressure, or replacing the fan's motor with a smaller energy-efficient motor. These options are described below.

### Larger Pulleys

*Replace the existing fan pulley with a larger fan pulley.* This will reduce the fan's speed, greatly reducing its power requirements. For example, reducing a fan's speed by 20 percent reduces its energy requirements by about 50 percent.

*Note that the new pulley should operate the fan at a reduced speed that matches current load requirements.*

Figure 4.1.1–1. Position of Controls Used To Determine Oversizing




## Static Pressure Adjustments

*Reduce the static pressure setpoint to match the measured static pressure.* Reducing the static pressure setpoint from 2.5 inches to 1.5 inches reduces energy consumption by 10 to 35 percent, depending on actual fan static pressure.
*Note: The method for measuring static pressure is described on the previous page.*

Static pressure should be adjusted only if temperature setpoints can be maintained in all zones. If temperature setpoints cannot be maintained in all zones, increase the static pressure setpoint in increments of 0.1 inches until the temperature setpoints can be maintained. This setting then becomes your most economical static pressure setpoint.

If you have an energy management system that monitors airflow, you can reduce static pressure and reduce energy consumption even more. As the measured airflow decreases in 25 percent increments, you can decrease the static pressure setpoint in 40 percent increments. Again, the zone temperature setpoints must be maintained. If the static pressure is reduced by 40 percent and the temperature setpoint in any zone cannot be maintained, increase the static pressure in 0.1-inch increments until the temperature setpoints can be maintained.

**Potential for Downsizing**

| If You Reduce Loads By . . . | You Probably Can Downsize Airflow (cfm) By . . . |
|---|---|
| Green Lights Upgrades | 15–30% |
| ENERGY STAR Office Equipment | 10–20% |
| Window and Roofing Upgrades | 5–15% |
| **Total Potential for Downsizing:** | **30–65%** |

### Smaller Energy-Efficient Motors

*Replace the existing motor with a smaller energy-efficient motor* that matches the current load requirements. For a given application where the motor is oversized, downsizing a 75-horsepower standard-efficiency motor to a 40-horsepower energy-efficient motor will result in average energy savings of 15 percent.

Most motor manufacturers now offer energy-efficient models that consume a minimum of 3 to 8 percent less energy than comparable standard-efficiency motors, depending on size and load.

## Economic Benefits

You can estimate the expected benefits of downsizing by running the EPA QuikFan program. The information required to run QuikFan is gathered during the Stage 4 Variable Air Volume System Survey (see Appendix A). Instructions for running the QuikFan program are provided with the software.

## Project Management Considerations

The first consideration in downsizing fan systems is to determine the components of the downsizing effort. For example, will you be replacing pulleys, adjusting static pressure, installing smaller energy-efficient motors, or using a combination of these?

The engineer verifying the downsizing potential you have calculated will need the information you collected for the QuikFan program, as well as the types of and efficiencies of the air-handling units, fans, and pulleys in your building.

If your company does not have an engineer on its staff, you should hire a consulting engineering firm to verify your choices.

Once the potential for downsizing is verified, qualified personnel should implement the changes—a controls technician to adjust static pressure, an electrician to replace motors and drives, and a mechanic to replace fan pulleys.

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# Energy-Efficient Motors

Energy-efficient motors use improved motor designs, more metal, and high-quality materials to reduce motor losses and therefore improve efficiency. They are more reliable than standard-efficiency motors and generally have longer manufacturer's warranties. These motors reduce operating costs by:

- Lowering energy consumption, which saves money by reducing the monthly electric bill (see Figure 4.1.2–1).
- Postponing or eliminating the need to expand the capacity of the electrical supply system in the building in response to changes in building use or installation of additional equipment.
- Reducing downtime, replacement, and maintenance costs.

Energy-efficient motors can be implemented individually or as part of a retrofit that includes downsizing, variable-speed drives, or both.

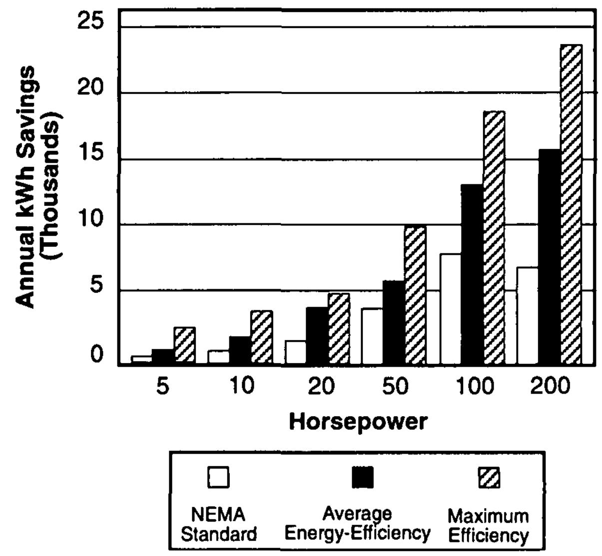
Whenever a motor is operating, some loss in efficiency is incurred. For example, if a motor is 85 percent efficient (see the formula below), 15 percent of the energy input dissipates as heat, which increases motor temperature. This in turn increases wear and wastes energy. Replacing a standard-efficiency motor with an energy-efficient motor reduces those losses and therefore also reduces costs (see Figure 4.1.2–2).

Fan motors operate best at 75 to 100 percent of their fully rated load because the efficiency curve peaks between 75 percent and 100 percent. However, a smaller energy-efficient motor can improve efficiency when operating under part-load conditions. Most savings occur when the motor is properly matched to its load. Thus, motors operating at less than 60 percent of their fully rated loads are excellent candidates for replacement with smaller energy-efficient motors. Table 4.1.2–1 shows the types of efficiency improvements that energy-efficient motors can provide.

When energy-efficient motors are part of a downsizing program, savings increase significantly. For example, downsizing a 75-horsepower standard-efficiency motor to a 40-horsepower energy-efficient motor will result in average energy savings of 15 percent.

**Figure 4.1.2–1. Energy-Efficient Motors Save Thousands of kWh Annually**

(1,800-RPM Totally Enclosed Fan-Cooled Motor)



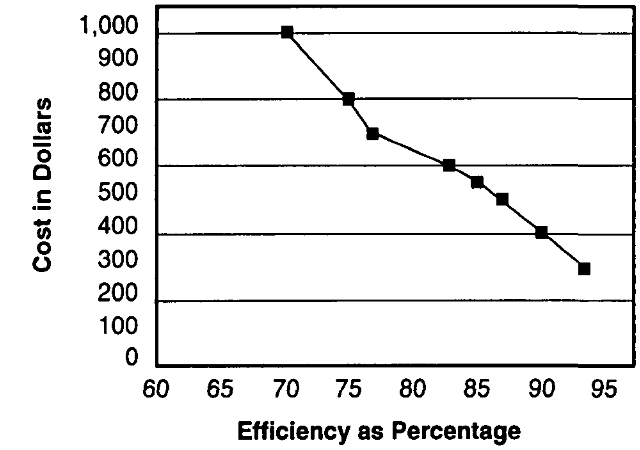

*Source:* U.S. Department of Energy.

**Determining Motor Efficiency**

$$100\% \times \frac{\text{Mechanical Power Output}}{\text{Electrical Power Input}}$$

Figure 4.1.2–2. Improved Efficiency Means Reduced Costs

(For 25-Horsepower Motor, per Year)




Source: U.S. Department of Energy.

Table 4.1.2–1. Comparison of Standard-Efficiency Motors and Energy-Efficient Motors

(1,800-RPM Totally Enclosed Fan-Cooled Motor)

| Horsepower | Average Full-Load Efficiency (percent): Standard-Efficiency Motor | Average Full-Load Efficiency (percent): Energy-Efficient Motor |
|---|---|---|
| 5 | 83.3 | 89.5 |
| 7.5 | 85.2 | 91.0 |
| 10 | 86.0 | 91.0 |
| 15 | 86.3 | 91.7 |
| 20 | 88.3 | 92.0 |
| 30 | 89.5 | 92.6 |
| 40 | 90.3 | 93.1 |
| 50 | 91.0 | 93.4 |
| 60 | 91.7 | 94.0 |
| 75 | 91.6 | 94.1 |
| 100 | 92.1 | 94.7 |

Note: Older standard-efficiency models have even lower efficiencies than those shown in this table.

*Source:* Calculations from Washington State Energy Office's *Motor Master* software program.

## Economic Benefits

You can estimate the expected benefits of an energy-efficient motor upgrade by running the EPA QuikFan program. The information required to run QuikFan is gathered during the Stage 4 Variable Air Volume System Survey (see Appendix A). Instructions for running the QuikFan program are provided with the software.

## Project Management Considerations

Once you have determined the type of energy-efficient motor to install, the engineer verifying your selection will need nameplate data and the loads for all motors you want to replace.

After the requirements are verified, a qualified electrician should replace the motors.

Consult with the manufacturer to determine if you will require an adaptor kit for the motor mounts, which may be needed to avoid problems with shaft alignment, base or frame size, and bolthole locations.

*Some additional considerations:*

- If your organization does not have an engineer on its staff, you should hire a consulting engineering firm to verify your choices.
- Variable air volume system motors must be sized to operate at peak load conditions. The motor output must be measured at maximum load. Worn belts and pulleys should be replaced before you take these measurements (these actions are part of the Stage 2 building tune-up and preventive maintenance program).
- For variable air volume systems, the replacement motor selected should be the next nameplate size above the existing motor's output when it is operating under full load conditions. For example, if the measured full-load output is found to be 18.5 horsepower, select a 20-horsepower motor. Voltage, amperage, kilowatt draw,

power factor, and slip should be metered for a variety of motor operating conditions to accurately determine maximum load.

- One of the inherent characteristics of high-efficiency motors is that they tend to have less "slip" than standard-efficiency motors and thus will run at slightly higher speeds than standard motors. When replacing a standard motor with a high-efficiency model of equivalent rated horsepower, you may need to install a larger pulley to compensate for the higher motor speed. Otherwise, the total energy savings will not be maximized because the energy saved by the high-efficiency motor will be partly offset by the additional energy used to run the fan at a higher speed.
- Replace a standard-efficiency motor with a high-efficiency unit of like speed to capture maximum energy conservation benefits and minimize equipment replacement costs (pulleys, sheaves, and so forth).

## Preparing Specifications

The motor you select should be able to meet load requirements. The general specifications on pages 4–12 and 4–13 will help you determine the requirements for your motors and ensure that your criteria are met when the new motors are installed.

## General Specifications for Energy-Efficient Motors

1. **Nameplate Data.** Most of the specifications for the motor can be obtained from the existing motor's nameplate. The new motor will need to improve on the existing motor as described below.
2. **Rating.** The standard torque-speed design for the new motor should have a NEMA B rating.
3. **Efficiency.** The motor should have the highest efficiency possible for the new horsepower rating (see the motor efficiency table on page 4-10).
4. **Heating.** Note any special cooling requirements needed to dissipate heat generated by the motor.
5. **Inrush Current.** Be sure protective devices (for example, circuit breakers or fuses) can safely handle the starting current.
6. **Temperature Rise and Insulation Class.** Note the ambient temperature at which the motor will be operating and specify the class of insulation required to protect the motor at the maximum ambient temperature (class F or H will be more efficient and have a longer life).
7. **Power Factor.** When specifying power factor, keep in mind that high-efficiency motors have higher power factors because they require less power to produce magnetic fields. Power factor range should be above 90 percent.
8. **Service Factor.** The new motor must have the ability to exceed its mechanical power output rating for a certain period of time. This will allow the motor to operate at higher horsepower, avoiding the need to obtain a larger motor. Minimum service factor should be 1.15.
9. **Sound Level.** If noise is a consideration, the motor should be equipped with appropriate bearings and ventilation systems.
10. **Number of Starts.** Be sure the motor and starter can handle the anticipated number of starts per hour.

## General Specifications for Energy-Efficient Motors

11. **Starter.** If you are not installing a variable-speed drive, the motor should be equipped with a starter.
12. **Motor Protection.** You may want to equip the motor with a disconnect source, overcurrent protection, and overload protection or low-voltage protection (or both).
13. **Torque.** The new motor's start torque (torque produced at zero speed) and breakdown torque (maximum torque the motor can produce before starting) must be equivalent to those on the existing motor.
14. **Environment.** Be sure to let the manufacturer know if the motor will be installed in an unusual environment (abrasion, high altitude, high or low ambient temperature, hazardous or other unusual types of materials nearby, or high humidity). These conditions may necessitate special enclosures, thermal protection, space heaters, heavy-duty electrical wiring or conduit, or other types of protection.

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# Variable-Speed Drives

SECTION 4.1.3

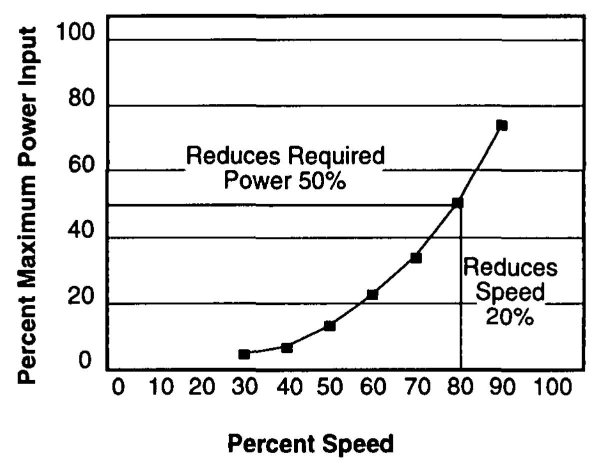
Variable-speed drives—an efficient and economical retrofit option—should be seriously considered for all variable air volume systems. These devices:

- Operate electronically rather than mechanically.
- Continually adjust the speed of the air-handling unit's fan motor to match the required load. Thus, the only power consumed is the power required to meet the demand (Figure 4.1.3–1).
- Require far less input power than existing methods used to control airflow in variable air volume systems (such as variable inlet-vane control and outlet-damper control) (Figure 4.1.3–2).
- Reduce fan speed, resulting in more efficient control of airflow, and reduce fan noise and vibration.
- Reduce motor wear by controlling current surge during startup. Variable-speed drives reduce current surge by replacing instantaneous startup with "soft starting," where startup is gradual, over several minutes.

**How Variable-Speed Drives Reduce Operating Costs**

- Soft-start capabilities allow motor speed to be gradually increased, reducing starting currents and thermal stresses.
- Controlled braking results in quick but safe reductions in motor speed.
- Soft start, controlled braking, and current reductions in response to reduced demand lead to longer equipment life. Belts, pulleys, bearings, motors, and transformers will also last longer.
- Routine maintenance is unnecessary. If service is required, the fan can operate independently (at full speed or under the original controls), which eliminates downtime.

**Figure 4.1.3–1. Variable-Speed Drives Reduce Maximum Power Input**




Source: Electric Power Research Institute.

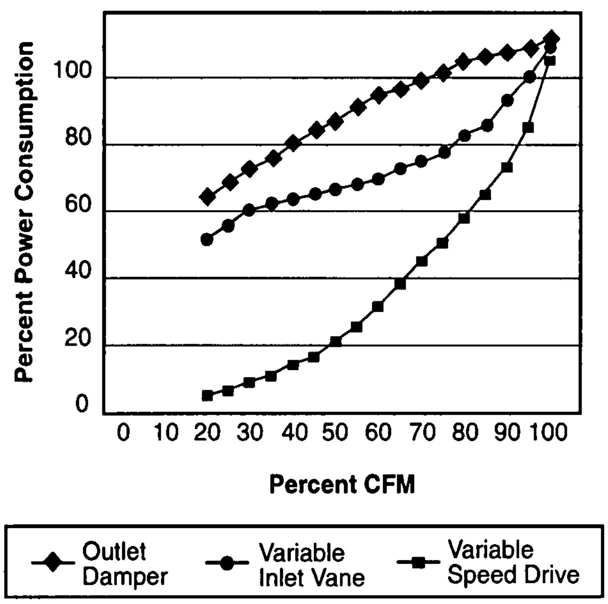
Variable-speed drives can be implemented individually or as part of a retrofit that includes downsizing, energy-efficient motors, or both. In retrofit applications, the existing control (an inlet vane or outlet damper) is locked in the fully open position or removed and the variable-speed drive controls the amount of discharge air by altering the speed of the fan.

Figure 4.1.3–3 shows the configuration of a variable air volume system with a variable-speed drive. Detailed technical information about variable-speed drives, including example specifications, are available on the Green Lights Bulletin Board.

## Economic Benefits

You can estimate the expected benefits of variable-speed drives by running the EPA QuikFan program. The information

**Figure 4.1.3–2. Variable-Speed Drives Reduce Power Consumption**




required to run QuikFan is gathered during the Stage 4 Variable Air Volume System Survey (see Appendix A). Instructions for running the QuikFan program are provided with the software.

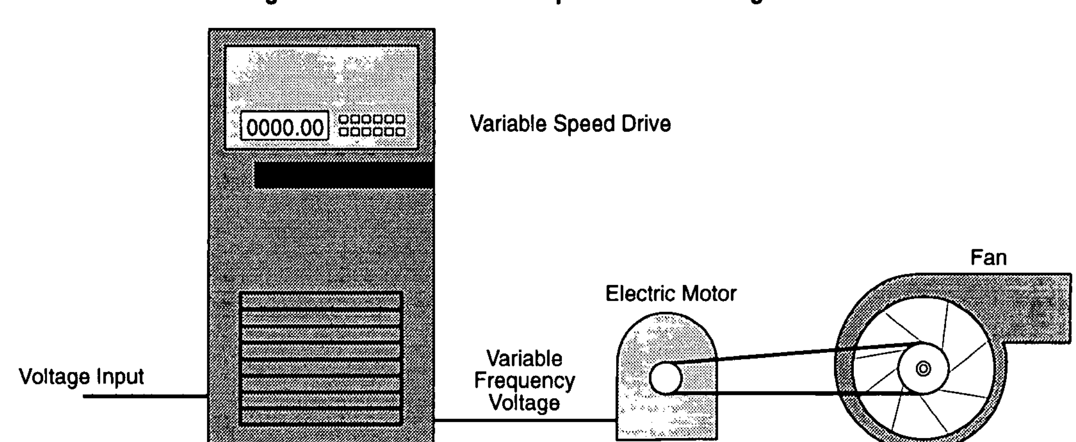
## Project Management Considerations

Once you have determined the type of variable-speed drive to install, the engineer verifying your selection will need to know the type of air-handling units in your building and all of the information you compiled for the QuikFan software, including the new motor horsepower and efficiency calculated by the program. If you cannot run the program, the engineer can use the load calculations from page 4–5 (see *Measuring Amperage*) in conjunction with the survey results to estimate the new motor size. When the requirements are verified, select a manufacturer who can meet your requirements.

*Some additional considerations:*

- If your organization does not have an engineer on its staff, you should hire a consulting engineering firm to verify your choices.
- Evaluate the contractor's capabilities and experience in light of the size of drive you have selected.
- Evaluate the manufacturer's capabilities in conducting harmonic, power factor, and torsional analyses.
- Be sure the contractor will be fully responsible for getting the job properly completed and having the manufacturer design around any potential electrical or torsional problems.
- Address maintenance contracts, startup, spare parts, on-site assistance during

**Figure 4.1.3–3. Variable-Speed Drive Configuration**



### How Variable-Speed Drives Save Energy

- The power required to run variable-speed drives is proportional to rpm$^3$. Therefore, a reduction in speed of as little as 10 percent results in a 27-percent drop in power consumption $(1 - 0.9^3)$. With a variable-speed drive, a fan in a typical variable air volume system runs at 80 percent speed or less 90 to 95 percent of the time. Compare this with a fan running at 100 percent speed 90 to 95 percent of the time.
- The initial power required to start a motor is about 600 percent of rated current when a motor is started at full voltage and frequency. If a motor is started at low voltage and frequency through use of a variable-speed drive, it will never need more than 150 percent of its rated current.

installation and precommissioning, and training for in-house staff.

- Be sure the manufacturer has a thorough functional testing, inspection, and check-out plan.
- Specify the types and numbers of drawings and manuals required.
- A coast-down test to compare mechanical resonance with speed response is important. Have the manufacturer bypass the critical or resonance frequency band(s) of the motor or fan to eliminate any noise or vibration problems.

### Indoor Air Quality

When downsizing, be sure to consider indoor air quality. For example, you must be certain that minimum outside air supply requirements established by ASHRAE standards or local codes are met, and you should ensure that air is always being supplied to each space (that is, the outside air damper is never closed when the building is occupied).

Appendix B contains more information on building environmental quality issues, including indoor air quality basics, ASHRAE standards and guidelines related to indoor air quality, and sources of more information about indoor air quality, including EPA's IAQ INFO hotline and the EPA/NISOH publication *Building Air Quality: A Guide for Building Owners and Facility Managers*.

A qualified electrician should install the drives and ensure that they are wired properly. The drives should be located in a clean and dry area. In addition, variable-speed drives must have an isolation transformer and power-system ground near the motor terminals to maintain proper line-to-ground voltages at the motor. Winding failures may result from high line-to-ground voltages at the motor.

Post-startup testing and evaluation consists of operating the motor at fixed speeds and determining power requirements at several load points approximating the load-duration curve.

## Preparing Specifications

The drive you select should be able to meet both motor and load requirements. The following steps should be taken to ensure that the proper drive is selected for a particular application.

- Obtain the air-handling unit's performance curves from the manufacturer. This information, along with information compiled for the QuikFan software, should be incorporated in the specifications to ensure that the proper drive is installed.
- Note any environmental, weight, or space constraints.
- Backward-curved or -inclined and airfoil fans are the best candidates for variable-speed drives. Some axial and forward-curved fans have narrow operating ranges; if the variable-speed drive operates outside this range, the fan will surge and the system will have difficulty maintaining static pressure. If your system has an axial or forward-curved fan, check with the fan's manufacturer to determine its compatibility with variable-speed drives.

### Wiring Guidelines

***Do*** run control wiring in separate conduits. This prevents critical control-signal variations that can result from coupled noise in high-power wiring.

***Do*** wire the variable speed drive to a good, independent ground. A variable-speed drive grounded through conduit may cause resistance between the variable-speed drive and the true ground.

***Do Not*** attempt to eliminate noise by connecting a variable-speed drive to another variable-speed drive's cabinet. This action will cause the noise to transmit between cabinets.

At a minimum, the selected drive should be equipped with the following options:

- A pulse-width modulated (PWM) inverter.
- A start-stop circuit interlocked with all motor disconnect switches.
- A set of dry contacts to interface with an energy management system.
- A place in the circuitry to install external emergency contacts such as low- and high-temperature thermostats and vibration switches.

It is important that a variable-speed drive for a high-efficiency motor have isolated gated bipolar transistors (IGBTs) in the inverter so that motor overheating does not occur at lower operating speeds.

The box on page 4–19 provides additional general specifications for variable-speed drives.

### Power Quality and Variable-Speed Drives

The following issues related to power quality could arise when installing variable-speed drives. An electrical engineer should be consulted to analyze any of these occurrences and, if necessary, to review your electrical distribution system.

- Harmonic voltage and current distortion levels in a building should be limited to less than approximately 5 percent. Harmonic distortion is site-specific and may have a number of causes, either preexisting or resulting from the variable-speed drive. Line filters will typically control the problem. A low power factor indicates a harmonic problem and low-efficiency equipment.
- Effective protection against electromagnetic interference should be designed into the inverter system.
- To protect the variable-speed drive from shutting down due to overvoltage or undervoltage conditions (nuisance tripping), use a filter or a standard isolation transformer.
- The variable-speed drive should be provided with ride-through capability so that nuisance tripping caused by voltage sags can be prevented. Power conditioners and uninterruptible power supply systems will also protect the variable-speed drive from tripping.
- Variable-speed drives can generate audible noise due to the several-kHz modulation frequency. An output filter will decrease the higher frequency harmonics seen by the motor and, therefore, the audible noise level.

## General Specifications for Variable-Speed Drives

1. **Performance Requirements.** The variable-speed drive must be compatible with the motor it will be installed on. You need to know the motor's horsepower, efficiency rating, amperage, voltage, frequency range, maximum torque, service factor, and power factor.
2. **Controller.** Select a controller appropriate for the motor on which the drive is to be installed (pneumatic, analog, or digital) and be sure to specify the type and extent of remote control, if required.
3. **Interface.** Specify if the variable-speed drive needs to interface with other devices such as an energy management system. The manufacturer will need to know the type of link required.
4. **Isolation Transformer.** Let the manufacturer know if an isolation transformer will be needed to separate the variable-speed drive from the incoming AC power line.
5. **Motor Heat Rate versus Load.** The drive manufacturer will need information on tested heat rate compared with load. This can be obtained from the motor's manufacturer.
6. **Fan.** The drive manufacturer will need a comparison of tested fan flow with load and also the fan curve. These can be obtained from the fan's manufacturer.
7. **Environment.** Be sure to let the manufacturer know if the drive will be installed in an unusual environment (abrasion, high altitude, high or low ambient temperature, hazardous or other unusual types of materials nearby, or high humidity). These conditions may necessitate special enclosures, thermal protection, space heaters, heavy duty electrical wiring, RF or EMI shields, or other types of protection.
8. **Power Quality.** A power analysis is essential to determine the presence of low power factors or harmonics in the building. If either are found, corrective measures, such as installing harmonic filters, should be taken.

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# Water-Side Upgrades

SECTION 4.2

In a building that utilizes pumps to transport chilled water, condenser water, or refrigerant, the ENERGY STAR Buildings approach can reduce pumping system energy by 50 percent or more. Traditional pumps use constant-volume flow. When smaller loads are needed, a throttle valve reduces the flow. This method is very inefficient.

## Best Opportunities

You can make water-side systems more energy efficient by implementing any of the following upgrades:

- Downsizing oversized pumps and motors.
- Installing variable-speed drives on pump motors.
- Converting single-loop configurations to configurations with primary and secondary loops.

## Downsizing

Downsizing pumps to accommodate lower-than-expected maximum loads will consume less energy. Replacing a 4-pole motor with a 6-pole motor and downsizing can result in energy savings of up to 70 percent.

When pump downsizing is based on load reductions, the maximum design load on the new pump must be greater than the measured maximum load for the system. It is also important to recognize that pump motors come in incremental sizes (5 horsepower, 7.5 horsepower, 10 horsepower, and so on). Be certain that the new motor is sized to meet the maximum load. For example, if your calculations show that load can be reduced to 7.6 horsepower, you can downsize to a 10 horsepower motor—not 7.5 horsepower.

Savings estimates for downsizing can be calculated by comparing rated energy curves at various loads for old and new pump sizes.

## Variable-Speed Drives

Installation of variable-speed drives will ensure that pumps are performing at maximum efficiency at part-load conditions. The power needed to run the pump motor is proportional to the cube of the load. For example, in a pump system with a variable-speed drive, reducing the load by 10 percent reduces the energy input by 27 percent $[1 - (0.9)^3 = 0.27]$. Variable-speed drives are expected to save up to 67 percent of pump energy consumption.

When installing variable-speed drives, several considerations must be addressed:

- Harmonic, power factor, and torsional analyses need to be completed before installation.
- A coast-down test to compare mechanical resonance with speed response is important.
- For chiller pump upgrades, it is important that maximum and minimum flow rates through the chiller be met, as mentioned above.
- A qualified electrician will need to install the drives on the motors.

### Estimating Savings From Pump Variable-Speed Drives

To estimate annual energy savings gained from installing variable-speed drives on pumps, estimate run times for all part-load conditions, based on either monitoring or load calculations. Then compare the efficiency of the existing motor at part-load conditions with the efficiency of the motor with a variable-speed drive installed at the same conditions. The change in efficiency multiplied by the motor's rating (kW) and run hours for the range of load percentages will give expected energy savings in kilowatthours.

*Example:*

A 30-horsepower variable-speed drive is installed on a chilled-water pump. The existing flow rate is 1,040 gallons per minute, existing hours of operation are 3,300 per year, and the pump's energy consumption is 66,900 kilowatthours per year. The initial cost of the variable-speed drive is $5,100.

The variable-speed drive reduces average flow to 700 gallons per minute.

Estimated new annual energy consumption = $(66{,}900)(700 \div 1{,}040)^3$ = 20,400 kilowatthours per year.

Estimated annual energy savings (66,900 – 20,400)($0.08 per kilowatthour) = $3,720 per year.

Simple payback = $5,100 ÷ $3,720 = 1.4 years.

## Single Loop to Primary/ Secondary Loop Conversions

For chiller applications, since there is a rated minimum flow for chilled water through the chiller (usually 70 percent), variable-speed drive flow reductions are limited to that rated flow. However, a primary/secondary loop configuration can allow for greater energy reductions without compromising chiller performance.

For example, a 20-horsepower motor that pumps chilled water through the chiller and directly to cooling coils could be replaced by a 5-horsepower motor pumping water to the chiller loop and a 15-horsepower motor pumping the chilled water to a separate cooling-coil loop. A variable-speed drive on the cooling coil loop motor would have free range to reduce flow (and therefore motor energy) to match load conditions without dropping low rates through the chiller. The 5-horsepower motor would maintain constant (100 percent) flow, but would only use a portion of the energy of the 20-horsepower motor.

Stage 5. HVAC Plant

# Stage 5: HVAC Plant

CHAPTER 5

In Stage 5 of the ENERGY STAR Buildings Program, you will be upgrading the energy efficiency and cost-effectiveness of chillers and other equipment associated with HVAC systems in your building. Each section in this chapter explains the most profitable opportunities for upgrades to a particular type of equipment.

This chapter contains the following sections:

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# Water-Cooled Centrifugal Chiller Upgrades

SECTION 5.1

In Stage 5 of the ENERGY STAR Buildings Program, you will be looking at upgrades to your building's HVAC plant. This section deals with water-cooled centrifugal chillers (see Figures 5.1–1 and 5.1–2). You should consider investing in these chiller upgrades for two reasons:

First, upgrades already done in the program—the tune-up, Green Lights, ENERGY STAR office equipment, and window, roof, and HVAC distribution system improvements—have most likely brought about a significant reduction in your cooling load requirements. A new, smaller, more energy-efficient chiller can increase the profits you are realizing from these upgrades.

Second, as of January 1, 1996, the type of refrigerant (R–11 or R–12) currently used in water-cooled centrifugal chillers will no longer be produced (see box). This phaseout of R–11 and R–12 is required by the sections of the Clean Air Act Amendments of 1991 that address chlorofluorocarbons (CFCs). While simply containing or recycling the existing refrigerant may seem like a viable alternative, consider the following:

- The phaseout that begins in 1996 will eventually cause serious shortages of R–11 and R–12.
- The price of R–11 and R–12 will probably increase dramatically beginning in 1996.

## Best Opportunities

- Chiller retrofit.
- Chiller replacement.

### CFCs Are on the Way Out

Eighty percent of today's chiller market is made up of centrifugal chillers that use R–11 as refrigerant. The alternative is HCFC–123. Some centrifugal chillers use R–12. Its alternative is HFC–134A.

**Phaseout Dates**

1996: R–11, R–12, R–500, HCFC–152A, CFC–114. No new refrigerant containing these compounds will be sold. Chillers using these refrigerants will no longer be manufactured.

2010: HCFC–22. No new refrigerant containing this HCFC will be sold. Chillers using refrigerants based on this HCFC will no longer be manufactured.

2020: HCFC–22. Chillers using refrigerant based on this HCFC will no longer be serviced.

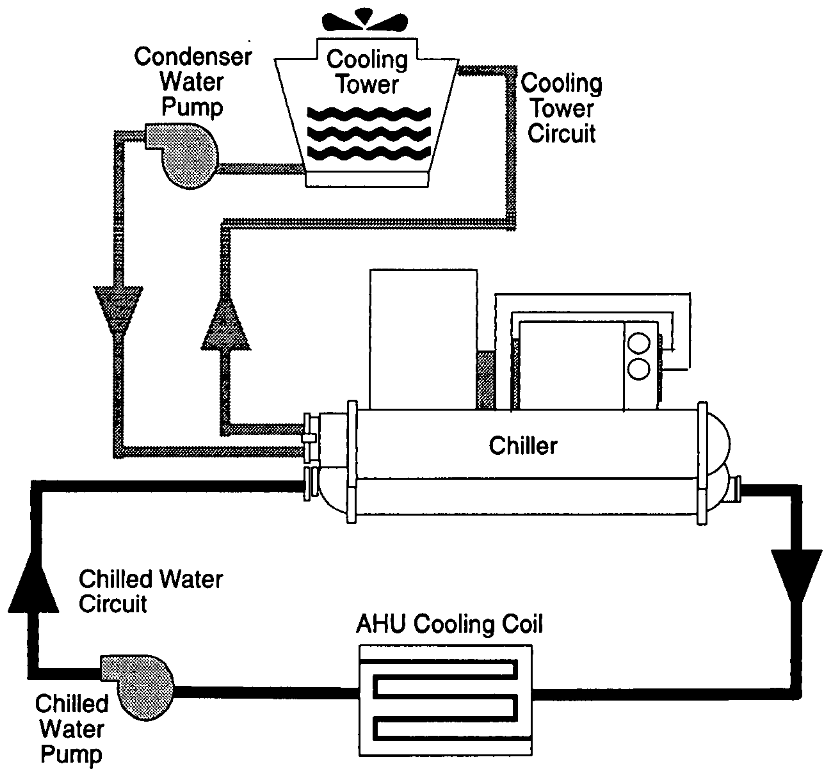
HCFC–123. No new refrigerant containing this HCFC will be sold. Chillers using refrigerants based on this HCFC will no longer be manufactured.

2030: HCFC–123. Chillers using refrigerant based on this HCFC will no longer be serviced.

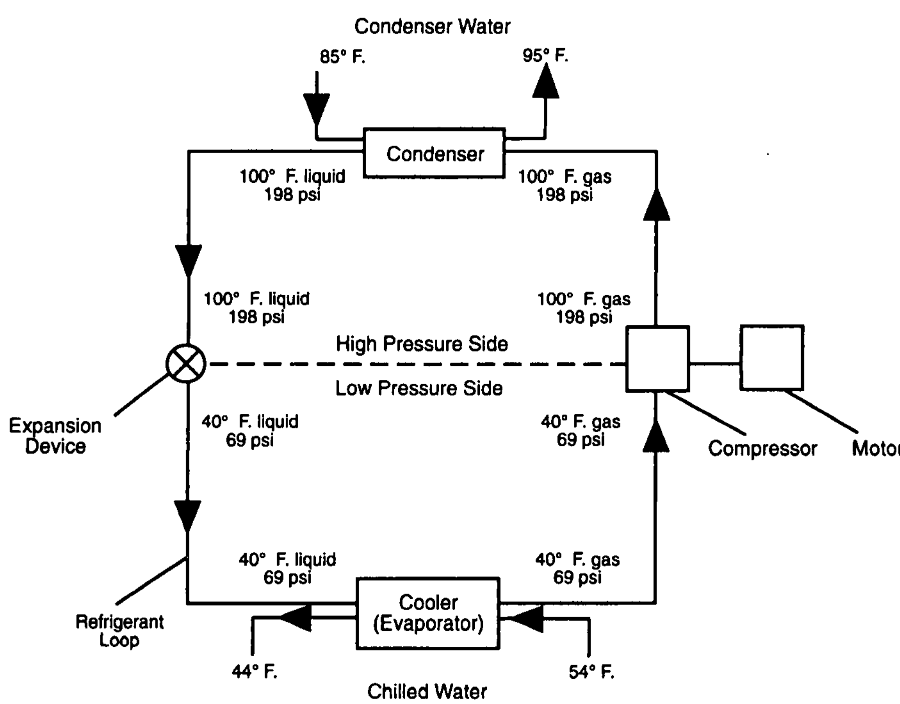
## Chiller Survey

The Chiller Survey is an essential first step in Stage 5 of the ENERGY STAR Buildings Program. This survey will familiarize you with the condition of your building's chiller and enable you to determine if it can be replaced profitably. Some of the information gathered during this survey will be used in calculating new cooling loads for your building. The Chiller Survey forms begin on page A–41.

## Figure 5.1–1. Typical Water-Cooled Chiller System




## Figure 5.1–2. Centrifugal Liquid Chiller Functions




**Note: Temperatures and pressures shown are approximations only and may vary, depending on the type of chiller, its application, and the type of refrigerant it uses.**

## Chiller Retrofit

If your chiller is up to 10 years old, retrofitting that chiller so that it operates more efficiently at the newly reduced loads and uses new refrigerants is probably the most profitable option, simply because it postpones investing in a new chiller.

Retrofitting for more efficient operation at newly reduced loads may involve replacing orifice plates, replacing impellers, or even replacing the compressor. The specific retrofits depend on the type of chiller and its manufacturer.

If you are replacing refrigerant, use HCFC–123 in place of R–11 and HFC–134A in place of R–12. To make your building's chiller compatible with one of these new refrigerants, you may also need to replace some gaskets and seals and rewind the motor.

Because of their properties, the new refrigerants are not as efficient and thus will affect the chiller's efficiency by reducing cooling tonnage at current or even increased levels of energy consumption. However, this loss will be offset by the reduced cooling loads obtained through previous ENERGY STAR Buildings upgrades.

## Chiller Replacement

Replacing the existing chiller with a new, smaller, more energy-efficient model that matches the newly reduced loads and uses new refrigerants can be considered at any time; however, this option is most profitable if the existing chiller is more than 10 years old.

Depending on the options implemented in Stages 1 through 4 of the ENERGY STAR Buildings Program, cooling load requirements in your building have probably been reduced by at least 10 percent and possibly by as much as 40 percent. Thus you have the opportunity to downsize the new chiller accordingly. While the new chiller must be sized for peak loads, you want to be sure that it operates efficiently at part-load conditions because that is where the chiller operates most of the time.

A new high-efficiency chiller's energy consumption could range from 0.15 to 0.30 kilowatts per ton less than the existing chiller's, depending on the efficiency of the existing chiller.

## Economic Benefits

The following example shows how to determine the economics of chiller retrofit and replacement.

A large office building (northeastern United States) has a 300-ton water-cooled centrifugal chiller and a peak cooling load of 300 tons. ENERGY STAR Buildings upgrades in Stages 1 through 4 have reduced peak load to 210 tons (part-load performances are shown in Table 5.1–1; the box on page 5–7 shows how to calculate the new cooling load) and the chiller can be resized accordingly.

Retrofits to switch the existing chiller from R–11 to HCFC–123 and to downsize the chiller to 210 tons by installing new gaskets, new orifice plates, new impellers, and a new compressor would cost approximately $25,000. Total annual energy savings from this investment would be approximately 15 percent, with an internal rate of return of 16.5 percent.

A new, energy-efficient 210-ton chiller that uses the new refrigerant would cost approximately $52,000. The difference in cost between the retrofits to switch to HCFC–123 (which must be done in 1996 regardless of the downsizing) and the cost of the new chiller is $27,000. Total annual cooling energy savings from this investment are 74,460 kilowatthours, or 25 percent. With energy costs of $0.08 per kilowatthour, the energy savings bring annual dollar savings of $8,775. The internal rate of return on the $27,000 investment is 31.5 percent.

Table 5.1–1. Energy Savings From Downsizing a 300-Ton Chiller to 210 Tons

| | | Annual Energy Consumption (kilowatthours) | | |
|---|---|---|---|---|
| Operating Load (tons) | Annual Operating Hours at Given Operating Load | Original 300-Ton Chiller | New 210-Ton Chiller | Annual Energy Savings From New Chiller (kilowatthours) |
| 210 | 85 | 13,430 | 10,200 | 3,230 |
| 189 | 170 | 23,800 | 18,020 | 5,780 |
| 168 | 255 | 32,130 | 24,480 | 7,650 |
| 147 | 340 | 39,440 | 29,920 | 9,520 |
| 126 | 340 | 36,040 | 26,860 | 9,180 |
| 105 | 425 | 39,525 | 29,750 | 9,775 |
| 84 | 510 | 41,310 | 31,110 | 10,200 |
| 63 | 680 | 45,560 | 35,360 | 10,200 |
| 42 | 595 | 31,535 | 22,610 | 8,925 |
| **Totals** | 3,400 | 302,770 | 228,310 | 74,460 |

## Project Management Considerations

This section contains some points to consider when planning to upgrade the HVAC plant in your building. A typical action plan for a chiller upgrade would include the following steps:

- Compare the advantages of retrofitting with those of replacement.
- Determine the type of chiller best suited for the building's cooling load requirements.
- Evaluate each refrigerant and chiller alternative for energy efficiency, profitability, and environmental acceptability.
- Develop an implementation schedule.

The following information may help you decide whether to retrofit or replace your chiller:

- ***Energy Efficiency.*** New chillers are 30 to 40 percent more efficient than chillers more than 10 years old and 10 to 20 percent more efficient than chillers 5 to 10 years old.
- ***Age.*** The average life of a chiller is 20 years.
- ***Location.*** It may be difficult or impossible to remove an existing chiller from its present location. If this is the case, the existing chiller and probably a new chiller would need to be broken down into components, which is expensive.
- ***Maintenance.*** An older retrofitted chiller may require much more mainte-

### Calculating Cooling Load

When doing load calculations, it is important to pay attention to the chiller configuration. Note that chillers in parallel require that all tonnages be added together for the full-load rating.

To determine your new cooling load, measure the following:

- Temperature of the chilled water supply (CHWS). A temperature gauge should be found on the pipe at the chiller's supply outlet.
- Temperature of the chilled water return (CHWR). A temperature gauge should be found on the pipe at the chiller's return inlet.
- Flow rate (GPM) in the chilled water supply. A flow rate gauge should be found on the supply pipe. An energy management system also may have this measurement.

These measurements must be taken in the afternoon on a typical hot summer day to capture the peak load effects on your system.

Use the measurements to calculate the following equations:

1. CHWS - CHWR = T
2. Load (in tons) = 500 × T × (GPM ÷ 12,000)
3. Load (in tons) × 1.1 = New Load

If you have no means of taking these measurements, you may want to contact a testing and balancing company who will have all of the equipment and training necessary to take the measurements.

If the new load for the chiller is 30 percent less than the installed capacity of your existing chiller, you should seriously consider replacing the chiller. The efficiency of the chiller decreases sharply below 70 percent loading. Remember, too, that the chiller is operating most of the time at part-load conditions with your newly reduced loads, which makes the existing system even more inefficient.

For example, a 300-ton chiller has a full-load performance rating of 0.6 kilowatts per ton. At 80 to 85 percent load, efficiency actually increases to 0.55 kilowatts per ton (this is where chillers are most efficient). At 70 percent load, efficiency decreases to 0.65 kilowatts per ton. At 60 percent load, efficiency decreases to 0.7 kilowatts per ton. At 50 percent load, efficiency decreases to 0.8 kilowatts per ton.

nance than a new chiller. Controls on new chillers require less maintenance.

- *Cost.* The initial capital cost of a new chiller must be weighed against its life-cycle costs and the energy savings to be gained.
- *Safety.* Whether you retrofit or replace, any conversion to an alternate refrigerant must meet ANSI/ASHRAE 15–1992 standards and local codes. Some changes to the ventilation system in the mechanical room may be necessary. Always follow the manufacturer's guidelines on proper handling and care of the alternative refrigerant.

You may want to discuss your building's requirements with a consulting mechanical engineer who can verify your cooling load calculations (see box opposite) and provide you with insight on the various alternatives. You may also want to have the engineer look at your cooling system's pumps to determine if variable-speed drives or flow-control valves can be installed. These devices can adjust pump flow to match cooling load requirements.

Because of the specialized type of work involved, a contractor or a manufacturer's representative generally must do the work for both chiller retrofit and chiller replacement. You may also need an electrician to modify branch circuit protection, overload heaters, and various protective relays required for the chiller. Be sure that all manufacturer's recommendations and instructions for installation and care of the chiller are followed.

*Some additional retrofit considerations:*

- The best time to retrofit is at the 10-year overhaul because the chiller is torn down at that time.
- If retrofitting, you may want to consider replacing the purge controls at the same time. Today's purge controls are 98 to 99 percent efficient.

- Determine if compressor performance will be affected when operating at partial loads with the new refrigerant.
- The physical location of the chiller plays an important role in determining whether or not a replacement will be possible. If removing the existing chiller and installing the new one requires great expense, the benefits of the new chiller may be offset. In some cases, it may be possible to keep the existing chiller's shell and replace the compressor and seals.
- Chillers with hermetic motors normally cost more to retrofit than those with open motors.
- The manufacturer will guarantee a minimum performance level for a new chiller for at least 10 years. However, a retrofit may have no guarantee.
- The cost to replace a chiller 10 to 20 years old is typically more than the cost of a retrofit; however, the energy savings make replacement much less expensive. Retrofitting a 300-ton hermetic chiller with new gaskets, orifice plates, and impellers as well as rewinding the motor costs approximately $25,000; a new chiller costs approximately $52,000. If the new chiller provides 25 percent energy savings, the $27,000 difference is a good investment.

*Some additional replacement considerations:*

- Absorption-type chillers use lithium-bromide instead of refrigerant and are driven by either steam, hot water, or gas. They typically cost $150 per ton more than centrifugal-type chillers. Absorption chillers are profitable where demand rates are high, where utilities offer rebates, and where gas or steam is available. Larger plants with several chillers may use a combination of absorption and centrifugal chillers when demand reduction is required. For example, the absorption chillers would be used during peak hours to avoid demand charges and the centrifugal chillers would be used during off-peak hours when using the absorption chillers would require more energy.
- Some manufacturers of rotary chillers guarantee that the chiller will maintain full-load performance under part-load conditions.

Chiller operation is also important. Because of the efficiencies of chillers at part-load conditions, you may save more energy by operating two chillers at 80 percent of their load rather than operating one chiller at 100 percent and one at 60 percent. On the other hand, one chiller operating at 100 percent is much more efficient than 2 chillers operating at 50 percent each.

### Environmental Considerations for Centrifugal Chillers

- ***Refrigerant Type.*** Be certain that the refrigerant does not contain CFCs. At this time, the acceptable replacement for R-11 is HCFC-123, and the acceptable replacement for R-12 is HFC-134A.
- ***Refrigerant Leak Test.*** The new chiller must be tested for refrigerant leaks upon installation and periodically thereafter, as recommended by the manufacturer.
- ***Pressure Relief Line and Discharge.*** The pressure relief line and discharge should be located in a safe area outside the building to prevent contamination caused by refrigerant infiltrating the building.
- ***Ventilation and Monitoring Requirement for New Refrigerant.*** New refrigerants require adequate ventilation and monitoring of air contamination levels as recommended by the manufacturer and required by the EPA.
- ***Evacuation and Dehydration.*** The chiller should be equipped with a vacuum pump for evacuation and dehydration to remove, restore, or recycle refrigerant.
- ***Isolation From Air-Handling Unit Intake.*** To protect indoor air quality, the chiller should be located away from the air-handling unit's intake as a precaution in case of refrigerant leakage.

## Preparing Specifications

If you are retrofitting an existing chiller, specifications for the components of the retrofit depend on the requirements established in the project management phase. Some of the accompanying specifications may apply as well.

If you are replacing the existing chiller, the chiller you select should be sized to meet the new cooling loads that result from previous ENERGY STAR Buildings Program upgrades. Be aware of the accompanying specifications that also may apply.

## General Specifications for Centrifugal Chillers

1. The chiller's refrigerant must not contain CFCs.
2. The chiller's size (tonnage) should be appropriate for the new cooling loads that result from previous Energy Star Buildings upgrades.
3. The chiller should be performance-tested at 100, 75, 50, and 25 percent of load in accordance with the latest ARI standard 550.
4. Specify the lowest full-load and part-load energy consumption available. Have three manufacturers provide their lowest available kilowatts per ton and compare these for the specification.
5. Request a part-load table in kilowatts per ton from 20 percent to 100 percent of load in 10-percent increments. Kilowatt values should be extended to three significant digits.
6. The maximum fouling factor in the evaporator and condenser should be no more than 0.00025.
7. Be sure that the chiller's condenser waterflow and temperature are compatible with your system's existing cooling tower.
8. Minimum load requirement ability should be as low as possible (that is, 10 percent or less).
9. The chiller's oil pump and oil heater should be separately powered to prevent damage to the compressor during startup and power outages.
10. The chiller's control panel should be compatible with NEMA 1 requirements for general applications or NEMA 12 requirements in very dusty applications. The function display should provide as much information as possible.
11. The chiller should be equipped with direct digital control (DDC) interface capabilities that enable it to be connected to an energy management system.
12. The chiller's loading rate (ramp function) should be between 2 minutes and 45 minutes.

## General Specifications for Centrifugal Chillers

13. The chiller should be equipped with safety shutoff features and alarms to protect against low oil pressure, low condenser water flow, and low chilled-water temperatures.
14. The chiller system should have a separately driven (both manual and automatic) purge compressor to transfer refrigerant.
15. The chiller's working pressure should be able to withstand system head.
16. The chiller's motor should have protective features to guard against electric faults, phase imbalance, and phase reversal.
17. The chiller should be equipped with a self-diagnostic control system that can identify the causes of safety shutdowns and retain them in memory until manually deleted.
18. The chiller should be equipped with a low-voltage soft start (Wye Delta type) starter.
19. If possible, the chiller should be equipped with a variable-speed drive, either as an integral part of the chiller or installed separately.
20. The manufacturer should provide training and startup assistance or the contractor should provide factory-authorized training and startup assistance.
21. The chiller should meet applicable NEMA, UL, NEC, ARI, ASME and ASHRAE requirements.
22. Multiple-chiller installations should be sequenced and interlocked properly to avoid simultaneous starts and stops.
23. The chiller's warranty should be adequate (minimum of 10 years).
24. The maximum water pressure drop across the chiller's evaporator and condenser, when each are added to the drop in the rest of the system, should not exceed the pump's head.

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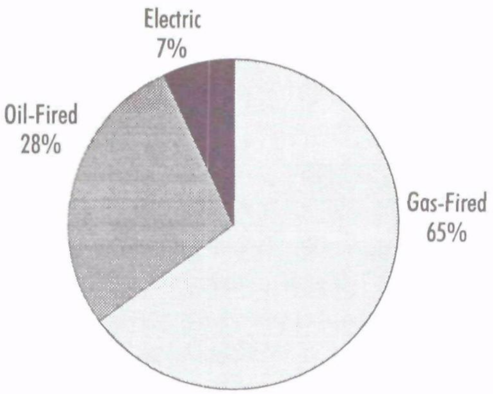
# Boiler Upgrades

SECTION 5.2

Approximately 20 percent of all commercial buildings use boilers for space heating. Of these, about 65 percent are gas-fired, about 28 percent are oil-fired, and about 7 percent are electric (Figure 5.2–1). The combustion efficiency of older boilers is generally between 65 and 75 percent, although inefficient boilers can have efficiencies between 40 and 60 percent. Boilers frequently operate at part-load conditions, and poorly operated boilers lose a significant level of efficiency.

Figure 5.2–1. Most Boilers Today Are Gas-Fired




## Best Opportunities

- Replace your existing boiler with a new, smaller, more energy-efficient model.
- Retrofit the boiler so that it can perform more efficiently.

## Boiler Replacement

The best opportunities for energy savings come with replacing an old or inefficient boiler with a more efficient system. Newer energy-efficient boilers have increased heating surface areas and improved controls for fuel and airflow over the range of load conditions. A staged system, which includes several small boilers operating in combination, can improve overall efficiency to 85 percent. Small boilers can be replaced with units with open-loop condensing systems. Here, combustion efficiency can be as high as 95 percent.

## Boiler Retrofit

Retrofitting existing boilers can dramatically improve peak and part-load efficiency. It can also extend the useful life of heating systems. Options include:

- **New Burners**—More efficient burners improve fuel combustion and reduce emissions of nitrogen oxide.
- **Baffle Inserts**—Baffle inserts induce combustion gases to flow in a turbulent spiral pattern, which increases the efficiency of heat transfer to the fire tubes.
- **Combustion Control**—Combustion controls, which include on-off and variable controls, respond to pressure and temperature readings to control the fuel flow and air-fuel combustion.
- **Warm-Weather Controls**—For hot-water boilers, circulation system temperatures can be reduced to account for warmer outdoor air temperatures or ambient indoor heat gains.

- **Economizers**—Economizers capture waste heat in the exhaust flue gases and use it to preheat the recovery feedwater before it enters the boiler.
- **Condensate Return**—Open-loop boiler systems drain the condensate from the heating unit and replenish the boiler with fresh water. This water is usually around 60 degrees F. and requires considerable energy to turn to steam. Condensate return converts this system to a closed loop, where hot condensate water (approximately 160 degrees F.) is returned to the boiler and recirculated.
- **Blowdown Heat Recovery**—For very large boilers, blowdown water can also be used to preheat recovery water. Blowdown water is the used boiler water, which is drained on a regular basis and then replaced with filtered feedwater. The amount of water typically drained is about one percent of the tank's capacity, so installing a heat-transfer device will only be profitable for large systems where significant heat can be extracted.

Improved operation and maintenance is an important part of the ENERGY STAR Buildings program (see Chapter 2) and can provide significant energy savings. An annual tune-up, improved water treatment, and a preventive maintenance program can reduce as much as 15 percent of boiler energy waste.

## Economic Benefits

Replacing inefficient or failed systems with modular boiler systems reduces fuel consumption over the heating season by 10 to 20 percent due to increased efficiency. New, energy-efficient burners increase combustion efficiency by 5 percent. Other retrofit options have the capability to increase combustion efficiency by as much as 15 percent (see Table 5.2–1)

On average, large commercial buildings (about 300,000 square feet) use about 4,800,000 Btu per hour of gas for heating. Therefore, a one percent increase in efficiency would save about 48,000 Btu per hour. For a system operating 2,000 hours per year, this corresponds to an annual savings of approximately $430 per year per one percent increase in efficiency. This number will vary based on loading, original efficiency, and line and system losses, but it provides a good baseline estimate.

Table 5.2–1
Potential Increase in Combustion Efficiency

| Retrofit Alternative | Efficiency Increase |
|---|---|
| Combustion Control | 5–10% |
| Economizers | 5–10% |
| Warm-Weather Controls | 5–10% |
| Condensate Return | 10–15% |

## Technical Considerations

There are limits to boiler heat-loss reductions. Because efficiency improvements cause more of the burner heat to go to the boiler water and less to the exhaust gases, increased efficiency lowers the exhaust temperature. The flue gases exhausting through the stack must be at a minimum temperature of 220 degrees F. for gas and 330 degrees F. for oil to prevent condensation. At temperatures below these minimums, the gas condenses into sulphuric acid on the inside of the stack. This is very corrosive to most stack materials. Condensing boilers do exist, generally for smaller applications due to their high material cost. These allow lower flue-gas temperatures and therefore condensation on specifically designed stainless-steel parts.

Draining a certain amount of the boiler water on a regular basis, known as blowdown, is necessary to keep the system clean. If open-loop systems are converted to closed-loop systems to take advantage of condensate heat, modifications must be considered to allow drainage and makeup.

## Project Management Considerations

Before considering potential upgrades, it is advantageous to perform an analysis of the existing system, both as a baseline for comparison and as an identifier of potential energy waste. There are two methods of boiler analysis[1]:

- The direct method, which measures fuel to steam efficiency.
- The indirect method, which measures combustion efficiency.

[1] Dyer and Maples, *Boilers Efficiency Improvement,* Boiler Efficiency Institute.

Overall boiler efficiency is defined differently in each of these methods:

- For the direct method, efficiency is defined as output power (mass flow of steam times enthalpy difference of steam leaving boiler and water entering boiler) divided by input power (mass flow of fuel times heat content of fuel plus pump and blower input power).
- For the indirect method, it is defined as the enthalpy difference of the products of combustion and reactants of combustion, divided by the heat content of the fuel.

More detail on these analyses will be provided in a future ENERGY STAR Buildings Technical Brief.

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# Packaged Air-Conditioning Unit Upgrades

SECTION 5.3

Combination cooling system, air-handling system, condensing system, and reheating system units are called packaged air conditioners. Packaged air-conditioning units are generally used in one-, two-, or three-story buildings that have small cooling loads (less than 75 tons). Retail spaces, small office buildings, and classrooms often use these units.

Packaged units are typically installed on rooftops so they do not use up building space. These units are less efficient than chiller systems (about 1.2 kilowatts per ton compared with 0.85 kilowatts per ton), but the decision to install the packaged unit may have been based on other considerations. For example:

- They are modular, so they can have their own simple control and duct systems
- They can be installed as part of a building renovation.
- They require little maintenance because they are self-contained.

Packaged units are designed to match a building's cooling and heating loads and to have low operational costs. They can be designed for single-zone or multi-zone air supply. The components of packaged units are described below.

### Cooling

- Vapor compression refrigerant cooling system.
- Fin-tube heat exchangers.
- Condensers.

### Heating

- Natural gas heating coils (or electric resistance heat coils if electricity is less expensive than natural gas).
- Heat pumps, which may be used to provide heating by transferring heat from the outside air to inside. Heat pumps are typically efficient in the heating mode if the building is located in a predominantly cooling climate.

## Best Opportunity

Most currently installed packaged units typically have energy-efficiency ratings—defined as cooling capacity (Btu per hour) divided by total unit power requirement (watts)—of less than 9. These systems could be improved by using higher efficiency compressors, larger condensers and evaporators, and variable-speed drives for the fans. Most systems use air to cool their condensers, but water could be used if a cooling tower is accessible. If these design changes were implemented, an energy-efficiency rating of 13 could be achieved.

## Economic Benefits

As shown in Table 5.3–1, for a typical 100,000 square foot office building that has 10 standard packaged units (energy-efficiency rating of 9, and 80 percent electric heating efficiency), electricity costs would be about $71,300 per year ($53,300 for cooling and $18,000 for heating, at $0.08 per kilowatthour). If a new energy-efficient unit had a cooling energy-efficiency rating of 13, the electricity costs for cooling mode would be about $36,900 per year, a savings of $16,400 per year. If the heating part of

Table 5.3–1. Annual Operating Costs of Ten 25-Ton Units

| Efficiency | Efficiency Rating | Heat Efficiency | Cooling Hours | Heating Hours | Energy Costs |
|---|---|---|---|---|---|
| Standard | 9 | 80% | 2,000 | 1,000 | $71,300 |
| Efficient | 13 | 80% | 2,000 | 1,000 | $54,900 |
| Efficient | 13 | 90% | 2,000 | 1,000 | $52,900 |

the system was 90 percent efficient compared with the standard 80 percent, heating system savings would be about $2,000 per year.

## Project Management Considerations

Certain issues must be addressed before determining if a retrofit will be profitable. Installation costs can be reduced considerably if the existing curb can be used with a replacement unit. This may not be possible with downsizing and must be considered in the cost analysis. In general, existing ductwork will not have to be modified for a new energy-efficient unit, and existing supply and return inlets and outlets should also be compatible with the new unit.

Additional Opportunities

# Additional Opportunities

CHAPTER 6

While the upgrades to your building's systems made over the five stages of the ENERGY STAR Buildings Program are generally the most effective upgrades that can be applied to typical buildings, there are several other areas where energy-efficiency improvements can be made. This chapter describes these additional opportunities and provides general guidelines on how to determine if they apply to your facility and the types of savings you can expect.

This chapter contains the following sections:

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# Transformers

SECTION 6.1

Every commercial and industrial building uses power and lighting transformers. These devices convert the voltage of electricity from the supply voltage to the voltage necessary to run building equipment and lighting. They are important because the voltage of an electric current supplied by the utility is generally too high to properly operate equipment.

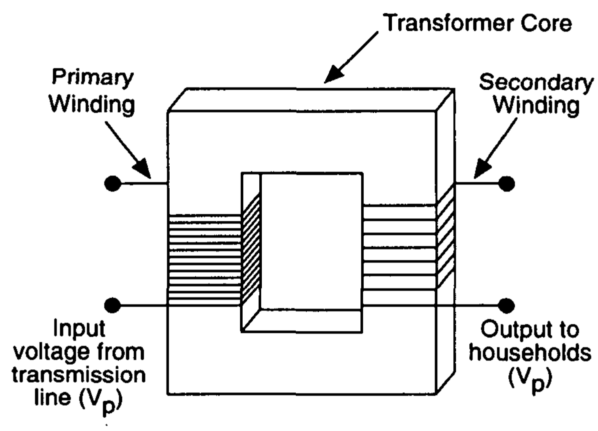
Commercial and industrial facilities have numerous transformers in service and thus numerous opportunities for energy savings. Most commercial buildings have at least one transformer on every floor to handle the electrical load for lighting and outlet functions such as computers, copiers, and fax machines. These buildings will also have one or more larger power transformers. Most industrial buildings have many transformers to serve motor and equipment loads.

Typical transformers have two basic components: the core and the coils. Electricity is converted by passing a current from one set of windings to another by means of a magnetized core (see Figure 6.1–1). The coils are usually made of copper or aluminum, while the cores, at least in commercial and industrial transformers, are most commonly made of steel.

Transformers are a constant source of energy loss, even when not in use, because energy must be consumed to energize the core, which must always be ready to serve any load that might appear on the system. This is referred to as "core loss." Core loss is constant any time a transformer is connected to the system.

A second type of loss is incurred when the transformer is in use. This is called "winding" or "load" loss and is caused by inefficiencies in transformer design and materials. Winding loss varies with the square of the load. Thus, if a transformer is operated at 50 percent of its rated load, the winding loss will be approximately one-quarter what it would be if the transformer were operating at 100 percent of its rated load.

**Figure 6.1–1. Transformers Regulate Electricity**




## Best Opportunities

The most efficient transformers currently available can reduce energy losses by as much as 70 percent. Opportunities to improve transformer efficiencies come in three main areas:

- First, core materials can be improved. For example, higher efficiency silicon steel or amorphous metal can be used for the core in place of the steel usually found in today's commercial and industrial transformers.

- Similarly, higher efficiency copper or aluminum windings can be used. Use of higher efficiency windings will help reduce load losses.
- Finally, energy losses can be reduced through the proper sizing of transformers. Because winding loss increases with the square of the load, an undersized transformer can cause excessive energy losses. Also, because the core experiences constant losses, using too big a transformer (with a higher core loss) for the necessary load can waste energy and money. In general, transformers experience peak efficiency when they are at an average of 30 to 60 percent of the rated load. Thus, the average load on a 75-kVa (kiloVolt-ampere) lighting transformer should be roughly in the neighborhood of 25 to 40 kilowatts to achieve maximum efficiency.

## Economic Benefits

There are two types of energy loss associated with transformers. Core loss (or no-load losses) is related to the power needed to continuously operate the transformer and does not change with variations in load. Winding loss is associated with the transfer of current through the transformer, and is directly proportional to the square of the percentage load. For energy-efficient transformers, both core loss and winding loss are significantly lower than in standard transformers.

To calculate the annual energy loss of a transformer, you need to know the core loss, the winding loss at 100 percent load, the average on-peak and off-peak load, and the winding temperature factor. The formula used is shown below.

It may also be possible to downsize a transformer due to initial oversizing or as a result of load reductions from other energy-efficiency measures. With downsizing, the new core and winding losses will be lower than those for the original units, and more savings will be realized.

## Project Management Considerations

There are several important factors to keep in mind when considering an investment in higher efficiency transformers. First, higher efficiency transformers cost more, so the costs and benefits must be carefully considered. EPA plans to introduce several simple cost-benefit calculation tools that will allow facility managers to make accurate cost

### Calculating Annual Energy Savings for a Transformer

On-peak losses = Core loss + Winding loss at 100% × (Percent on-peak load)$^2$ × Temperature factor

Off-peak losses = Core loss + Winding loss at 100% × (Percent off-peak load)$^2$ × Temperature factor

Annual losses = On-peak losses × On-peak hours + Off-peak losses × Off-peak hours

**Example**

A 75-kVa transformer has a 30-percent load factor on-peak and a 16-percent load off-peak.
Cost of electricity is $0.08 per kilowatthour.

Standard: 500-watt core loss, 2,660-watt winding loss at 100-percent load

Efficient: 130-watt core loss, 1,850-watt winding loss at 100-percent load

On-peak savings: $(500-130) + (2660 \times (0.30)^2 \times 0.8 - 1850 \times (0.30)^2 \times 0.8) = 428$ watts

Off-peak savings: $(500-130) + (2660 \times (0.16)^2 \times 0.8 - 1850 \times (0.16)^2 \times 0.8) = 387$ watts

[$0.08/kWh × (428 × 3120 on-peak hours + 387 × 5640 off-peak hours)] ÷ 1,000
= $280/year

comparisons. These tools will be available to ENERGY STAR Buildings and ENERGY STAR Transformer program participants.

In addition, you need to be sure that the higher efficiency transformer can fit within the space used for the existing transformer. Transformers are generally made more efficient by using a greater volume of higher efficiency material in the core, which increase the overall size of the transformer. Be sure that any item you purchase can comfortably fit in the space available.

Third, when changing the size (rating) of the transformers, you may need to change the circuit board for lighting and outlet load. You will need to factor this change into your cost calculations.

Finally, changing transformers can be a costly procedure. The best time to consider high efficiency transformers is when it is time to replace an obsolete transformer. However, opportunities may exist for replacing low-efficiency transformers with remaining useful life. Because costs are generally lower if several transformers are purchased at the same time, you should consider opportunities to replace other transformers at the same time you are replacing an obsolete transformer.

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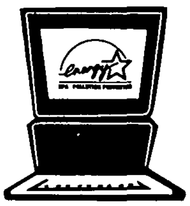
# ENERGY STAR Office Equipment

SECTION 6.2



Computers and office equipment are the fastest-growing electric loads in the business world. They account for 5 percent of commercial electricity consumption and—if action is not taken—could account for as much as 10 percent by the year 2000. Ironically, much of this energy is wasted. For example, research shows that:

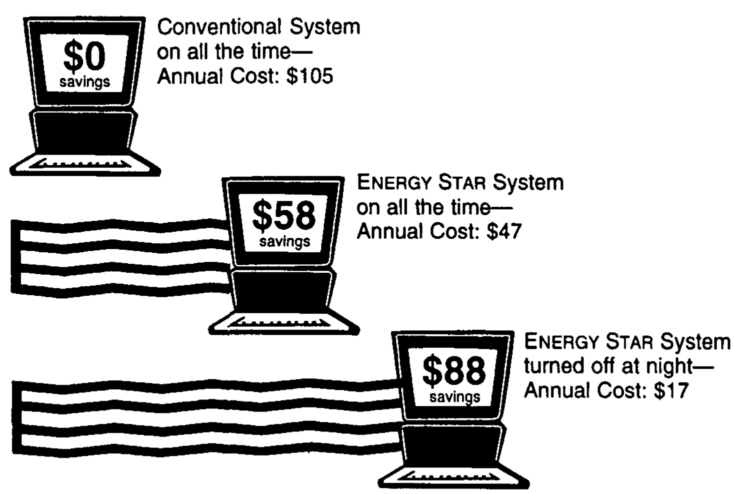
- ***Personal computers*** are not actually in use most of the time they are on, and 25 to 40 percent of them are left needlessly running at night and over weekends.
- ***Printers and fax machines*** are typically left on 24 hours a day, but are active only a small percentage of the time. In fact, fax machines are in use less than 5 percent of the time they are on.
- ***Copiers*** also are idle for several hours each day, and are often left on overnight and through the weekend.

To reduce this waste of energy and the pollution associated with it, leading manufacturers of computer equipment, printers, fax machines, and copiers have partnered with EPA to introduce ENERGY STAR machines that automatically "power down" when not in use. EPA has calculated that by the year 2000, these energy-efficient products could save enough electricity each year to power Vermont, New Hampshire, and Maine; cut electric bills by $2 billion; and reduce carbon dioxide pollution by the equivalent of 5 million automobiles (see Figure 6.2–1). ENERGY STAR products are easy to recognize because they are identified by the EPA ENERGY STAR logo (Figure 6.2–2). However, their added functionality is invisible, both in terms of performance and price.

## Application to ENERGY STAR Buildings

In addition to their direct energy consumption, office equipment gives off heat. In today's modern office building, a rough estimate is that regular office equipment contributes one-third the amount of heat as the lighting. However, because ENERGY STAR office equipment powers down when not in use, it gives off less heat. Less heat emitted means less load on the building's cooling system, thus increasing the opportunities for energy conservation and

Figure 6.2–1. ENERGY STAR Systems Save Money




*Compared with a typical computer and monitor left on all day and night, assuming 150W, 8¢/kWh. Does not include heat gain from computer equipment.

potential downsizing of HVAC equipment. For maximum economic benefit, ENERGY STAR office equipment, should be considered prior to the HVAC distribution system and HVAC plant upgrades in Stages 4 and 5 of the ENERGY STAR Buildings Program.

## Purchasing ENERGY STAR Equipment

The best part about ENERGY STAR office equipment is that it costs no more than regular equipment. Therefore, specifying ENERGY STAR products when purchasing new equipment or replacing old equipment is a highly profitable endeavor. Committing to an ENERGY STAR purchasing strategy is the first crucial step. The second step is determining which ENERGY STAR products to buy; since not all are the same, your choice will depend on your needs and preferences. EPA offers a number of informational fact sheets and brochures on ENERGY STAR products, and maintains a detailed list of qualified products that is updated monthly. For more information ask your EPA ENERGY STAR Buildings point of contact, or call the ENERGY STAR hotline at (202) 775-6650.

*Note: EPA seeks only to promote energy efficiency and pollution prevention and does not endorse any particular company or its products.*

**Figure 6.2–2. Look for the ENERGY STAR Logo**

energy

EPA POLLUTION PREVENTER

# Survey Forms and Instructions

APPENDIX A

This appendix contains the forms that you will be using to conduct the surveys described in the Introduction to this manual.

Survey forms that can be used during each stage of the ENERGY STAR Buildings Program are included, as listed below.

*Note: Stage 1 surveys related to your lighting systems are completed as part of your participation in the Green Lights Program. Refer to your Lighting Upgrade Manual for more information.*



Additional survey forms will be added as more sections are developed for this manual.

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# Survey Instructions

This appendix contains surveys for Stages 2 through 5 of the ENERGY STAR Buildings Program. This section provides a brief description of each of the surveys, recommends members for the survey team, and lists some materials that will be useful as you conduct the surveys.

## How To Conduct the Surveys

The survey forms are designed so that you can conduct each survey when you are ready to start a particular stage of the ENERGY STAR Buildings Program. As an alternative, you can conduct all of the surveys at one time. You may even want to conduct the surveys more than once, for example, as a way to see before-and-after results of your energy-efficiency improvements.

To help you collect complete and meaningful data, each survey includes information and examples at each step. Space to record your findings accompanies each question.

**Copy the survey forms before you begin the survey.**

You can use the copy if you need more room for additional responses, if you have additional facilities to survey, or if you want to conduct the survey a second time at the same facility.

## About The Surveys

This section contains a brief description of each survey.

### Stage 1—Green Lights

Surveys for Stage 1 are completed as part of your participation in the Green Lights Program and are described in your *Lighting Upgrade Manual.*

### Stage 2—Building Tune-Up

The Building Tune-Up Survey will familiarize you with the condition of your building's systems and enable you to determine which systems need to be tuned up in Stage 2 of the ENERGY STAR Buildings Program.

The Stage 2 survey has two main tasks: analysis and inspection. To complete it, you will need to analyze some existing information and then gather additional information by conducting general inspections in various areas of the building.

### Stage 3—Windows and Roofing

The Window and Roofing Survey will familiarize you with the condition of your building's exterior shell and enable you to determine if window and roof upgrades can be profitable for your building in Stage 3 of the ENERGY STAR Buildings Program.

To complete the survey, you will need to visually inspect your building's windows, roofing, and insulation. You will also need to analyze some existing information and perform a few simple calculations.

### Stage 4—Variable Air Volume Systems

The Variable Air Volume System Survey provides the data needed to use the QuikFan computer program to determine which variable air volume system upgrades can be profitable in your building in Stage 4 of the ENERGY STAR Buildings Program. It also provides other information about your air-handling units and their fans and motors that may be needed as you plan your upgrades.

To complete the survey, you will need to obtain some general information about your building, perform a few simple calculations, and visually inspect the air-handling units and record some nameplate information.

### *Stage 5—Chillers*

The Chiller Survey will familiarize you with the condition of your chiller and enable you to determine if you can replace the chiller with a smaller, more energy-efficient chiller in Stage 5 of the ENERGY STAR Buildings Program. Some of the information gathered during this survey will be used in calculating new cooling loads for your building.

To complete the survey, you will need to visually inspect the chiller and record some nameplate information, then perform some simple calculations.

## Survey Team Members

The ***Stage 2*** survey team should include the building engineer, an HVAC technician, and a controls technician.

The ***Stage 3*** survey team should include the building engineer.

The ***Stage 4*** survey team should include the building engineer, an HVAC technician, and an electrician.

The ***Stage 5*** survey team should include the building engineer, an HVAC technician, and an electrician.

## Items Needed for the Surveys

The following items should be ready to use as you conduct each survey.

### *Stage 2—Building Tune-Up*

- As-built drawings for all systems.
- Maintenance logs (including records of complaints).
- If you have an energy management system, the system logs showing conditions for a variety of operating schedules, sequences, and control conditions.
- Operations and maintenance manuals for major systems.
- Utility bills (gas and electric) from the last 24 months.
- Sequences of operations for major systems.
- Temperature and humidity probes.
- Green Lights surveys and implementation reports (if available).
- Calculator.

### *Stage 3—Windows and Roofing*

- Latest version of the architectural drawings for your building.
- Maintenance logs (including records of complaints).
- If you have an energy management system, the system logs showing conditions for a variety of operating schedules, sequences, and control conditions.
- Operations and maintenance manuals for major systems.
- Calculator.

### *Stage 4—Variable Air Volume Systems*

- Latest version of the architectural, mechanical, and electrical drawings for your building.
- If you have an energy management system, the system logs showing conditions for a variety of operating schedules, sequences, and control conditions.
- Electric bills from the last 12 months.
- Calculator.

### *Stage 5—Chillers*

- Latest version of the specifications for the chiller.
- Operations and maintenance manual for the chiller.
- If you have an energy management system, the system logs showing chilled water supply and chilled water return temperatures and flow rates.
- Calculator.

# Stage 2
## Building Tune-Up Survey

### I. Analyze Current Energy Consumption.

✔ Chart your energy consumption (in kilowatthours) for the last 24 months on the form on the following page. Do not chart demand.

✔ Chart your energy consumption in therms or other units, as reported on your gas or steam bill, for the last 24 months on a copy of the same form.

✔ Note any unusual patterns in consumption. These may help you determine systems that need to be tuned up.

*Examples:*
- *Energy consumption in the spring or fall is exceptionally high.*
- *Usage in a certain month is much higher than consumption for that month in the previous year.*

__________________________________________________________________

✔ Calculate your average annual cost of energy per square foot. Use the following formula:

Total Annual Cost of Energy ÷ Total Building Area

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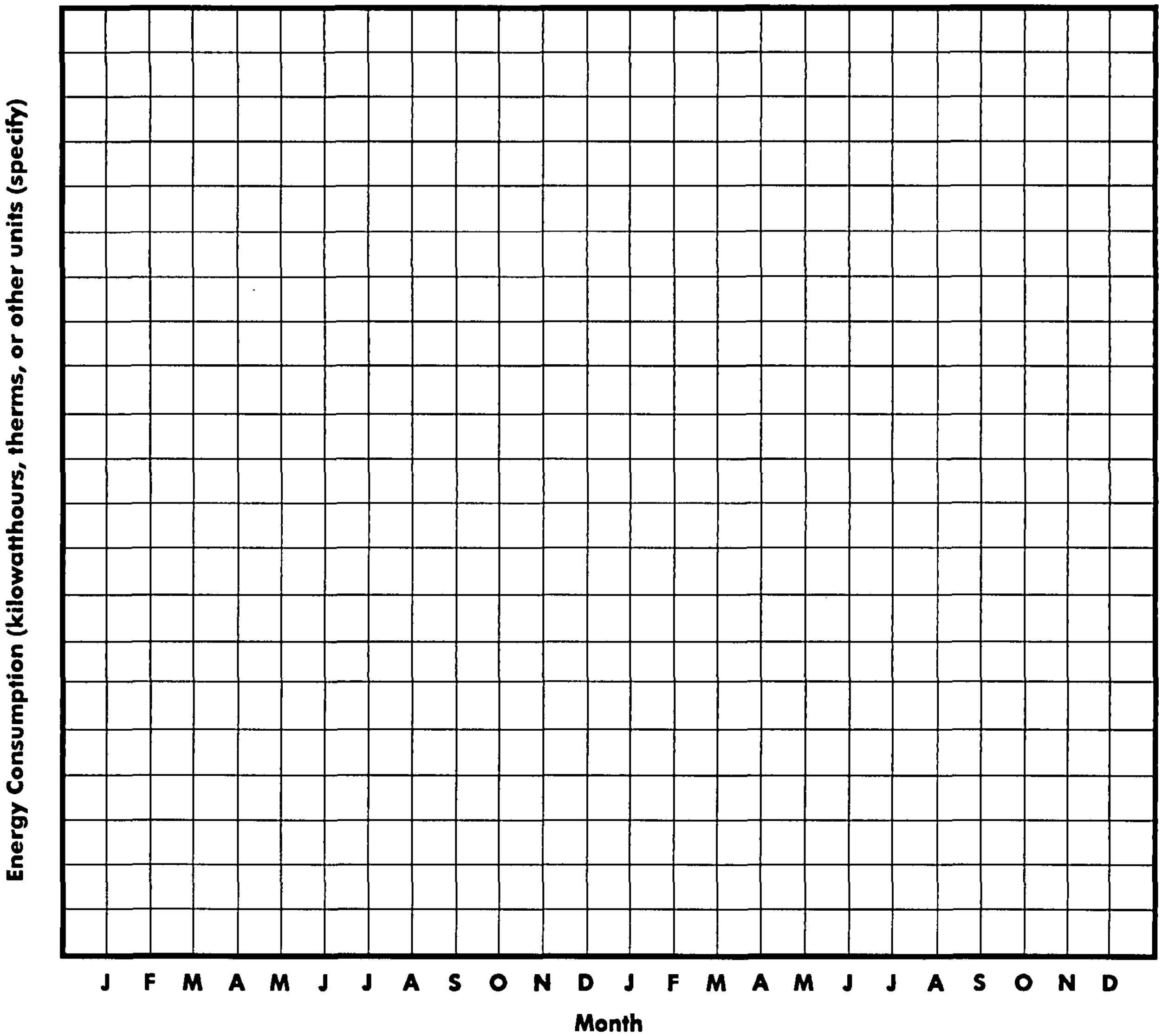
## 24-Month Energy Consumption Table




### Average Cost of Energy in Major U.S. Cities (dollars per square foot per year)

| City | Cost of Energy | City | Cost of Energy |
|---|---|---|---|
| Atlanta, Georgia | 1.54 | Los Angeles, California | 1.91 |
| Baltimore, Maryland | 2.21 | Memphis, Tennessee | 1.19 |
| Birmingham, Alabama | 1.69 | Miami, Florida | 1.93 |
| Boston, Massachusetts | 1.99 | Nashville, Tennessee | 1.59 |
| Charlotte, North Carolina | 1.40 | New Orleans, Louisiana | 1.35 |
| Chicago, Illinois | 1.49 | New York, New York | 2.93 |
| Cleveland, Ohio | 2.02 | Philadelphia, Pennsylvania | 2.42 |
| Denver, Colorado | 1.28 | Seattle, Washington | 0.91 |
| Houston, Texas | 1.49 | St. Louis, Missouri | 2.00 |

*Source:* Building Operating Management Experience Exchange Report, 1991.

✔ Contact your local utilities to determine if your average cost of energy falls within the average costs for your area and building type.

✔ Compare your annual cost of energy to the average costs for various cities in the table on the previous page. Is there a wide variation?

✔ If you have more than one building, compare the annual cost of energy for each building.

## 2. Analyze the Complaint Logs for Your Building.

✔ Record any areas where there have been consistent complaints about temperature or humidity.

| Location | Problem | Recommended Action |
|---|---|---|
| 4th Floor, SW side | Temperature too cold in P.M. | Check location of thermostat Relocate if necessary |
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## 3. Analyze the Energy Management System Logs.

✔ If you have an energy management system, look at the logs for the past heating or cooling season (or both) and note any areas that consistently do not maintain temperature or humidity settings during certain parts of the day.

| Location | Problem | Recommended Action |
|---|---|---|
| Zone 16 (4th floor, SW) | 10 a.m. temperature is 72°<br>3 p.m. temperature is 81° | Check location of thermostat<br>Check damper operation |
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## 4. Inspect temperature and humidity sensing devices, particularly in the areas listed in Items 2 and 3.

✔ Look for sensing devices located near supply diffusers, drafts, and outer walls or in direct sunlight (the best location is near the return air grille).

✔ Take temperature and humidity readings with temperature and humidity probes. Note the location of sensors whose readings do not match the probes.

| Location/Problem | Problem | Recommended Action |
|---|---|---|
| Room 471 cold in PM | Sensor in direct sunlight | Relocate sensor |
| Zone 21 temps. falling | Zone 21 damper stuck fully open | Repair damper |
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## 5. Inspect the Building's Exterior Systems.

✔ Walk through the building to inspect the condition of windows, outer doors, and other openings. Record the location of the following:

- Leaks.
- Drafts *(Note: complaint logs may also help locate drafts).*
- Missing or worn weatherstripping, sealant, or caulking.

| Location | Problem | Recommended Action |
|---|---|---|
| North entrance lobby | Room is drafty – weatherstripping around doors is worn out | Replace weatherstripping |
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## 6a. Inspect the Mechanical Equipment Rooms (Air Side).

✔ Conduct an inspection of the mechanical equipment rooms in your building and note the location of any problems. For air-side systems, look for the following types of problems:

- *Ducts:* Leaks in ducts or missing insulation in mechanical equipment rooms.
- *Dampers:* Leaks, worn seals, or other problems (such as dampers stuck open).
- *Controls:* Not calibrated. Not operating according to sequence of operation.
- *Fans:* Excessive vibration or noise. Worn or loose belts. Leaking lubricant.
- *Air Filters:* Filters need to be cleaned or replaced.

| Equipment/Location | Problem | Recommended Action |
|---|---|---|
| ME Room 4N<br>AHU 12N | Air duct is leaking | Repair or replace air duct |
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## 6b. Inspect the Mechanical Equipment Rooms (Water Side).

✔ Conduct an inspection of the mechanical equipment rooms in your building and note the location of any problems. For water-side systems, look for the following types of problems:

- Leaks in pipes, steam traps, pumping glands, valves, boilers, and elsewhere.
- *Pipes, Tanks:* Lack of adequate insulation. Condensation.
- *Pumps:* Dirty strainers.
- *Air Separator:* Allowing air into the system.
- *Controls:* Not operating according to sequence of operation.
- *Cooling Towers:* Excessive rust. Leaks. Dirty cells. Improper fan operation. Faulty freeze protection.

| Equipment/Location | Problem | Recommended Action |
|---|---|---|
| Cooling plant<br>CHW pump 3 | Leak in pumping gland | Repair or replace pumping gland |
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## 7a. Analyze Operating Schedules (Lights).

✔ Walk through the building during occupied and unoccupied hours. Record unoccupied areas where lights are on.
*Note: Stage 1 surveys conducted for the Green Lights Program may already have covered this item.*

| Room(s)/Location | Schedule/Occupancy | Recommended Action |
|---|---|---|
| Second floor – meeting rooms in Conf. Center | Lights on late in evening – no conference activities scheduled | Install timers or sensors in all meeting rooms |
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# 7b. Analyze Operating Schedules (Office Equipment).

✔ Walk through the building during occupied and unoccupied hours (combine these circuits with the lighting survey circuits if desired). Record office equipment in unoccupied areas that has been left on.

| Room(s)/Location | Equipment/Schedule | Recommended Action |
|---|---|---|
| Third floor – Billing and Accounting Dept. | Computers and printers on after working hours. Copier is on, too. | Talk to manager about schedule. ENERGY STAR equipment for next buy |
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# 7c. Analyze Operating Schedules (HVAC Equipment).

✔ Record the operating schedules for air-handling units and other equipment and compare them to the schedules specified in their sequences of operations.

| Location | Equipment/Schedule | Problem/Action |
|---|---|---|
| Sixth floor<br>M.E. Room 6E | Unit appears to be on 24 hrs.<br>Operations sequence says 12 hrs. | Faulty relay does not turn fan off.<br>Repair faulty relay. |
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# 8. Inspect Temperature and Humidity Controls.

✔ Conduct a spot inspection of the accuracy of temperature and humidity controls. Check at least one interior and exterior area on each floor as well as all heat- and humidity-sensitive areas such as computer rooms.

| Location | Temp./Humidity Readings | Recommended Action |
|---|---|---|
| 5th floor<br>Zone 5–4 | Sensor – 74°<br>Probe – 79° | Replace faulty thermostat. |
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# Stage 3
# Window and Roofing Survey

## 1. Analyze the Maintenance and Complaint Logs for Your Building.

✔ List areas where complaints about leaks or drafts, excessive heat or glare from windows, or other complaints related to the windows or roof have been recorded.

| Location | Problem | Recommended Action |
|---|---|---|
| Room 2E-11 | Window leaks | Repair window seals |
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## 2. Analyze the Energy Management System Logs.

✔ If you have an energy management system, look at the logs for the last heating or cooling season (or both) and note any areas on the top floor or on the outside perimeter of any floor that consistently do not maintain temperature or humidity settings during certain parts of the day.

| Location | Problem | Recommended Action |
|---|---|---|
| 10th floor | Temp. 8° warmer than floors 1–9 | Inspect insulation and roof covering |
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# 3. Conduct a General Inspection of the Windows and Roof.

✔ Note the location of any areas with leakage or damage. Pay particular attention to the areas noted in items 1 and 2 above.

| Location | Problem | Recommended Action |
|---|---|---|
| NW corner of roof | Standing water leaks to insulation | Repair leak and replace insulation |
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✔ Describe the general condition of the roof.

✔ What color is the roof covering and what is its general condition?

✔ Note the location of any areas where the roof insulation is wet.

✔ Record the number, size, and location of each type of window on the building (for example, fixed-sash, double-hung, casement).

| Type of Window | Location | Size | Number |
|---|---|---|---|
| Fixed sash | 1st floor | 72 x 72 | 70 |
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✔ Record the number, size, and location of windows with each type of glazing (for example, single, double, triple).

| Type of Glazing | Location | Size | Number |
|---|---|---|---|
| Single | 2nd floor | 36 x 72 | 135 |
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✔ Note the number, size, and location of windows that have window coatings (for example, clear, tinted or colored, reflective).

| Type of Coating | Location | Size | Number |
|---|---|---|---|
| Reflective | 8th floor – computer center | 36 x 72 | 20 |
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✔ Note the number, size, and location of windows with each type of interior shading (for example, shades, horizontal blinds, vertical blinds, curtains).

| Type of Shading | Location | Size | Number |
|---|---|---|---|
| Insulated curtains | 1st floor | 72 x 72 | 70 |
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## 4. Record the Following Additional Information About Your Building's Roof.

✔ Type of roof construction (for example, built-up, asphalt roll, modified bitumen, shingle, metal).

✔ Type of decking (for example, steel, precast concrete).

✔ Type of insulation (for example, mineral fiber, polystyrene, polyisocyanurate, foam, fiberboard).

✔ R-Value of insulation (between 0 and 44).

## 5. Record the Following Information About Your Building.

✔ Number of floors.

✔ Number of heating days.

✔ Number of cooling days.

✔ Roof-to-building-envelope ratio. Use the following formula:

Total roof area (square feet) ÷ Total gross area of building exterior (square feet)

*Example:*

Building is 120 feet long, 100 feet wide, 45 feet high.

Roof area is 12,000 square feet (120 × 100).

Total gross area is 31,800 square feet:

(120 × 100) + [(100 × 45) × 2] + [(120 × 45) × 2]

Roof-to-building-envelope ratio (12,000 ÷ 31,800) is 38 percent.

✔ Glass-to-exterior-wall ratio on each side of the building. Use the following formula:

First calculate the total area of the wall:

Width × Height

Next calculate the total area of windows on the wall:

Number of Windows × (Width of Window × Height of Window)

Finally, divide the window area by the wall area:

Total Window Area ÷ Total Wall Area

*Example:*
A single-story building has a north wall 100 feet long and 10 feet high.
The wall has four windows, each 5 feet long and 6 feet high.
Total wall area is 1,000 square feet:

100 feet × 10 feet

Total window area is 120 square feet:

4 × (5 feet × 6 feet)

Percent of glass to exterior wall is 12 percent:

120 square feet ÷ 1,000 square feet

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# Stage 4
## Variable Air Volume System Survey

**1. Record the following information about the building's air-handling unit(s).**

✔ Unit identification number(s) or serial number(s).

______________________________

✔ Net conditioned area served by each unit (in square feet).

______________________________

✔ Operating hours (weekday, Saturday, and Sunday/holiday). Note number of holidays.

Weekday ______________________________

Saturday ______________________________

Sunday/Holiday ______________________________

Number of Holidays per year ______________________________

✔ Supply Fan Motor(s):

Horsepower ______________________________

Age ______________________________

Efficiency (in percent). This is the nominal NEMA efficiency from the motor's nameplate, or calculate:

(Output Power ÷ Input Power) × 100

✔ Type of supply fan (for example, forward curved, backward curved, backward inclined, airfoil, radial).

__________________________________________

✔ Supply fan's variable air volume control (for example, inlet vane, discharge damper, variable pitch, variable-speed drive).

__________________________________________

✔ Air-handling unit's design (installed) airflow (in cubic feet per minute). This can be obtained from the air-handling unit schedule in the building's mechanical drawings.

__________________________________________

✔ Air-handling unit's maximum airflow (percent).
Measure airflow at maximum load conditions (for example, a hot summer day). Divide the result by the design airflow, then multiply the result by 100.

(Airflow at maximum load ÷ Design airflow) × 100

| |
|---|
| |

✔ Air-handling unit's minimum outside airflow (percent).
This can be obtained from the air-handling unit schedule in the building's mechanical drawings.

__________________________________________

If the minimum outside airflow is given in cubic feet per minute (cfm) rather than a percentage, divide the minimum airflow cfm by the design the airflow cfm and multiply the result by 100.

| |
|---|
| |

✔ Ratio of required airflow to design airflow. This is a measure of whether the unit is oversized or undersized. To determine the ratio:
Measure airflow (cfm) at maximum load conditions (for example, a hot summer day). Subtract the maximum airflow (cfm) from the design airflow (cfm). Divide the result by the design airflow, then multiply the result by 100.

[(Design airflow – Maximum airflow) ÷Design airflow] × 100

*Example 1 (Undersized System):*
Airflow at maximum load conditions is measured at 12,000 cubic feet per minute.
Design airflow is 10,000 cubic feet per minute.
The difference is 2,000 (12,000 – 10,000).
The percent of design CFM is [(2,000 ÷ 10,000) × 100].
The unit is undersized by 20 percent.

Note that in this case the motor may be operating above 100 percent of its rating or static pressure might not be being maintained.

*Example 2 (Oversized System):*
Airflow at maximum load conditions is measured at 8,000 cubic feet per minute.
Design airflow is 10,000 cubic feet per minute.
The difference is –2,000 (8,000 – 10,000).
The percent of design CFM is [(–2,000 ÷ 10,000) × 100].
The unit is oversized by 20 percent.

✔ Return Fan Motor:

Horsepower ______________________________

Age ______________________________

Efficiency (in percent). This is the nominal NEMA efficiency from the motor's nameplate, or calculate:

(Output Power ÷ Input Power) × 100

| |
|---|
| |

✔ Type of return fan (for example, forward curved, backward curved, backward inclined, airfoil, radial, vane axial, tube axial).

______________________________

✔ Return fan's variable air volume control (for example, inlet vane, discharge damper, variable pitch, variable-speed drive).

______________________________

## 2. Calculate the required cooling load for the building.

### A. Chiller load method:

✔ What is the installed capacity of the chiller (in tons)?

______________________________

✔ What is the required cooling load for the chiller (in tons)?
To determine the required cooling load, take the following measurements in the afternoon on a typical hot summer day (to capture peak load effects on your system).
*Note: an energy management system may also have these measurements.*

a. Temperature of the chilled-water supply (CHWS). A temperature gauge should be found on the pipe at the chiller's supply outlet.

b. Temperature of the chilled-water return (CHWR). A temperature gauge should be found on the pipe at the chiller's return inlet.

c. Flow rate of the chilled-water supply in GPM (gallons per minute). A flow rate gauge should be found on the supply pipe.

Now do the following calculations:

$\text{CHWR} - \text{CHWS} = \Delta T$

$\Delta T \times 500 \times (\text{GPM} \div 12{,}000) = \text{Load (in tons)}$

$\text{Load} \times 1.1 = \text{Required Cooling Load}$

*Example:*
A building has a chiller with an installed capacity of 170 tons.
Measured CHWR temperature is 55° F.
Measured CHWS temperature is 45° F.
Measured flow rate is 300 GPM.

T = 10 (55 – 45).

Load = 125 tons [10 × 500 × (300 ÷ 12,000)].

Required cooling load = 138 tons (125 × 1.1).

✔ What is the percentage of chiller utilization?
To determine the percentage:
Divide the required cooling load (in tons) by the installed chiller capacity (in tons), multiply the result by 100.

(Required cooling load ÷ Installed chiller capacity ) × 100

*Example:*

Installed chiller capacity is 170 tons; required cooling load is 138 tons, as determined in the example above.

Ratio of required capacity to installed capacity is 0.81 (138 ÷ 170).

Percentage of chiller utilization is 81 percent (0.81 × 100).

✔ What percentage of the chiller's load does this air handling unit represent?
To determine the percentage:
From the air-handling unit schedule in the building's mechanical drawings, record the cooling coil's flow rating in GPM (gallons per minute).
Divide this number by the flow rate (also in GPM) of the chilled-water supply (see above), then multiply the result by 100.

*Example:*

Cooling coil's flow rating is 60 GPM.

Flow rate of the chilled water supply is 300 GPM.

Ratio of the flow rating to flow rate is 0.20 (60 ÷ 300).

Percentage of the chiller's load is 20 percent (0.20 × 100).

b. Temperature of the chilled-water return (CHWR). A temperature gauge should be found on the pipe at the chiller's return inlet.

c. Flow rate of the chilled-water supply in GPM (gallons per minute). A flow rate gauge should be found on the supply pipe.

Now do the following calculations:

$$\text{CHWR} - \text{CHWS} = \Delta T$$

$$\Delta T \times 500 \times (\text{GPM} \div 12{,}000) = \text{Load (in tons)}$$

$$\text{Load} \times 1.1 = \text{Required Cooling Load}$$

*Example:*
A building has a chiller with an installed capacity of 170 tons.
Measured CHWR temperature is 55° F.
Measured CHWS temperature is 45° F.
Measured flow rate is 300 GPM.

T = 10 (55 – 45).

Load = 125 tons [10 × 500 × (300 ÷ 12,000)].

Required cooling load = 138 tons (125 × 1.1).

✔ What is the percentage of chiller utilization?
To determine the percentage:
Divide the required cooling load (in tons) by the installed chiller capacity (in tons), multiply the result by 100.

(Required cooling load ÷ Installed chiller capacity ) × 100

*Example:*

Installed chiller capacity is 170 tons; required cooling load is 138 tons, as determined in the example above.

Ratio of required capacity to installed capacity is 0.81 (138 ÷ 170).

Percentage of chiller utilization is 81 percent (0.81 × 100).

✔ What percentage of the chiller's load does this air handling unit represent?
To determine the percentage:
From the air-handling unit schedule in the building's mechanical drawings, record the cooling coil's flow rating in GPM (gallons per minute).
Divide this number by the flow rate (also in GPM) of the chilled-water supply (see above), then multiply the result by 100.

*Example:*

Cooling coil's flow rating is 60 GPM.

Flow rate of the chilled water supply is 300 GPM.

Ratio of the flow rating to flow rate is 0.20 (60 ÷ 300).

Percentage of the chiller's load is 20 percent (0.20 × 100).

## B. Supply-Air Method

✔ From the air-handling unit schedule in the building's mechanical drawings, record the design supply-air dry-bulb temperature. Then record the return-air dry-bulb temperature, and the return-air wet-bulb temperature.

Supply-air dry-bulb temperature ______________________

Return-air dry bulb temperature ______________________

Return-air wet bulb temperature ______________________

# 3. Record Load Reductions

## A. Lighting

✔ Using Green Lights survey data, record lighting power requirements (in watts per square foot) both before and after implementation of Green Lights upgrades.

Before ______________________

After ______________________

✔ If Green Lights survey data are not available, you should be able to estimate lighting power requirements before and after Green Lights implementation by using the Quikalc Fixture Table in your *Lighting Upgrade Manual*:

1. Identify the building's most common fixture, lamp, and ballast combination.

   ______________________

2. Use the Fixture Table to find the fixture system wattage for that combination.

   ______________________

3. Multiply: Fixture System Wattage × Number of Fixtures in a Typical Space.

4. Divide the result by the Area of the Office (square feet).

5. The result is the lighting power requirement in watts/square foot.

---

✔ A third alternative is to use the following formula to estimate lighting power requirements before and after Green Lights implementation. This formula does not take lighting ballast into account, but will provide a reasonable approximation of the lighting power requirements.

1. Record the number of lighting fixtures in the room. ____________________
2. Record the number of lamps per fixture. ____________________
3. Record the wattage of one of the lamps. ____________________
4. Multiply:

   Number of Fixtures × Lamps per Fixture × Watts per Lamp

5. Divide the result by the Area of the Office (square feet)

6. The result is the lighting power requirement in watts/square foot.

## B. Other Load Reductions

✔ To determine other load reductions, subtract the required cooling load (in tons) from the installed capacity of the chiller.
See item 2 above for these two numbers.

## 4. Determine the Cost of Electricity for the Building

✔ Calculate the average yearly cost of electricity for your building in dollars per square foot. To determine the cost of electricity per square foot:
From your electric bills for the last 12 months, calculate the total cost of electricity (kilowatthours plus demand) for the year.
Divide that total by total kilowatthours used.
Divide the result by the total square footage of the building.

[(Kilowatthours + Demand) ÷ Total kilowatthours used] ÷ Building square footage

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# Stage 5
## Chiller Survey

## I. Compile the Following Basic Information About Your Chiller

✔ Type of chiller.

Compression refrigeration:

Air-cooled centrifugal ____________________

Water-cooled centrifugal ____________________

Reciprocating ____________________

Helical Rotary ____________________

Absorption refrigeration:

Steam heat ____________________

Hot-water heat ____________________

Direct-fired heat ____________________

✔ Manufacturer.

____________________

✔ Type of refrigerant.

____________________

✔ Age.

____________________

✔ Efficiency (kilowatts per ton).

____________________

____________________

✔ Size (in tons) (12,000 Btu per hour = 1 ton).

______________________________________

______________________________________

## 2. Calculate the Required Cooling Load for Your Building

✔ What is the capacity of the chiller (in tons)?

______________________________________

✔ What is the required cooling load for the building (in tons)? To determine required cooling load, take the following measurements in the afternoon on a typical hot summer day (to capture peak load effects on your system). *Note: an energy management system may also have these measurements.*

Temperature of the chilled-water supply (CHWS). A temperature gauge should be found on the pipe at the chiller's supply outlet.

Temperature of the chilled-water return (CHWR). A temperature gauge should be found on the pipe at the chiller's return inlet.

Flow rate (GPM) of the chilled-water supply. A flow-rate gauge should be found on the supply pipe.

Temperature of CHWS ______________________

Temperature of CHWR ______________________

Flow rate (GPM) of CHWS ______________________

✔ Now do the following calculations:

CHWR – CHWS = ΔT

ΔT × 500 × (GPM ÷ 12,000) = Load (in tons)

Load × 1.1 = Required Cooling Load

✔ What is the ratio of required chiller capacity to installed chiller capacity (in tons)?

*Example:*
A building has a chiller with an installed capacity of 170 tons.
Measured CHWR temperature is 55° F.
Measured CHWS temperature is 45° F.
Measured flow rate is 300 GPM.

T = 10 (55 – 45).

Load = 125 tons [10 × 500 × (300 ÷ 12,000)].

Required cooling load = 138 tons (125 × 1.1).

Ratio of required capacity to installed capacity is 0.81 (138 ÷ 170).

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# Indoor Air Quality

APPENDIX B

As you implement upgrades to your building's systems over the course of the ENERGY STAR Buildings Program, you must ensure that the building's environmental quality is maintained. This appendix explains the effects of energy conservation measures on environmental quality and provides general guidelines on how to maintain building environmental quality.

In recent years, the sources and quantities of pollutants within buildings have proliferated, increasing the likelihood of indoor air quality problems. At the same time, increasingly sophisticated HVAC system designs have raised occupant expectations for comfort and air quality. Because most people spend at least a third of their day at the workplace, and the quality of the air they breathe at work affects their comfort, their health, and even their job performance, building occupants are less tolerant of fluctuating temperatures, unpleasant odors, and other departures from ideal conditions. Therefore, you must be aware of issues related to indoor air quality and take steps to ensure that indoor air quality is not degraded as you implement the various upgrades of the ENERGY STAR Buildings Program.

The costs of poor indoor air quality to building tenants include increased absenteeism, lower productivity, compensation claims linked to adverse health effects, strained relations with employees, and damage to public image or reputation. Individuals suffer from illness, lost work time, discomfort, dissatisfaction, and irritation. Potential costs to the building owners, designers, and product manufacturers include strained relations with tenants or customers, lost occupancy, damage to sales and reputation, and liability expenses. Soiling of surfaces and furnishings and damage to equipment and office machines incur both aesthetic and economic costs. Many insurance policies do not cover pollution-related personal or property damage.

Indoor air quality is the result of a combination of variables and processes controlled or determined by the building designer, the building owner, and the building occupants. Factors external to the building itself also play a role. Numerous daily occurrences such as ventilation system schedules, occupant activities, and variations in outdoor air quality are involved.

You can tell if there is poor indoor air quality in your building by looking for the following general indicators:

- Increasing number of health problems such as coughing, eye irritation, headache, and allergic reactions (in extreme cases, life-threatening conditions such as Legionnaire's disease and carbon monoxide poisoning may be possible).
- Decreasing productivity due to discomfort or increased absenteeism.
- Accelerating deterioration of furnishings and equipment.

## Factors Affecting Indoor Air Quality

Four elements contribute to the development of indoor air quality problems:

- ***Source.*** There is a source of contamination or discomfort indoors, outdoors, or within the mechanical systems of the building. In some cases, the building's occupants and their activities can contribute to indoor air quality problems.

- ***HVAC System.*** The HVAC system is not able to control existing air contaminants and ensure temperature and humidity conditions that are comfortable for most occupants.
- ***Pathways.*** One or more pathways connect the source of the pollutant to the occupants, and a driving force exists to move pollutants along these pathways.
- ***Occupants.*** Building occupants are affected by the contaminants.

It is important to understand the role that each of these factors plays as you investigate and resolve existing indoor air quality problems and work to prevent future problems.

## Source

Indoor air contaminants can originate within the building or be drawn in from outdoors. If contaminant sources are not controlled, indoor air quality problems can arise, even if the HVAC system is properly designed and well-maintained. Contaminants generally fit into the following broad categories. *Note: The examples given are not intended to be a complete list.*

- Sources Outside Building
  - —Contaminated outside air (pollen, dust, fungal spores, industrial pollutants, general vehicle exhaust).
  - —Emissions from nearby sources (emissions from vehicles on nearby roads or in parking lots or garages, from dumpsters, or from loading docks; exhaust air drawn back into the building from the building itself or from nearby buildings; unsanitary debris near the outdoor air intake).
  - —Soil gas (radon, leakage from underground fuel tanks, contamination from previous uses of the site, pesticides).
  - —Moisture or standing water producing excess microbial growth on rooftops or in crawlspace.
- Equipment Sources (Non-HVAC)
  - —Emissions from office equipment (volatile organic compounds, ozone).
  - —Supplies (solvents, toners, ammonia).
  - —Emissions from shops, laboratories, and cleaning processes.
  - —Elevator motors and other mechanical systems.
- Human Activities
  - —Personal activities (smoking, cooking, body odor, cosmetics).
  - —Housekeeping activities (cleaning materials and procedures, emissions from stored supplies or trash, use of deodorizers and fragrances, airborne dust and dirt circulated by sweeping and vacuuming).
  - —Maintenance activities (microorganisms in mist from improperly maintained cooling towers; airborne dust or dirt; volatile organic compounds from use of paint, caulk, adhesives, and other products; pesticides from pest-control activities; emissions from stored supplies).
- Building Components and Furnishings
  - —Locations that produce or collect dust or fibers (textured surfaces such as carpeting, curtains, and other textiles; open shelving; old or deteriorated furnishings; materials containing damaged asbestos).
  - —Unsanitary conditions and water damage (microbiological growth on or in soiled or water-damaged furnishings or carpet; microbiological growth in areas of surface condensation; standing water from clogged or poorly designed drains; dry traps that allow passage of sewer gas).
  - —Chemicals released from building components or furnishings (volatile

organic compounds or inorganic compounds).

- Other Sources

  —Accidents (spills of water or other liquids; microbiological growth due to flooding or leaks from roofs or pipes; soot, PCBs, and odors from fires).

  —Special-use areas and mixed-use buildings (smoking lounges, laboratories, print shops, art rooms, exercise rooms, beauty salons, food preparation areas).

  —Redecorating, remodeling, and repairs (emissions from new furnishings; dust and fibers from demolition; odors and volatile organic and inorganic compounds from paint, caulk, and adhesives; microbiologicals released from demolition or remodeling activities).

### HVAC Systems

A properly designed and functioning HVAC system performs the following functions:

- Provides thermal comfort.

  —Uniformity of temperature is important to comfort. Temperature stratification is a common problem.

  —Radiant heat transfer can cause discomfort even though the thermostat setting and the measured air temperature are within the comfort range. Large window areas sometimes have acute problems with radiant heat gain and loss during the day as the sun angle changes. Airflow over large vertical surfaces can cause problems with drafts.

  —Excessively high or low humidity affects comfort. High humidity reduces the ability to lose heat through perspiration and evaporation, so the effect is similar to raising the temperature. High humidity also promotes the growth of mold and mildew.

  —The activity level, age, and physiology of each person affect the thermal comfort requirements of that individual.

- Distributes enough outdoor air to meet the ventilation needs of all building occupants.

  —The correct blend of outdoor air and recirculated indoor air is necessary to meet both thermal comfort and ventilation requirements.

  —Proper design, installation, testing, and balancing and regular inspection and maintenance are critical to the correct operation of all types of HVAC systems, especially variable air volume systems.

  —Variable air volume system designs should ensure that a minimum supply of outdoor air is provided to all zones and rooms at all times when the building is occupied.

- Isolates and removes pollutants through pressure controls, filtration, and exhaust fans.

  —One technique for controlling odors and contaminants is to dilute them with outside air. Dilution can work only if there is a consistent and appropriate flow of supply air that mixes effectively with room air.

  —Another technique is to design and operate the HVAC system so that pressure relationships between zones and rooms are controlled. This is accomplished by adjusting the air quantities that are supplied to and removed from each room. Control of pressure relationships is critically important in mixed-use buildings or buildings with special-use areas.

  —A third technique is to use local, or dedicated, exhaust systems to ventilate a particular piece of equipment or an entire room. Air should be exhausted to the outdoors, not recirculated. Spaces with local exhaust must be provided with make-up air, and the local exhaust must function in coordination with the rest of the ventilation system.

—Air cleaning and filtration devices designed to control contaminants are found as components to HVAC systems and can also be installed as independent units. The effectiveness of air cleaning depends on proper equipment selection, installation, operation, and maintenance.

Indoor air contamination caused by the HVAC system can originate from the following sources:

- Insufficient outside air intake.
- Microbiological growth in drip pans, humidifiers, ductwork, and coils.
- Dust or dirt in ductwork or other components.
- Cooling tower located near outside air intake.
- Improper use of biocides, sealants, and cleaning compounds.
- Improper venting of combustion products.
- Refrigerant leakage.

## Pollutant Pathways

Airflow patterns in buildings result from the combined action of mechanical ventilation systems, human activity, and natural forces. Pressure differentials created by these forces move airborne contaminants from areas of relatively higher pressure to areas of relatively lower pressure through any available openings.

The HVAC system is generally the predominant pathway for air movement in buildings. However, all of a building's components (walls, ceilings, floors, penetrations, HVAC equipment, and occupants) interact to affect the distribution of contaminants. For example, supply air can be diverted or obstructed from the return grille by partitions, walls, and furnishings. It can be redirected by openings that provide pathways for air movement. In a localized area, movement of people has a major impact on the movement of pollutants. Pathways change as doors and windows open and close. The stack effect (the flow of air driven by the tendency of warm air to rise) can transport contaminants between floors by way of stairwells, elevator shafts, utility chases or other openings. Depending on leakage openings in the building exterior, wind can affect the pressure relationships within and between rooms.

Air moves from areas of higher pressure to areas of lower pressure through any available openings. A small opening can admit significant amounts of air if the pressure differentials are high enough. Even when the building as a whole is maintained under positive pressure, there is always some location (for example, the outdoor air intake) under negative pressure relative to the outdoors. Entry of contaminants may be intermittent, for example, occurring only when the wind blows from the direction of the pollutant source. The interaction between pollutant pathways and intermittent or variable driving forces can lead to a single source causing indoor air quality complaints in areas of the building that are distant from each other and from the source of the pollutant.

## Building Occupants

Because of varying sensitivity among people, one individual may react to a particular indoor air quality problem while surrounding occupants have no ill effects. In other cases, complaints may be widespread. A single indoor air pollutant or problem can trigger different reactions in different people. Some may not be affected at all.

The effects of indoor air quality problems are often nonspecific symptoms rather than clearly defined illnesses. Symptoms commonly attributed to indoor air quality problems include headache; fatigue; shortness of breath; sinus congestion; coughing; sneezing; eye, nose, or throat irritation; skin irritation; dizziness; and nausea. All of these symptoms, however, may also be caused by other factors and are not necessarily indicators of indoor air quality problems.

Some complaints by building occupants are clearly related to discomfort. For example, when the air in a room is slightly too warm for a person's activity level, that person may experience mild discomfort. If the temperature continues to rise, discomfort increases and symptoms such as fatigue, stuffiness, and headache can appear. Environmental stressors such as improper lighting, noise, vibration, overcrowding, ergonomic stress, and psychosocial problems such as job stress can produce symptoms that are similar to those associated with poor air quality. Odors are often associated with a perception of poor air quality, whether they cause symptoms or not.

## Developing an Indoor Air Quality Profile

Creating an indoor air quality profile for your building is a good first step toward ensuring that your ENERGY STAR upgrades are contributing to adequate indoor air quality. The indoor air quality profile is an organized body of information that you can use in planning renovations, negotiating leases and contracts, and responding to future complaints. It describes the building's structural features, functions, and occupancy levels, all of which affect indoor air quality. It should enable you to answer the following questions, which are key to maintaining indoor air quality:

- How was the building originally intended to function? Consider the building's components and furnishings, mechanical equipment (HVAC and non-HVAC), and the occupants and their activities.
- Is the building functioning as designed? Compare the commissioning information with the current conditions.
- What changes in building layout and use have occurred since the original design and construction? Determine whether the HVAC system has been reset and retested to reflect the changes.
- What changes may be needed to prevent indoor air quality problems from developing in the future? Consider potential changes in future uses of the building and additional ENERGY STAR upgrades.

### Steps in Creating an Indoor Air Quality Profile

*Note: This section summarizes the steps involved in creating an indoor air quality profile as described in the EPA/NIOSH publication* Building Air Quality: A Guide for Building Owners and Managers, *which provides more detailed information on conducting the profile and analyzing the results and also contains blank forms to use in compiling the profile.*

The process of creating an indoor air quality profile takes place in three major stages:

1. Collecting and reviewing existing records.
2. Conducting a walkthrough inspection of the building.
3. Collecting detailed information on the HVAC system, pollutant pathways, pollutant sources, and building occupancy.

The type of information required for each of these stages is summarized below.

#### Collecting and Reviewing Existing Records

- ***Review*** construction and operating documents:

  —Commissioning reports.

  —Operations manuals.

  —Addenda for remodeled areas.

  —Plans for addition, removal, or replacement of HVAC equipment.

  —Plans for changes in room use.

- ***Check*** HVAC system maintenance records against equipment lists. Collect existing maintenance and calibration records and check them against equipment lists, mechanical plans, and so forth, to see whether all components are receiving regular attention.

- ***Review*** records of complaints to identify building areas that deserve particular attention.

## Conducting a Walkthrough Inspection of the Building

- ***Discuss*** indoor air quality with staff and other occupants. Inform them about the concept of indoor air quality and their responsibilities in relation to housekeeping and maintenance. Learn about routine activities in the building to help clarify elements that should be included in an indoor air quality plan.

- ***Review*** facility operation and maintenance.

  —HVAC operating schedule.

  —HVAC maintenance schedule.

  —Use and storage of chemicals.

  —Schedule of shipping and receiving, including handling of vehicles at the loading dock.

  —Scheduling and other procedures for isolating odors, dust, and emissions from painting, roof repair, and other contaminant-producing activities.

  —Budgeting.

- ***Review*** housekeeping activities.

  —Cleaning schedule.

  —Trash storage and collection schedule.

  —Use and storage of chemicals.

- ***Review*** pest-control procedures.

  —Schedule and location of pesticide applications.

  —Use and storage of chemicals.

  —Pest-control activities other than use of pesticides.

- ***Look*** for signs of indoor air quality problems.

  —Odors.

  —Dirty or unsanitary conditions, particularly in equipment and mechanical rooms.

  —Visible fungal growth or moldy odors on walls, ceilings, and floors.

  —Poorly maintained filters.

  —Staining and discoloration.

  —Smoke damage.

  —Presence of hazardous substances.

  —Potential for soil gas entry.

  —Unusual noises from light fixtures or mechanical equipment.

  —Inadequate maintenance.

  —Signs of occupant discomfort.

  —Overcrowding.

  —Blocked airflow.

  —Obstructed or diverted airflow in plenums. Debris and damaged or loose material in plenum area.

  —Concentrations of equipment or lighting.

  —Inadequate pressure relationships in special-use areas.

  —Improperly located vents, exhausts, and air intakes.

## Collecting Detailed Information

- ***Inspect*** the HVAC system's condition and its operation. Identify equipment that needs to be repaired, adjusted, or replaced. Record control settings and operating schedules for HVAC equipment for comparison to occupancy schedules and current uses of space.

- ***Conduct*** an inventory of potential pollutant pathways. Observe and record airflow between spaces.
- ***Conduct*** an inventory of potential pollutant sources.
- ***Collect*** information on building occupancy.
- ***Obtain*** EPA indoor air quality publications (see box on page B–10).

## Operating and Maintaining HVAC Equipment To Ensure Indoor Air Quality

Maintaining good indoor air quality in your building involves reviewing and amending current practices. Once you have created an indoor air quality profile of your building, you can use it to develop an indoor air quality management plan. Such a plan will ensure that indoor air quality considerations become a part of routine procedures. The plan should include the following activities:

- Informing and training staff, occupants, and contractors as to their responsibilities relating to indoor air quality.
- Maintaining all equipment and controls in proper working order.
- Keeping equipment and mechanical rooms as well as the interior of ductwork clean and dry.

Indoor air quality can be affected both by the quality of maintenance and by the materials and procedures used in operating and maintaining the building and its systems, particularly the HVAC system. The maintenance staff can best respond to indoor air quality concerns if they understand how their activities affect indoor air quality. It may be necessary to change existing practices or introduce new procedures in any of the following areas:

- ***Equipment Operating Schedules.*** The building should be flushed by the ventilation system before occupants arrive. Occupancy cycles should correspond to actual occupied periods.
- ***Controlling Odors and Contaminants.*** Maintain appropriate pressure relationships among building usage areas. Provide adequate local exhaust. Ensure that paint, solvents, and other chemicals are stored and handled properly, with adequate ventilation provided.
- ***Ventilation Quantities.*** Compare outdoor air quantities with the building's design goal and local and state building codes. Make adjustments as necessary. You may also find it informative to compare your ventilation rates with ASHRAE standard 62–1989 (or the latest standard), as it was developed with preventing indoor air quality problems in mind.
- ***Equipment Maintenance Schedules.*** Inspect all equipment regularly to ensure that it is in good condition and is operating as designed. Be thorough in conducting these inspections. Components exposed to water require scrupulous maintenance to prevent microbiological growth and the entry of undesired microbiologicals or chemicals into the indoor airstream.
- ***Building Maintenance Schedules.*** Schedule maintenance activities that interfere with HVAC operations or that produce odors and emissions to occur when the building is unoccupied.
- ***Purchasing.*** Request information from suppliers about chemical emissions associated with materials being considered for purchase.
- ***Preventive Maintenance Management.*** Maintenance "indicators" (for example, manometers for filter banks) can help the staff determine when routine maintenance is required. Computerized systems that prompt the staff to

## ASHRAE Standards and Guidelines Related to Indoor Air Quality

The American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE) has published three standards and one guideline related to indoor air quality. These standards are summarized below. ASHRAE materials are available from their Publications Sales Department, 1791 Tullie Circle NE, Atlanta, Georgia 30329 (Phone 404–636–8400).

### Standard 62–1989, Ventilation for Acceptable Air Quality

ASHRAE 62–1989 is intended to assist in designing building ventilation systems. It presents two procedures for ventilation design. With the *Ventilation Rate* procedure, acceptable air quality is achieved by specifying a given quantity and quality of outdoor air based on occupant density and space usage. The *Air Quality* procedure is a performance specification that allows acceptable air quality to be achieved within a space by controlling known and specifiable contaminants. Important features of the standard include the following:

- A definition of acceptable air quality.
- A discussion of ventilation effectiveness.
- Recommendation of the use of source control through isolation and local exhaust contaminants.
- Recommendations for the use of heat recovery ventilation.
- A guideline for allowable carbon dioxide levels.
- Appendices listing suggested possible guidelines for common indoor pollutants.

### Standard 55–1992, Thermal Environmental Conditions for Human Occupancy

ASHRAE 55–1992 covers several environmental parameters, including temperature, radiation, humidity, and air movement. It specifies conditions to ensure the comfort of healthy people in normal indoor environments in winter and summer conditions. It also attempts to introduce limits on temperature variations within a space and describes adjustment factors for various levels of occupant activity and types of clothing. Important features of the standard include the following:

- A definition of acceptable thermal comfort.
- A discussion of additional environmental parameters that must be considered.
- Recommendations for summer and winter comfort zones for both temperature and relative humidity.
- A guideline for making adjustments for various activity levels.
- Guidelines for taking measurements.

### Standard 52.1–1992, Gravimetric and Dust-Spot Procedures for Testing Air-Cleaning Devices Used in General Ventilation for Removing Particulate Matter

This standard describes two ways to test air cleaning systems.

The *atmospheric dust spot test* determines the efficiency of a medium-efficiency air cleaner by evaluating its ability to reduce soiling of a clean paper target. The *weight arrestance test* is generally used to evaluate low-efficiency filters by determining the weight of a standard synthetic dust trapped in the filter. Important features of the standard include the following:

- Definitions of arrestance and efficiency.
- Establishment of a uniform comparative testing procedure for evaluating performance of air cleaning devices used in ventilation systems.
- Establishment of a uniform reporting method for performance.
- Methods for evaluating resistance to airflow and dust-holding capacity.

### Guideline 1–1989, Guideline for the Commissioning of HVAC Systems

This guideline is intended to assist professionals by providing procedures and methods for documenting and verifying the performance of HVAC systems so that they operate in conformity with the design intent. Important features of the guideline include the following:

- Definition of the commissioning process.
- Discussion of the process involved in a proper commissioning procedure.
- Sample specification and forms for logging information.
- Recommendation for implementation of corrective measures as warranted.
- Guidelines for operator training.
- Guidelines for periodic maintenance and recommissioning as needed.

carry out maintenance activities at the proper intervals are also available.

### Diagnosing HVAC-Related Indoor Air Quality Problems

Indoor air quality complaints often arise because the quantity or distribution of outdoor air is inadequate to meet the ventilation needs of building occupants. An investigation of these complaints should begin with the components of the HVAC systems that serve the complaint area and surrounding rooms and then be expanded as necessary. The following questions should be answered:

- Are the components that serve the immediate complaint area functioning properly?
- Is the HVAC system adequate for the current use of the building?
- Are ventilation (or thermal comfort) deficiencies evident?
- Should the definition of the complaint area be expanded based upon the HVAC system's layout and operating characteristics?

An evaluation of the HVAC system may include limited measurements of temperature, humidity, airflow, and carbon dioxide as well as smoke-tube observations.

The following items should be included in an HVAC system inspection:

- ***Check*** temperature and humidity to see if the complaint area is in the comfort range.
- ***Check*** for indicators of adequate ventilation.
- ***Check*** to see if the equipment serving the complaint area is operating properly.
- ***Compare*** the current system to the original design.
- ***Check*** to see if the layout of air supplies, returns, and exhausts promotes efficient air distribution to all occupants and isolates or dilutes contaminants.
- ***Consider*** whether the HVAC system itself may be a source of contaminants.
- ***Compare*** the original uses of space to current uses.
- ***Observe*** the direction of air movement.

A detailed engineering study may be required if the investigation discovers the following problems:

- Airflows are low.
- HVAC controls are not working or are working according to inappropriate strategies.
- Building operators do not understand (or are unfamiliar with) the HVAC system.

A review of existing HVAC system documentation (plans, specifications, testing and balancing reports) should provide information about the original design and later modifications. If there is no documentation, an intensive on-site inspection will be required.

The building staff can provide important information about equipment operating and maintenance schedules and breakdowns or other incidents. In addition, inspection reports or other written records may be available for review. Those who are familiar with building systems in general and with specific features of the building under investigation can be helpful in identifying conditions that may be causing complaints about indoor air quality.

## Mitigating Indoor Air Quality Problems

Modifications to ventilation systems are often used to correct or prevent indoor air quality problems. This approach can be effective when buildings are under-ventilated or when a specific source of contamination cannot be identified. Venti-

## Sources of Additional Information on Indoor Air Quality

EPA's Indoor Air Quality Clearinghouse, **IAQ INFO**, is an easily accessible central source of information and publications on indoor air quality. It provides information on indoor air pollutants and their sources, health effects related to indoor air pollution, testing and measuring of indoor air pollutants, controlling indoor air pollutants, constructing and maintaining buildings to minimize indoor air quality problems, standards and guidelines related to indoor air quality, and general information on Federal and State legislation related to indoor air quality.

An IAQ INFO specialist can quickly put you in touch with a variety of resources, including citations and abstracts on more than 2,000 books, reports, and articles; an inventory of Federal Government publications; and information on more than 150 government, research, public interest, and private-sector organizations involved with indoor air quality. The specialist can answer questions, send Federal Government publications (most are free) or a list of publications, refer you to appropriate government or other organizations, and provide you with a bibliography on a topic for further reference.

Among the publications available are the following:

- The Inside Story: A Guide to Indoor Air Quality (IAQ–0009)
- Fact Sheet: Respiratory Health Effects of Passive Smoking: Lung Cancer and Other Disorders (IAQ–0046)
- Targeting Indoor Air Pollution: EPA's Approach and Progress (IAQ–0029)
- Fact Sheet: Ventilation and Air Quality in Offices (IAQ–0003)
- Fact Sheet: Sick Building Syndrome (IAQ–0004)
- Fact Sheet: Report to Congress on Indoor Air Quality (Summary of Report) (IAQ–0006)
- Fact Sheet: Carpet and Indoor Air Quality (IAQ–0040)
- Current Federal Indoor Air Quality Activities (IAQ–0011)
- Directory of State Indoor Air Contacts (IAQ–0012)
- Compendium of Methods for Determination of Air Pollutants in Indoor Air—Project Summary (IAQ–0022)

To request any of these titles (please include the catalog number), to request a complete list of titles, or to speak to an IAQ INFO specialist, call IAQ INFO's toll-free number, 1–800–438–4318, Monday through Friday, 9 a.m. to 5 p.m. eastern time (after hours you can leave a message). You can write or fax any time. The address is IAQ INFO, P.O. Box 37133, Washington, D.C. 20013–7133. The fax number is 301–588–3408.

The EPA and National Institute for Occupational Safety and Health (NIOSH) publication ***Building Air Quality: A Guide for Building Owners and Facility Managers*** provides valuable information on how to develop a building profile that can help you prevent indoor air quality problems, create an indoor air quality management plan, identify causes of indoor air quality problems and develop solutions to those problems as they occur, identify appropriate control strategies, and decide if you need outside technical assistance. You will also find sections covering key causes of indoor air quality, air quality sampling, HVAC systems, and moisture problems, plus a wide variety of checklists and forms that can help you manage indoor air quality and diagnose problems. The publication also includes an extensive listing of indoor air quality information resources.

This publication, published in a looseleaf binder format, is available for $24 from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402–9325 (credit card orders by phone, 202–783–3238, or fax, 202–512–2250).

The National Environmental Health Association's ***Introduction to Indoor Air Quality*** set, a reference manual and a self-paced learning module, is available from the Association at 720 Colorado Boulevard, 970 South Tower, Denver, Colorado 80222 (phone 303–756–9090). The price is $40 for members and $47 for nonmembers.

The ***Survey of Indoor Air Quality Diagnostic and Mitigation Firms*** is available in hardcopy ($44.50) and microfiche ($12.50) from the National Technical Information Service, 5245 Port Royal Road, Springfield, Virginia 22161. Phone 800–553–6847 or 703–487–460. Order item number PB90–130469.

Also available from the National Technical Information Service is the four-volume ***Report to Congress on Indoor Air Quality*** (item number PB90–167362; $77 papercopy, $34 microfiche). The volumes are also available individually: Executive Summary and Recommendations (item number PB90–167370; $17.50 papercopy, $9 microfiche); Volume 1—Federal Programs Addressing Indoor Air Quality (item number PB90–167388; $19.50 papercopy, $9 microfiche); Volume 2—Assessment and Control (item number PB90–167396; $36.50 papercopy, $12.50 microfiche); and Volume 3—Research Needs Statement (item number PB90–167404; $19.50 paper-copy, $9 microfiche).

lation can be used to control indoor air contaminants by:

- Diluting contaminants with outdoor air.
  - —Increasing the proportion of outdoor air to total air.
  - —Improving air distribution.
- Isolating or removing contaminants by controlling air pressure relationships.
  - —Installing effective local exhaust at the location of the source.
  - —Eliminating recirculation of contaminated air.
  - —Locating contamination sources near exhaust registers.
  - —Using air-tightening techniques to maintain pressure differentials and eliminate pollutant pathways.
  - —Closing doors when necessary to separate zones.

Other ways to maintain indoor air quality include the following:

- Correcting design deficiencies such as inadequate outside air intakes or variable air boxes that close completely because they do not have a set minimum.
- Eliminating reentrainment of exhaust air and combustion gases.
- Eliminating reentrainment through heat-recovery wheels (when applicable).
- Improving the efficiency of the air cleaning and filtration system.
- Ensuring proper operation of the HVAC system.
- Performing regular maintenance on the HVAC system.
- Eliminating or controlling microbiological and chemical contaminants.
- Educating the building operating staff and tenants about indoor air quality.

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# More on Program Management

APPENDIX C

This appendix contains supplemental program management information on financing your ENERGY STAR Buildings upgrades and on preparing requests for proposals and quotations.

## Financing

Many profitable upgrade projects are delayed by restricted availability of capital. Utility incentives (particularly through EPA Super Ally Program utility partners), national purchasing agreements, and equipment financing (with or without performance guarantees) can help ENERGY STAR Buildings Partners overcome financing obstacles and obtain the financial advantages of energy efficiency.

Alternatives to using in-house capital for energy-efficiency upgrades include conventional financing, leasing (capital leases and operating leases), and shared savings financing. These financing options can provide positive cash flow when the periodic energy cost savings exceed the amount of payments. The risk of the investment can be reduced or eliminated with guaranteed savings insurance and shared savings financing. National purchasing agreements, if applicable, can reduce costs and improve service.

Several types of utility incentives and financing options reduce or eliminate the need for capital, reduce risk, and improve cash flow. Although third-party financing may be a slightly more expensive approach to procuring energy-efficiency upgrades, it may still be the best alternative because it allows you to retain more capital for use in your specific business activities.

This section addresses the attributes of the more popular financing options that can be used for procuring ENERGY STAR Buildings upgrades. Note, however, that terms and conditions for each option will vary among these financing sources.

You can obtain detailed information about the utilities and financing companies that offer the various financing options described in this section from the Green Lights database of financing programs, described later in this section.

### Utility Incentives

Electric utilities in some areas are helping their customers reduce the cost of energy-efficiency upgrades by offering rebates and other incentives. By encouraging reduced customer loads, an electric utility can meet new customer demand while avoiding the costs required to add more generating capacity.

**Action Steps for Financing**

1. Use the Green Lights database of financing programs to:
   — Determine the availability of utility incentives.
   — Review services and terms offered by financing organizations.
2. Work with your financial and tax analysts to determine the appropriate financing option based on:
   — Cost of capital.
   — Eligibility for utility incentives.
   — Perceived investment risk.
   — Flexibility.
3. Work with manufacturers and service companies to investigate national purchasing agreements.

Before you proceed with your ENERGY STAR Buildings upgrades, contact your local utility and obtain specific incentive program information. Pay particular attention to customer eligibility criteria and the specific technologies that qualify for incentives or rebates. Be certain to verify the deadline for the rebate applications or for the upgrades themselves. These deadlines are important for determining whether you can qualify for rebates or incentives. To determine the incentives that may apply to your upgrades, consult the Green Lights database of financing programs (described later in this section).

Specific types of utility incentives are described below.

**Rebates**

— The utility company reimburses the building owner for a portion of the cost of energy-efficiency improvements implemented.

— Rebates may be based on peak load reductions (that is, dollars per kilowatt) or based on a fixed rebate for each energy-efficient product purchased (that is, dollars per item).

— A given technology may qualify under one or more programs offered by the utility. Typically, only one incentive program application may be submitted per building. Check with your utility for details.

— Rebates have been the most common form of utility incentive during the past several years.

**Direct Utility Assistance**

— The utility pays some or all of the cost of the upgrade directly to the installing contractor selected by the customer.

— Alternatively, the utility provides energy-efficiency products or services to the customer through utility personnel or contractors selected by the utility.

**Low-Interest Loans**

— Some utilities offer low-interest financing for energy conservation projects. Loan payments can be added to your utility bills.

## *National Account Agreements*

National purchasing agreements, also called national accounts, are negotiated relationships between suppliers and nationwide buyers of products and services. National accounts provide the following benefits:

- Streamlined coordination of energy-efficiency equipment purchases.
- Guaranteed availability of selected technology.
- Competitive prices.
- Multi-location shipping directly from the manufacturer.
- Standardized installation and maintenance.
- Additional support services available only from the manufacturer.

National account programs can assist ENERGY STAR Buildings Partners by simplifying the procurement process for energy-efficiency upgrades. They may or may not take the form of written agreements. To be legally binding, however, the agreements are written, agreed to, and signed by both parties. A request for proposals (RFP) to solicit bids on a national account may or may not be necessary.

ENERGY STAR Buildings Partners interested in exploring national account agreements should take the following steps:

- Determine the types of upgrades suitable for national accounts.
- Determine the quantities and prices for the products and services required.

- Plan and aggregate company-wide purchases to gain the maximum discount for quantity purchases.
- If possible, reduce the diversity of products to increase purchase quantities and further increase discounts for quantity purchases.
- Identify which products will be specified for purchase and whether or not substitutes would be acceptable.
- If applicable, determine annual purchasing volume.
- Contact the appropriate manufacturers to inquire about establishing a national account.
- If necessary, issue an RFP to solicit bids from interested manufacturers or contractors (see page C–7 for more information about proposals and quotations).

## Overview of Financing Options

Financing organizations can provide the needed capital for implementing your ENERGY STAR Buildings upgrades. These financing options are designed to reduce or eliminate up-front project expenditures and distribute these costs over time. In many cases, the periodic energy cost savings exceed the periodic financing payments, resulting in positive cash flow from the beginning of the project. In addition to providing capital, several organizations provide the expertise to design and install the upgrades while assuming some or all of the performance risk.

There are many variations of financing options available to ENERGY STAR Buildings Partners. In the descriptions that follow, the most common attributes of the financing methods are described. However, note that the specific terms and conditions vary among the large number of financing entities. To determine the incentives that may apply to your upgrades, consult the Green Lights database of financing programs (described later in this section).

*Note: Because tax laws are frequently revised and sometimes are difficult to interpret, check with your tax and financial analysts to determine bottom-line impacts before entering into an agreement with a financing company.*

Table C–1 provides a summary of the attributes of the financing options described in the rest of this section. Other options may be applicable to projects that involve cogeneration or thermal storage systems.

### Lease Purchase

Two basic types of leases can be used to finance energy-efficiency improvements: capital leases and operating leases.

***Capital leases*** are installment purchases. Little or no initial capital outlay is required to purchase the equipment. You are considered the owner of the equipment and may take deductions for depreciation and for the interest portion of the payments to the lessor. Similar to conventional loans, capital leasing is "on balance sheet" financing, meaning that the transaction will be recorded on your balance sheet as both a liability and an asset. Capital leases are offered by banks, leasing companies, installation contractors, suppliers, and some electric utilities.

Under ***operating leases***, the lessor owns the equipment that is, in effect, "rented" (leased) to you for a monthly fee during the contract period. This provides an "off balance sheet" financing option. Because the lessor is considered the owner of the energy-efficiency equipment, he claims the tax benefits associated with the depreciation of the equipment. At the end of the contract term, you can elect to purchase the equipment at fair market value (or at a predetermined amount), renegotiate the lease, or have the equipment removed.

Some energy-efficiency upgrades may not qualify for an operating lease based on the criteria defined by Financial Accounting Standards Board (FASB) Statement 13. These criteria disallow automatic ownership transfer and bargain purchase options,

## Table C–1. Comparison of Financing Options

| | Cash Purchase | Conventional Financing | Capital Lease | Operating Lease | Shared Savings |
|---|---|---|---|---|---|
| **Initial Payment** | 100 Percent of Project Cost | 0 to 30 Percent of Project Cost | $0 or Deposit | $0 | $0 |
| **Periodic Payment** | None | Fixed | Fixed | Fixed | Percentage of Energy Cost Savings |
| **Payment Source** | Capital | Capital | Capital | Operations | Operations |
| **Performance Risk** | Owner* | Owner* | Owner* | Lessor | Investor |
| **Contract Termination Options**** | Not Applicable | Principal Payoff | Principal Payoff | Fair Market Value Buyout; Renew; Return | Fair Market Value Buyout; Renew; Return |
| **Ownership** | Building Owner | Building Owner | Building Owner | Lessor | Investor |
| **Tax Deductions***** | Depreciation | Depreciation and Interest | Depreciation and Interest | None**** | Shared Savings Payments |

* Owner's risk may be reduced with guaranteed savings insurance.
** At end of term.
*** Subject to change in tax laws; consult with tax advisor regarding eligibility.
**** No tax benefits to owner. Lessor claims tax benefits associated with depreciation.

set the maximum term of the lease at 75 percent of economic life, and limit the present value of rental payments (plus any residual value guarantee) to less than 90 percent of fair value of the leased equipment. In such cases, shared savings financing may offer many of the advantages of operating leases.

### Shared Savings

Shared savings is a unique financing method whose primary benefit is that it reduces the risk of the energy-efficiency upgrade investment. The features of shared savings include the following:

- ***No Down Payment.*** Entire cost of the upgrade is paid for by the third-party financing source.
- ***Third-Party Ownership.*** Third-party investor provides the capital for the project and owns the improvements during the term of the agreement. As a result, the financing obligation does not appear on your balance sheet. At the end of the contract, you have the option to purchase the improvements at an agreed-upon value, renegotiate the contract terms, or terminate the agreement and allow the investor to recover the equipment.
- ***Performance-Based Payments.*** Periodic variable "energy service" payments are based on the measured or calculated energy cost savings performance attributed to the upgrades. These payments will typically be made from your operating budget (not your capital budget). You pay a portion of the cost savings back to the investor according to ratios outlined in the contract. The energy services contractor takes responsibility for maintaining the system in order to ensure energy savings.

- ***Positive Cash Flow.*** Because you make no down payment and periodic payments are taken from realized savings, the resulting cash flow is always positive.
- ***No Performance Risk.*** Because the third-party investor gets paid only in proportion to the financial performance of the upgrade, the risk of the investment is shifted to the third party. However, the overall costs associated with reducing risk through shared savings should be carefully evaluated.

### Guaranteed Savings Insurance

Guaranteed savings insurance may be applied to the following types of financing approaches:

- Cash Purchase.
- Conventional Financing.
- Lease Purchase.

The guaranteed savings option consists of an agreement to ensure that the periodic energy cost savings will exceed an established minimum dollar value. This guarantee is usually provided by the supplier, installer, or energy services company who sold the upgrade. In many cases, this minimum guaranteed savings value is set equal to the financing payment value for the same period in order to ensure a positive cash flow during the financing term.

Entering into a guaranteed savings agreement is like buying an insurance policy. To compensate the guarantor for assuming some of the performance risk as well as costs associated with ensuring guaranteed performance (such as maintenance and monitoring costs), you will pay an indirect insurance premium. When combined with conventional or lease financing, this premium can be added to the monthly payment or paid directly to the guarantee provider.

## Choosing a Financing Option

With many options available to ENERGY STAR Buildings Partners for financing energy-efficiency upgrades, how does one go about determining which method is most advantageous? The final answer can not be computed by purely quantitative methods. Instead, the financing decision must take the following factors into account:

- Cost of Capital.
- Eligibility for Utility Incentives.
- Perceived Risk.
- Impact on Balance Sheet.
- Flexibility.

These factors are discussed in the following subsections.

### Cost of Capital

In any economic study, the cost of capital must be considered. The capital cost factor most often applied in financial analysis is the Discount Rate, expressed as a percentage. Simply put, the discount rate may be assumed to be the corporation's minimum required rate of return on invested capital. ENERGY STAR Buildings Partners may choose the prime interest rate plus six points to determine their discount rate. Most corporations have a specific discount rate that is used in their financial analyses.

There is a simple relationship between the cost of capital and the attractiveness of third-party financing. The higher the cost of capital (that is, the higher the discount rate), the more attractive third-party financing becomes. Perform a Net Present Value analysis of the 20-year cash flows resulting from your proposed financing alternatives. The option with the highest net present value would be the most attractive financing alternative for your corporation, based on your cost of capital.

### Eligibility for Utility Incentives

Before entering into a shared savings financing agreement, check with your local utility to determine who is eligible to receive any incentives—the ENERGY STAR Buildings Partner or the third-party investor. If the investor is to receive the incentive, negotiate reduced payments that take into account the value of the utility incentives paid to the financing entity.

### Perceived Risk

Compared with other investments, energy-efficiency upgrades are low-risk investments. Nevertheless, returns on these investments are dependent on such external factors as electricity rates, building occupancy, and usage. To reduce these risks, your financial officer may choose to pay additional premiums for a savings guarantee or enter into a shared savings agreement. Note, however, that the risks associated with achieving reduced electrical load are minimal; actual load reductions can be easily measured in the field.

### Impact on Balance Sheet

With conventional loans or capital leases, the transaction is recorded on the company's balance sheet as both an asset and a liability. For companies that are not in a position to incur additional liabilities, or are concerned about impacts on their return on assets, the shared savings and operating lease approaches should be considered. These are the only commonly available financing options for energy-efficiency upgrades that are considered to be "off the balance sheet." Some energy-efficiency upgrades may not qualify for financing with an operating lease because of FASB requirements.

### Flexibility

Regardless of the financing approach, verify that no penalties will be incurred by prepayment or early buyout of the financing liability. For shared savings agreements, be certain that provisions exist for purchasing the equipment at fair market value prior to the end of the contract term. In addition to these contract termination options, also look for financing sources that can adapt the financing agreement to include future purchases of energy-efficient equipment.

## Green Lights Database of Financing Programs

The Green Lights database of financing programs provides information on both utility incentives and non-utility financing options for lighting and other building upgrades. The database, which is updated regularly, runs on IBM PC or compatible computers. You can obtain a copy by calling the ENERGY STAR hotline at 202–775–6650 (fax 202–775–6680) or writing to EPA's Atmospheric Pollution Prevention Division, USEPA/OAR (6202–J), 401 M Street SW, Washington, D.C., 20460.

The Green Lights database of financing programs consists of the following two modules.

### Utility Incentives

To quickly identify rebates or other utility incentives that may apply to your energy-efficiency upgrades, select the Utility Financing module from the bulletin board's main menu. Then select your utility company from the next menu that is displayed. You will then see a display of the specific incentive levels, eligibility criteria, and contact information. If you want a copy of the data for future reference, you can choose a print option from the menu.

For each utility, the following information is displayed:

- Utility Name.
- Program Name.
- Incentive Type (rebate, loan, etc.).
- Sectors (eligible customer groups).
- Situation (retrofit, new construction).
- Contact Information.
- Program Details.

The database can also be searched for specific technologies. For example, you could create a list of all incentive programs that address water-cooled centrifugal chillers.

### Non-Utility Financing Sources

By selecting the Financing Products module from the bulletin board's main menu, you can see a list of organizations that provide project financing. Note that each organization may have minimum requirements for project size and client gross revenue. Maximum contract terms and loan amounts are specified for each organization.

For each financing organization, the following information is displayed:

- Name, Address, Contact Name, Telephone Number.
- Type of Organization.
- For Each Financing Product Offered:
  - — Equipment Covered
  - — Terms
  - — Markets
  - — Census Regions.
- Sources of Capital.
- Eligibility Criteria.

## Requesting Proposals and Quotations

Many companies that do not have the in-house capacity to survey, specify, and implement a comprehensive energy-efficiency project will turn to outside consultants, vendors, and contractors. This section briefly discusses some of the issues related to requesting proposals and quotations.

*Note: EPA cannot provide legal advice, and this section is not intended to do so. Because RFPs and quotations are legal documents, appropriate legal advice should be sought when writing these documents.*

### RFPs and RFQs

A request for proposals (RFP) or request for quotations (RFQ) enables a building owner to communicate all pertinent information about a potential project to prospective bidders. If an RFP or RFQ is complete and detailed, the bids received in response to the RFP or RFQ will more than likely be complete and detailed as well. While there are many similarities, the purposes of the RFP and the RFQ are different.

An RFP is an invitation for bidders to propose a project. It may ask the bidder to propose one or more of the following:

- Specification of the scope of work.
- Specifications for materials.
- Financing options or terms.
- Performance guarantee(s).
- Extended warranty or maintenance terms.
- Project price.

In short, the RFP is a request for bidders to determine both the scope of work and the cost to complete the work. The successful bidder is awarded the project on the basis of the quality of the proposal as well as price.

An RFQ is an invitation for a bidder to quote a price for a project that is specified by the building owner in the request. The determination of the scope and specifications of the project are made prior to and separate from the RFQ. The successful bidder is generally awarded the project on the basis of cost and the building owner's confidence in the bidder's capabilities.

### Content of RFP and RFQ

The RFP or RFQ should contain all information about a project that a prospective bidder needs to prepare a proposal. The items described in this subsection should be included.

#### Timetable

A timetable provides important dates and deadlines, including the following:

- Dates for pre-bid meetings.
- Schedule for site visits.
- Due date for proposals or bids.
- Date that work may begin.

- Date required for project completion.

### Scope of Work

In this section, the services to be performed by the bidder are defined. The description of work should be clear and concise so that there is no confusion as to the requirements. For example, the bidder should be provided the size, location, and number of buildings included in the project.

A typical scope of work contains the following:

- Goals and objectives of the project.
- Restrictions and preferences for equipment to be used.
- Applicable laws, codes, and standards.
- Instructions for disposal of obsolete equipment.
- Target values for variables such as load, watts per square foot, internal rate of return, or shared savings terms.

### Bidding Procedure and Instructions

The bidder needs specific instructions about the time, location, and format of the bid. Minimum bidder qualifications, if any, should be described. The instructions usually provide a date by which bidders will be notified of the results of the proposal evaluation will be complete.

To ensure that bidders provide complete information in a format that is consistent, an RFP or RFQ usually includes forms to be completed by the bidders. These forms provide information about the bidder's staff, previous projects, and other data that may help the building owner choose the best contractor for the project. The following items are usually requested on these forms:

- Key project participants, including resumes.
- Subcontractors.
- Previous projects.
- References.
- Other support and resources available.

A point of contact and telephone number should be provided in case bidders have any questions related to the RFP or RFQ.

### Selection Criteria

To help bidders provide information that is important to the building owner, the RFP or RFQ should include a description of the criteria that will be used to evaluate the proposals or quotations. This may include listing the selection factors and the relative importance of each to the decision.

### Financing Methods and Payments

The financing method, if any, should be outlined in the RFP. For example, if the building owner desires a shared savings contract, the terms should be outlined in this section. Similarly, specific payment schedules and methods, if desired, should be explained. Bidders should also know if the project is to be bid on a lump sum or unit price basis.

### General Conditions

This part of the RFP or RFQ contains contractual issues and details. Items in this section include the following:

- Contract change procedures.
- Insurance and worker compensation.
- Maintenance.
- Guarantees.
- Samples and demonstration installations.

## Types of RFPs and RFQs

Because each project is different, with unique characteristics and objectives, no two RFPs and RFQs are the same. General types of RFPs and RFQs are described below. An RFP or RFQ may consist of any combination of these types.

### Request for Quotation, Consulting Only

This RFQ is used to solicit engineering and design services for a project. The actual installation is not included in this proposal.

As an example, the bidder responding to this RFQ would develop a proposal to design an upgrade, provide equipment specifications, and provide an economic analysis.

### Request for Quotation, Performance

This RFQ is used to obtain a quotation for the installation only. The scope of work for the upgrade in this case is already defined, so the engineering and design is not part of this proposal. The proposal would require estimates of labor and material costs rather than, for example, internal rate of return, load, or watts per square foot.

### Request for Quotation, Financial

This request would be used only if financial analysis is desired. It requests bids on such items as initial investment, internal rate of return, simple payback, rebates, and other financial analyses to ensure the profitability of the project. Once again, the scope of the project is already defined, so project engineering and design are not included.

### Request for Proposal, Design and Build

Here an RFP is used to solicit proposals for all design and installation of the energy-efficiency upgrade. One company will be selected to perform the survey and analysis for, design, and install the upgrade. This RFP is unique from the other RFPs and RFQs because it is for an entire project, from start to finish.

### Request for Proposal, Shared Savings

This is a specific RFP, similar to the RFP for design and build described above. However, here a section of the RFP contains specific details on how the initial cost will be financed. In this case, the future energy cost savings are shared between the building owner and the bidder. The bidder will finance the initial cost and receive some of the energy cost savings as compensation.

### Request for Proposal, Guaranteed Savings

This is another specific RFP, similar to the RFP for shared savings. Here, the bidder must be prepared to assume the risk of investment and guarantee minimum energy savings. The proposal must contain details on financing and guaranteed energy cost savings that will free the building owner from any risk in the project.

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# Glossary

APPENDIX D

***AC.*** Alternating current.

***Actuator.*** Device that activates equipment.

***AHU.*** Air-handling unit.

***Air-Side Systems.*** Equipment used to distribute conditioned air to a space. Includes heating and cooling coils, fans, ducts, and filters.

***Air-Handling Unit.*** The heart of an air-handling system. Circulates, cleans, heats, cools, humidifies, dehumidifies, and mixes interior air.

***Air Separator.*** Device that removes the circulating air in water-side systems.

***Alternating Current.*** Electric current that reverses direction in a circuit at regular intervals.

***Ammeter.*** Instrument used to measure electric current.

***Ampere.*** Unit of electric current in the meter-kilogram-second system.

***ANSI.*** American National Standards Institute.

***ARI.*** Air-Conditioning and Refrigeration Institute.

***ASHRAE.*** American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.

***ASME.*** American Society of Mechanical Engineers.

***Balancing.*** Process of measuring and adjusting differential pressures to obtain design flows. Applied to both air-side and water-side systems.

***Ballast.*** Power-regulating device that modifies incoming voltage and controls current to provide the electrical conditions necessary to start and operate electric discharge lamps.

***Bleeding.*** Process of removing minerals from the water in an open recirculating cooling system by draining small amounts of water that contain concentrated minerals.

***Boiler.*** Pressure vessel designed to transfer heat (produced by combustion) or electric resistance to a fluid. In most boilers, the fluid is usually water in the form of liquid or steam.

***Calibration.*** Process of adjusting equipment to ensure that operation is within design parameters.

***Carbon Dioxide.*** Colorless, odorless, incombustible gas formed during respiration, combustion, and organic decomposition. Increasing amounts of carbon dioxide in the atmosphere are believed to contribute to the global warming phenomenon.

***CAV.*** Constant air volume.

***CFC.*** Chlorofluorocarbon.

***CFM.*** Cubic feet per minute.

***Chiller.*** Device that generates cold liquid, which is circulated through an air-handling unit's cooling coil to cool the air supplied to a building.

***Chlorofluorocarbons.*** Halocarbon compounds consisting of carbon, hydrogen, chlorine, and fluorine, once used widely as aerosol propellants and refrigerants. Believed to cause depletion of the atmospheric ozone layer.

***Coil, Cooling.*** Heat exchanger used to cool air under forced convection, with or without dehumidification. May consist of a single coil section or several coil sections assembled into a bank.

***Coil, Condenser.*** In an evaporative condenser, heat exchanger used to circulate vapor from the compressor discharge. The coil is continuously wetted on the outside by a recirculating water system. Air is simultaneously directed over the coil, causing a small portion of the water to evaporate. This evaporation removes heat from the coil, thus cooling and condensing the vapor.

***Coil, Heating.*** Heat exchanger that heats air under forced convection. May consist of a single coil section or several coil sections assembled into a bank.

***Compressed Air System.*** Equipment that uses compression to boost the pressure of air.

***Condenser.*** Heat exchanger in a refrigeration system that rejects heat from a system to some cooler medium. The cool refrigerant condenses to the liquid state and drains from the condenser to continue in the refrigeration cycle.

***Constant Air Volume.*** Type of air-handling system that maintains comfort in buildings by providing a constant airflow and varying the temperature of that airflow.

***Control.*** Device that analyzes the difference between an actual process value and a desired process value and brings the actual value closer to the desired value.

***Convector.*** Heat-distributing unit that operates with gravity-circulated (natural convection) air. A heating element is surrounded by an enclosure, with an air inlet opening below and an air outlet opening above.

***Cooling Tower.*** Device that dissipates heat from water-cooled systems through a combination of heat and mass transfer. The water to be cooled is distributed in the tower and exposed to circulated atmospheric air.

***Dampers.*** Single blade or multiple blades that are either manually or automatically opened or closed to control the amount of air entering or leaving an air-conditioning system.

***DC.*** Direct current.

***Demand.*** Rate at which electrical energy is delivered to or by a system at a given time or averaged over a designated period. Expressed in kilowatts.

***Demand Charges.*** Fees levied by a utility company for electric demand.

***Design (Load) Conditions.*** Optimal thermal environmental conditions that enable HVAC systems to ensure the comfort of healthy people in buildings.

***Direct Current.*** Electric current flowing in one direction only.

***Direct Expansion System.*** Cooling system in which the refrigerant runs in the cooling coil to directly cool the air; that is, there is no water loop between the refrigerant and the air to be cooled.

***Downsizing.*** Process of reducing the size (capacity) of equipment so that it operates efficiently at design load conditions.

***Drip Pocket.*** Device that holds condensate and sediment removed from steam lines.

***Ductwork.*** Distribution system for air in HVAC systems. Usually made of sheet metal or fiberglass.

***Efficiency.*** Ratio of power output to power input.

***Electromagnetic Interference.*** Unwanted electromagnetic signals or noise, caused by electric or electronic equipment, which can affect the operation of other equipment.

***Eliminator.*** Stationary vanes or louvers designed to remove water entrained in an airstream.

***EMI.*** Electromagnetic interference.

***EMS.*** Energy management system.

***Energy Management System.*** Control system that monitors the environment and energy usage in a building and adjusts the parameters of local control loops to conserve energy while maintaining a suitable environment.

***Envelope (Building).*** Elements of a building that enclose the internal space, including all external materials, windows, and walls.

***Exhaust Air.*** Air removed from a portion of a building and not reused.

***Fan, Airfoil.*** Centrifugal fan used in general HVAC applications. Its 10 to 16 blades of airfoil contour are curved away from the direction of rotation.

***Fan, Axial.*** Fan that produces pressure through a change in the velocity of air passing through the impeller. Common types are propeller, tube-axial, and vane-axial.

***Fan, Backward Curved.*** Centrifugal fan used in general HVAC applications. Its 10 to 16 single-thickness blades are curved or inclined away from the direction of rotation.

***Fan, Cooling Tower.*** Two types of fans can be found in cooling towers: (1) axial fans used to draw air into and discharge that air out of the cooling tower and (2) centrifugal fans used to cool the water in the cooling tower via forced air.

***Fan, Forward Curved.*** Centrifugal fan primarily used in low-pressure HVAC applications. Its blades are curved or inclined toward the direction of rotation.

***Fan, Inlet Vane.*** Fan that controls airflow volume and pressure by automatically adjusting the position of vanes located at the air inlet.

***Fan, Return.*** Fan that returns air from a conditioned area.

***Fan, Supply.*** Fan that provides air to a conditioned area.

***Fan Pulley.*** A wheel with a grooved rim and a belt that transfers electrical energy from a motor shaft to mechanical energy on a fan shaft.

***Fenestration.*** Arrangement, proportioning, and design of windows and doors in a building.

***Filter, Final.*** Filter that removes fine particles from the supply airstream in an air-handling system.

***Filter, Line.*** Any filter located along the flow of a substance (water, refrigerant, air, gases).

***Filter, Pre-.*** Filter that removes debris from the mixed airstream in an air-handling system. Located upstream of the final filter.

***Fouling Factor.*** Performance measure for a condenser in which scaling and deposits are measured.

***Gaskets.*** Seals.

***Glass to Exterior Wall Ratio.*** Amount of glass on a wall compared with the total surface of the wall.

***Glazing.*** Glass set or made to be set in frames.

***GPM.*** Gallons per minute. Measure of flow rate.

***Harmonics.*** Distortion of input signals which causes an output signal to have frequency components that are integer multiples of an input frequency.

***Head.*** Pressure that a pump or fan has to work against in order for liquids to flow.

***Heat-Exchange Area.*** Area where heat is transferred from one medium to another.

***Heat Pump.*** Device that extracts heat from one substance and transfers it to another portion of the same substance or to a second substance at a higher temperature.

***Humidifier.*** Device that adds moisture to air.

***HVAC.*** Heating, ventilating, and air-conditioning.

***IEEE.*** Institute of Electrical and Electronic Engineers.

***IGBT.*** Isolated gated bipolar transistor.

***Impeller.*** The rotating element of a fan or pump, used to circulate the air or water.

***Internal Rate of Return.*** Compound interest rate at which the total discounted benefits become equal to total discounted costs for a particular investment.

***Inverter, Pulse-Width Modulated.*** Component of a variable-speed drive in which the DC voltage on the intermediate DC link is inverted into AC current or voltage at a frequency required to control the motor's speed.

***IRR.*** Internal rate of return.

***Isolation Transformer.*** Transformer used to separate an electrical device from a main power source.

***Kilowatt.*** Unit of power equal to 1,000 watts.

***Kilowatt Draw.*** Amount of electrical energy required to operate a piece of equipment.

***Kilowatthour.*** Unit of electric power equal to the work done by one kilowatt acting for one hour.

***kW.*** Kilowatt.

***kWh.*** Kilowatthour.

***Linkage.*** Mechanism that uses cranks, arms, rods, and slides to open and close dampers.

***Load.*** Power required to maintain an indoor design temperature over a range of outdoor temperatures.

***Luminaire.*** Complete lighting unit, consisting of one or more lamps together with a housing, the optical components to distribute the light from the lamps, and the electrical components (ballast, starters, etc.) necessary to operate the lamps.

***Manometer.*** Instrument used to measure the pressure of liquids and gases.

***Megawatt.*** One million watts.

***Megawatthour.*** A unit of electric power equal to the work done by one megawatt acting for one hour.

***Meter.*** Device used to measure and display or record data.

***Mixing Box.*** Component of an air-handling unit, in which air drawn from the building and air drawn from the outside are mixed to create a uniform airstream before reaching the heating and cooling coils.

***Nameplate.*** Manufacturer's data for a piece of equipment, imprinted on metal and affixed to the equipment.

***NEC.*** National Electric Code.

***NEMA.*** National Electrical Manufacturers Association.

***NIOSH.*** National Institute for Occupational Safety and Health.

***Nitrogen oxides.*** Chemical compounds that contain nitrogen and oxygen. They react with volatile organic compounds in the presence of heat and sunlight to form ozone, and are a major precursor to acid rain.

***Occupancy Sensor.*** Device that detects the presence or absence of people within an area and causes equipment to be adjusted accordingly.

***Orifice Plate.*** Device that measures the drop in pressure when fluid is forced through the plate.

***Outside Air.*** Air that is brought into a building from outdoors through a ventilation system and has not previously been circulated through an air handling system.

***Part-Load Conditions.*** Time when equipment is operating at less than design loads; represents the majority of the time equipment is operating.

***Payback, Simple.*** Measurement of the elapsed time between an initial investment and the point at which accumulated savings are sufficient to offset the initial investment.

***Peak Load.*** Maximum power required to maintain an indoor design temperature under the most adverse outdoor air conditions.

***Pneumatic Lines.*** Tubing that carries air.

***Power Factor.*** Ratio of real power to total apparent power.

***Pump, Chilled Water.*** Device that circulates chilled water.

***Pump, Condenser Water.*** Device that circulates condenser water.

***Purge Control.*** Device that regulates purging operations.

***Pumping Down.*** Process of removing the refrigerant from a cooling system.

***Purge Compressor.*** Device that removes air and water from refrigerant, then compresses and condenses the refrigerant and returns it to the system.

***PWM.*** Pulse-width modulated.

***R-Value.*** Thermal resistance value, a measure of the ability of a material to retard the flow of heat.

***Radiator.*** Device that provides warmth to a space through radiant or convective heat provided by either steam or hot water.

***Recommissioning.*** Process of performing maintenance and modifying equipment and procedures to enable a building's systems to operate at designed efficiencies.

***Refrigerant.*** Substance, such as air, ammonia, water, or carbon dioxide, used to provide cooling, either as the working substance of a refrigerator or by direct absorption of heat.

***RF.*** Radiofrequency.

***Roof to Building Envelope Ratio.*** Ratio of roof area compared with the total exterior area (walls and roof) of a building.

***Sequence of Operation.*** Consecutive series of operations.

***Setpoint.*** Desired temperature in a space.

***Shading Coefficient.*** Ratio of solar heat gain through a given glazing system to that of a standard pane of glass 1/8-inch thick under the same conditions.

***Sheave.*** Wheel or disk with a grooved rim used as a pulley.

***Slip.*** Difference between the frequency of the voltage applied to a motor and the equivalent mechanical frequency of the voltage applied to that motor.

***Space.*** Distinct area to which conditioned air is delivered.

***Sprays.*** Devices used to dispense water in the form of droplets into the airstream for humidification.

***Static Pressure.*** Condition that exists when an equal amount of air is being supplied to and removed from a space.

***Steam Trap.*** Valve that allows water condensate to flow from a steam supply line without allowing any of the steam to escape.

***Strainer Screen.*** Filtering device used in water-side systems to protect equipment from dirt, rust, and other particles.

***Submeter.*** Meter installed on a subsystem.

***Sulfur Dioxide.*** Heavy, colorless, pungent air pollutant formed primarily by the combustion of fossil fuels. It is a respiratory irritant and a precursor to the formation of acid rain.

***Supply-Air Diffuser.*** Device used to evenly distribute supply air to a space.

***Terminal Reheat.*** Type of air-handling system (commonly integrated with variable air volume and constant air volume systems) that maintains comfort in a building by cooling the air (typically to 55° F.) at the air-handling unit and then reheating the air near its point of use.

***Thermostat.*** Device, as in a home heating system, a refrigerator, or an air conditioner, that automatically responds to temperature changes and activates switches controlling the equipment.

***U-Value.*** Heat-transfer coefficient or thermal transmittance. The inverse of R-value; the time rate of heat flow per unit area under steady conditions from the warm side of a barrier to the cold side. Per-unit temperature difference between the two.

***UL.*** Underwriters Laboratories Inc.

***Variable Air Volume.*** Type of air-handling system that maintains comfort in a building by varying the quantity of air supplied through the building.

***Variable-Speed Drive.*** Device used to adjust the speed of an AC motor to match load requirements.

***VAV.*** Variable air volume.

***Volts.*** International System unit of electric potential and electromotive force.

***VSD.*** Variable-speed drive.

***Water Column.*** Common pressure measurement for air at low pressure (that is, below 1 pound per square inch).

***Water-Side Systems.*** Equipment used to supply heating and cooling for air-side systems. Includes pumps, chillers, boilers, and other devices.

***Winding.*** Conductive path inductively coupled to a magnetic core or cell.

***Zone.*** An distinct area of space to which conditioned air is delivered.