FAA
ENERGY MANAGEMENT HANDBOOK

April 1996

Environmental, Energy, and Safety Team
ANS-500

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PREFACE

The Environmental, Energy and Safety Team (ANS-500) is the program office responsible for implementation of AF's Energy Management and Conservation Program. The driving force behind AF energy conservation efforts is the Energy Policy Act (EPAct) of 1992 and Executive Order (EO) 12902, Energy Efficiency and Water Conservation at Federal Facilities. The EPAct of 1992 and EO 12902 require all agencies to reevaluate energy management and consumption in all federal buildings and facilities. Also, EO 12902 sets new and higher goals for reducing consumption over a longer period of time.

Efforts to conserve energy at the FAA's facilities can deliver a wide range of benefits, including reduced operational costs, improved environmental compliance, and enhanced workplace productivity and morale. It can also benefit the agency and the environment by reducing energy waste and its related pollution and cost.

The FAA's *Energy Management Handbook* is intended to assist regional and field personnel with implementation of a comprehensive energy management program. The information in this handbook has been obtained from a wide variety of sources. This handbook provides a basis for managerial, fiscal, and technical approaches to implementing and managing FAA energy conservation programs.

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CHAPTER 1. INTRODUCTION TO ENERGY MANAGEMENT

1.1 KEY CONCEPTS

- Energy conservation delivers a wide range of benefits, including dollar savings, reduced pollutant emissions, and improved energy security.
- Every energy manager faces the challenge of reducing energy use and energy costs as much as possible without jeopardizing mission capabilities or reducing the quality of life of FAA personnel.
- Because fully functional energy conservation programs need adequate funding and staffing, FAA energy managers need to convince top management of the cost savings and benefits that can be realized through energy conservation.
- Since the mid-1970s, the President and Congress have promoted energy efficiency in Federal agencies.
- In order to establish and maintain a successful energy program, the energy manager needs a keen understanding of both the technical and managerial aspects of energy management.

1.2 ENERGY MANAGEMENT

Energy management is a continuous planning process to accomplish the efficient use of energy. Properly administered energy management programs not only save money but conserve our national and world fuel resources. Energy Management may simply be described as:

The judicious and effective use of energy to maximize benefits and enhance competitiveness, without compromising mission critical needs, employee safety, and comfort.

Effective energy management requires goals and long-term economics planning. In order for it to succeed, the plan must have support at all levels of the organization. Continuous monitoring of energy conservation measures is required to provide feedback and ascertain savings. Implementation of a successful energy management program may involve a major upfront investment to obtain a demonstrable savings of 25 to 50 percent in the long-term period. Energy Management requires continuous updating

due to changing financial conditions and energy technologies.

1.3 BENEFITS OF ENERGY CONSERVATION

Energy conservation within FAA means improved energy management. Conservation does not mean simply turning off the switch, it means using energy more efficiently to achieve the same or an improved level of benefits at lower cost. Planned and practiced conservation helps facilities deal with resource limitations without reducing mission capabilities, productivity, or the quality of life for FAA personnel.

Energy conservation delivers a wide range of tangible and intangible benefits. Tangible benefits include dollar savings resulting from the improved operating efficiency of energy-using systems, as well as extended operational-life of the equipment. Less tangible national benefits include reduced pollution from energy generators, improved energy security, and lowered need for crude oil imports.

Energy efficiency benefits the local environment directly, helping FAA to meet their environmental goals. Less electricity consumption means less air pollution; a 10 percent reduction in U.S. electricity use would cut annual carbon dioxide emissions by over 200 million tons, sulfur dioxide emissions by 1.7 million tons, and nitrogen oxide emissions by 900 thousand tons. Energy efficiency helps our environment directly and indirectly by reducing or eliminating the causes of smog, acid rain, global warming, ozone depletion, and air and water pollution.

1.4 NATIONAL ENERGY GOALS AND POLICIES

Our Federal Government is the nation's largest consumer of energy. Data for FY 1991 indicates that the cost of total Federal energy consumption was $11.20 billion. The cost of energy consumption in its buildings and facilities alone was $3.7 billion. The FAA spends about $70 million annually for facility and building energy. Most experts agree that an aggressive drive to use energy more efficiently can significantly reduce those energy costs without any adverse mission impact. For example, the Electric Power Research Institute (EPRI) estimates that a 24 to 44 percent reduction in U.S. electricity use is technically feasible, although at 44 percent the reduction may not be cost-effective; the Rocky Mountain Institute estimates a fully cost-effective electricity savings of 75 percent. Combining electricity savings with

the potential for nonelectric energy savings, an overall reduction in energy use of 20 percent is not unreasonable and would result in large savings of funds for other pressing FAA requirements.

Since the mid-1970s, the President and Congress have promoted energy efficiency in Federal agencies. Table 1-1 summarizes the most significant legislation regarding Federal energy management. Although the policy emphasis has varied over the past 20 years, each statute and Executive Order represents a milestone in implementing the Federal Government's energy conservation strategy. Appendix A provides a summary of Federal energy legislation and Executive Orders. Appendix D contains Subtitle F—Federal Agency Energy Management of the Energy Policy Act of 1992 (P.L. 102—486) and the relevant portions of the National Energy Conservation Policy Act as amended by Subtitle F. Appendix B includes the recent Executive Order 12902 pertaining to Federal Energy Efficiency and the President's goal. These laws provide the foundation for FAA's energy management program.

1.5 FAA ENERGY CONSERVATION GOALS

As a fundamental basis of its energy policy, the FAA promotes energy efficiency and conservation in the NAS by:

> *...Designing, building, and operating energy efficient FAA system facilities and aircraft.*
>
> *...Encouraging R&D efforts for development and use of renewable energy resources in airway system facilities.*
>
> *(FAA Order 1053.2, Aviation Energy Policy)*

The FAA's energy conservation goals are based on goals established under Executive Order (EO) 12902, *Energy Efficiency and Water Conservation at Federal Facilities*. FAA's energy management program ensures that local initiatives and strategies will support national conservation goals.

EO 12902 mandates development and implementation of programs to:

- Perform prioritization surveys of all department facilities, conduct comprehensive facility audits for 10 percent of facilities each year, and implement both existing and new audit recomendations. This

goal will apply to facilities owned or managed by FAA, except when exempt of audit requirement by law. This goal also applies to facilities for which FAA pays the utility bills.

- Reduce energy consumption by 30 percent by FY 2005, based on data obtained in FY 85, measured in Btus per gross square foot.
- Increase energy efficiency for facilities by 20 percent by FY 2005, as compared to the 1990 benchmark.
- Significantly increase the use of solar and other renewable energy sources.
- Minimize the use of petroleum products at the facilities by switching to less polluting alternative energy sources.
- Designate one major building as a showcase for energy or water efficiency.
- Design and construct new facilities to minimize life-cycle costs through energy efficiency or water conservation.

Management of Energy Policy Compliance

A better understanding of FAA policies allows energy managers to define their management responsibilities and the importance of energy conservation tasks. Specific FAA energy policies are issued at headquarters, mandating full compliance from all organizations. FAA regional components develop their own policies and regulations based on Headquarters' policies. A few specific regulations apply to all FAA facilities. FAA regions follow those regulations which are contained in the Federal Property Management Regulations (Appendix C).

TABLE 1-1 SUMMARY OF SIGNIFICANT FEDERAL ENERGY MANAGEMENT LEGISLATION

Federal Energy Management Laws and Provisions
EPCA (1975) • Directs the President to: o develop mandatory standards for agency procurement policies with respect to energy efficiency; and o develop and implement a 10-year plan for energy conservation in Federal buildings, o including mandatory lighting, thermal, and insulation standards. • Requires that the Federal vehicle fleet meet corporate average fleet fuel efficiency standards.
DOEOA (1977) • Establishes "656 Committee" to strengthen energy conservation programs.
NECPA (1978) • Defines Federal Energy Initiative. • Establishes use of life-cycle cost (LCC) method. • Establishes publication of Energy Performance Targets. • Requires LCC audits and retrofits of Federal buildings by 1990. • Establishes Federal Photovoltaic Program. • Buildings exceeding 1000 square feet are subject to energy audits. • Establishes Federal Solar Program.
COBRA (1985) • Amends Federal Energy Initiative authorizing agencies to use shared energy savings.
FEMIA (1988) • Amends Federal Energy Initiative. • Allows Secretary of Energy to set discount rate used in LCC analysis. • Removes requirements that agencies perform LCC retrofits by 1990. • Establishes energy performance goals for Federal buildings, including a 10 percent reduction in building energy use by 1995. • Directs agencies to establish incentives for energy conservation. • Creates Interagency Energy Management Task Force on Federal energy management.

Notes: *EPAct = Energy Policy Act (1992). Public Law 102-486*
EPCA = Energy Policy and Conservation Act (1975). Public Law 94-163. (15 USC 753 and 42 USC 6201.)
DOEOA = Department of Energy Organization Act (1977). Public Law 95-91. (3 USC 19 and 42 USC 2201.)
NECPA = National Energy Conservation Policy Act (1978). Public Law 95-619. (12 USC 1451 and 42 USC 300.)
COBRA = Comprehensive Omnibus Budget Reconciliation Act (1985). Public LW 99-272.
FEMIA = Federal Energy Management Improvement Act (1988). Public Law 100-615. (42 USC 8201)
OMB = Office of Management and Budget
GSA = General Services Administration

Source: U.S. Congress. Office of Technology Assessment, *Energy Efficiency in The Federal Government : Government by Good Example?*, OTA-E-492, U.S. Government Printing Office, May 1991.

TABLE 1-1 SUMMARY OF SIGNIFICANT FEDERAL ENERGY MANAGEMENT LEGISLATION (....Continued)

Federal Energy Management Laws and Provisions
EPAct (1992) Subtitle F
• Requires that all energy and water conservation measures with Life Cycle Cost (LCC) paybacks of less than 10 years be installed in all U.S. owned Federal Buildings by January 1, 2005. • Contains provisions regarding energy management requirements, LCC methodology, budget treatment for energy conservation measures, incentives for Federal agencies, reporting requirements, new technology demonstrations, and agency surveys of energy-saving potential. • Authorizes GSA to receive rebates, incentive payments, or goods and services from utilities and deposit funds into the Federal Buildings Fund for use in energy management improvement programs. • Amends the NECPA on ESPC, gives agencies new authority to enter into energy performance contracts, and describes methodology of contract implementation. • Requires GSA and the Interagency Energy Management Task Force to hold 5 conferences in FY93 on energy management, conservation, efficiency, and planning strategy, and to hold biennial workshops thereafter. • Defines "trained energy manager" and requires Federal agencies to establish and maintain programs to train energy managers and to increase the number of trained energy managers. • Requires DOE to make available energy audit teams for Federal facilities and to establish programs to monitor implementation of energy efficiency improvements based on audit team recommendations. • Directs OMB to issue guidelines for accurately assessing energy use in Federal buildings or facilities to be used in agency reports to DOE. • Directs agency Inspectors General to assess compliance with existing energy management requirements and accuracy of reported energy-use and cost data. • Directs GSA, DoD, and DLA to identify energy-efficient products on the Federal supply schedules that offer significant potential for LCC savings. • Requires DOE to report to Congress on options for financing energy conservation measures, the investment required, and the use of revolving funds. • Directs agencies to establish criteria for improving energy efficiency in Federal facilities operated by contractors and to include such criteria in cost-plus, award-fee contracts. • Expands upon the activities and goals of Section 11 of EO 12759 dealing with Federal fleets. Amends the AMFA to include all types of alternative fuels and all light duty vehicles, and changes definition of fleet to "20 or more vehicles in metropolitan areas of more than 250,000 people"; mandates fleet requirements for new acquisitions to the Federal fleet; and requires use of commercial refueling facilities, if available.

Notes: EPAct = Energy Policy Act (1992). Public Law 102-486
EPCA = Energy Policy and Conservation Act (1975). Public Law 94-163. (15 USC 753 and 42 USC 6201.)
DOEOA = Department of Energy Organization Act (1977). Public Law 95-91. (3 USC 19 and 42 USC 2201.)
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Source: U.S. Congress. Office of Technology Assessment, *Energy Efficiency in The Federal Government : Government by Good Example?*, OTA-E-492, U.S. Government Printing Office, May 1991.

CHAPTER 2. ENERGY MANAGEMENT STRATEGY

2.1 KEY CONCEPTS

- FAA is committed to improved energy resource management in its facilities, while meeting mission requirements.
- An understanding of FAA energy policies and goals, and applied conservation technologies enables energy managers to define their management responsibilities and identify local energy conservation opportunities.
- Various features and systems contributing to a building's total energy use are interrelated, and these specific interrelationships among systems are unique to each building. Alteration of one factor will affect other factors. Therefore, an energy management program should be implemented in a specific sequence for maximum savings.
- A significant amount of energy can be lost by air infiltration and exfiltration through the building envelope.
- Energy is wasted when lighting systems provide more light than is necessary, lighting is poor quality, light is misdirected, and/or lamps and ballasts are inefficient.

2.2 ENERGY MANAGEMENT PROGRAMS: CHALLENGES AND OPPORTUNITIES

The purpose of energy management is to minimize energy consumption and costs while meeting all operational mission requirements and providing quality working conditions for FAA personnel. Energy management requires a careful balancing between efforts to use energy efficiently and meet quality of life requirements while insuring that primary mission requirements are met. Effective energy management strives to avoid conflicts between the two while achieving substantial energy reductions and cost savings.

Energy conservation is important to the mission of the FAA because it allows the more efficient use of limited resources. Its benefits include dollar savings resulting from the improved operating efficiency of energy-using systems, as well as extended operational-life of the equipment.

A major challenge facing every energy manager is to reduce unnecessary energy use and curtail energy costs as much as possible without jeopardizing mission capabilities or reducing the quality of life for FAA personnel. A functional energy management program must overcome obstacles like inadequate funding, limited vendor qualifications, personnel limitations, insufficient recordkeeping and maintenance procedures, and weak enforcement of building construction or performance standards. The energy manager must develop and orchestrate the implementation of an integrated energy conservation program suitable for the local mission. That program must involve every energy user at a facility, from management, down the chain of command to all personnel.

While some improved energy efficiency can be obtained at little or no cost, fully successful energy conservation programs need adequate investment funding and staffing. To obtain the needed resources, energy managers must convince top management of the cost savings and benefits that can be realized through energy conservation. Taking full advantage of energy conservation opportunities requires that management place a high priority on energy conservation projects and staffing. Convincing management to readjust resource priorities usually requires a well-planned energy program, effective "salesmanship," and a commitment of time to realize results.

The energy manager should have the expertise to pick the most effective energy conservation projects because the application of conservation technologies and their return-on-investment can vary widely. Numerous energy conservation opportunities exist at FAA facilities. To achieve the best energy and cost savings, those opportunities need to be ranked in terms of life-cycle costs. Poorly-conceived energy projects will generate poor returns on investment.

There are various methods of financing projects, including facilities and equipment (F&E) funds, energy savings performance contracting (ESPC), federal energy efficiency funds (FEEF), and demand-side management (DSM) programs. A detailed discussion of these funding sources is provided in Chapter 3.

Like all managers, energy managers must deal with uncertainty. For example, fluctuating energy prices change the return on investment of energy projects, which may require project reevaluation. Changing technologies tend to

make some projects more attractive, so energy managers need to stay abreast of changes in the energy field. Lighting and thermal storage are examples of technologies that continue to evolve quite rapidly.

Since there is no substitute for a well-trained, competent, and dedicated energy manager, professional development of energy managers is an important part of an energy program. Attendance at professional forums and seminars is a good way to exchange useful program management ideas, and to discuss field applications of existing and emerging technologies.

2.3 FACTORS AFFECTING ENERGY CONSUMPTION

Energy consumption is affected by the interrelationships among three basic systems—*energized*, *non-energized*, and *human*. When any system, or even any one of a system's components is changed, it is likely that system interrelationships will cause chain reactions that affect other systems or components.

Energized systems consume energy directly. They include the HVAC system, lighting, service water heating, elevators, and office equipment.

Non-energized systems do not consume energy, but do affect the amount of energy consumed by other systems. An example is a building's glazing system—that is, its windows and skylights. If the glazing system does not have adequate solar controls, much of the heat that radiates into the building through the glazing in the summer must be offset by the cooling system.

Human systems consist of the people who have anything to do with the building—those who manage it, those who operate it, those who maintain it, and those who use it. The actions and attitudes of these people have a great effect on energy consumption. For example, if not operated properly, even the most efficient energized systems devised will still waste energy.

Systems Interrelationships

Perhaps the most important concept to understand when considering energy use in existing buildings is that the various features and systems contributing to a building's total annual energy use are interrelated in significant ways and that the specific interrelationships among systems are

unique to each building. For example, a reduction in the building's lighting level affects the building's cooling load and demands on heating and humidity control equipment, which in turn affect the load demand on pumps, fans, boilers, and chillers.

A reduction in the heat produced by equipment on a lower floor may have a "ripple effect" on the floor above, as well as on adjacent zones—possibly an undesirable effect. Such interrelationships, which become more complex in larger and more elaborate buildings, are the reason why a facility's energy use patterns must be studied methodically and systematically. Interrelationships should always be kept in mind when considering the energy efficiency opportunities discussed in this manual.

Because of the interrelationships among the many factors determining a building's energy use, alteration of one factor, such as insulation, will affect other factors, such as air requirements for cooling. Similarly, a series of alterations will have a cumulative effect on the total building load which must be understood and accounted for in the conservation program. Therefore, to get maximum energy savings, an energy management program should be implemented in the following sequence:

- Implement operational energy efficiency options.
- Reduce building loads.
- Reduce distribution losses from the central plant to the terminal units.
- Improve the efficiency of primary energy conversion equipment.

Consider, for example, the "cumulative" effect of a reduction in lighting load through removal of lamps. This automatically reduces the cooling load and allows distribution flow rates to be reduced, which in turn reduces fan and pump energy consumption. Thus, a change in the building load will improve the efficiency of the distribution system even before specific improvements in that system have been considered, and it will affect the improvements that can be implemented.

The cumulative effect of loads becomes particularly significant in cases where the peak building load can be reduced. Distribution systems are designed to accommodate the worst possible conditions (the hottest or coldest days, when systems are operating at their peak), even though these peak loads occur for relatively short periods of time

(usually less than 5 percent of the year). Ductwork and fans are selected according to their capacity to meet peak load conditions. In many cases, these systems are not just selected for peak load capacity, they also operate at that peak load capacity all the time. Thus, if the peak building load can be reduced, the output of many systems can be reduced. The same rule applies to water distribution and pump sizes, cooling requirements, and minimum chilled water temperature. In each case, reduction of a peak building load will often lead to an even greater reduction in the distribution load.

Every building load, when changed, will likely have some impact on other loads. For example, changing lighting loads will probably increase heating energy use and decrease air-conditioning loads. Increasing the square footage of glazing and using perimeter dimming (daylighting) will reduce overall energy use because lighting energy use will decrease, and depending on the building's location and orientation, heating energy may remain the same. Therefore, building loads and energy use should be looked at from the total building perspective.

2.4 COMMON INEFFICIENCIES IN ENERGIZED SYSTEMS: AN OVERVIEW

This section provides an overview of how major energized systems typically cause energy to be wasted.

Building Envelope

A significant amount of energy can be wasted by air infiltration and exfiltration through the building envelope. Infiltration is outside air that enters a building through cracks and other openings in the building envelope, including open windows and doors. Exfiltration is conditioned air that is lost to the outside through the same openings. When conditioned air leaks out of a building, it must be replaced by newly conditioned indoor air. When outdoor air leaks in, it must be conditioned. In addition, heat transmission, which occurs when heat enters or escapes through the components of the building envelope, can create problems similar to those caused by infiltration and exfiltration.

Heating, Ventilation, and Air-Conditioning

A building's HVAC system usually consumes more energy than any other, making it the most expensive to operate, particularly if the system is more than 20 years old.

A typical cause of HVAC system energy waste is oversizing. Some HVAC systems may be inefficient by design, regardless of size. This is especially true of systems that provide simultaneous heating and cooling, such as terminal reheat systems. Such systems are inefficient because they use energy to lower air temperature and then consume more energy to raise the temperature of the same air.

Another major energy concern is excessive ventilation. Unless heat recovery equipment is installed, all air that is exhausted by the ventilation system takes with it all the energy used to condition it.

In terms of non-energized systems, insulation on ducts and pipes in the HVAC distribution network can deteriorate over time, causing unwanted heat gain and loss.

Human systems also contribute to HVAC system energy waste. Careless use of doors and windows contributes to infiltration and exfiltration problems. Improper maintenance results in inefficient operation.

Lighting

Lighting typically accounts for the largest portion of a building's overall electricity bill. The lighting system in a building may be wasting energy by:

- providing more light than is necessary for the task being performed in the space,
- providing poor-quality lighting (that is, excessive glare and veiling reflection, poor color rendering and lamp color temperature),
- providing light that is misdirected, and
- using inefficient lamps and ballasts.

People also have a great effect on lighting efficiency. Lighting left on when it is not needed wastes a great amount of energy. In addition, when lighting systems are not maintained properly, for example, when bulbs, lenses, and reflectors are dirty, light from the source can be wasted because it is absorbed by the dirt. Because lighting systems present many complex interrelationships, changes should be studied carefully.

Office Equipment

Because of the growing use of computers, fax machines, and photocopiers, office equipment is now the primary

cause of increasing electricity consumption in commercial buildings. In its 1994 Annual Energy Outlook, the Energy Information Administration forecasts a 150-percent increase in energy use by office equipment between 1990 and 2010. Most of this electricity is wasted given the fact that the majority of office equipment is not in use during much of the time it is turned on. New office equipment has often been redesigned to save energy by entering a low-power standby mode when not in use.

Service Hot Water

A building's service, or domestic, hot water system consists of the components that generate, store, distribute, and dispense hot water. Depending on the amount and end uses of the hot water, this system can be a major source of energy waste, and relatively minor adjustments may achieve substantial savings. For example, if service hot water is used primarily for hand washing, a storage tank temperature setting of 105°F or less usually is adequate. In many buildings, however, the original factory setting of 140°F has not been changed since the unit was installed. For seldom used or remote washrooms, consider using point-of-use or instant-on water heaters.

The most obvious energy waste associated with hot water is a dripping hot water faucet that is not reported and repaired in a timely manner. In addition, many older types of faucets are inefficient and waste hot water.

Electrical Systems

Many building electrical systems—for example, elevators, escalators, water coolers, and vending machines—run more than necessary. Many electric motors are old and inefficient. In addition, many building owners pay too much for energy because they cannot control demand for electricity during peak hours. Low power factors increase losses in electrical distribution and equipment and also reduce the load-handling capacity and voltage regulation of the building's electrical system. Older transformers are also inefficient.

2.5 HOW AN ENERGY MANAGEMENT PROGRAM CAN HELP

Energy management is an ongoing process. It will more than likely be implemented in phases, and analysis and improvement will no doubt continue long after the initial major efforts are complete. Regardless of economic fluctuations, all times are right for using energy productively

and efficiently. Energy management is a matter of cost, remaining competitive, and perhaps even survival.

Practicing better energy use involves the entire facility community, and the challenge is influencing and motivating everyone. The benefits are many. From a national standpoint, effective energy management promotes economic growth, enhances the environment, and improves energy security. From the standpoint of a facility manager, energy management means reduced costs without reduced comfort levels, more efficient operations, a competitive edge, and a building with increased value. From the point of view of an individual facility energy manager, operating engineer, or maintenance supervisor, energy management presents a personal challenge that can make the job more interesting and stimulating, an opportunity for recognition for a job well done, and greater knowledge in an important professional area. In short, no matter what a particular point of view may be, one will find that energy management is good business practice.

2.6 PLANNING THE ENERGY MANAGEMENT PROGRAM

The purpose of energy management is to minimize energy consumption and costs while meeting all operational mission requirements and providing quality working conditions for FAA personnel. Energy management requires a careful balancing between efforts to use energy efficiently and meet quality of life requirements while insuring that primary mission requirements are met. Effective energy management strives to avoid conflicts between the two while achieving substantial energy reductions and cost savings.

In order to establish a successful energy program, the energy manager must have a keen understanding of both the technical and managerial aspects of energy management. The technical aspects require a good understanding of physical energy systems and the development of engineering solutions to increase efficiency. The managerial aspect requires the ability to communicate with people, to establish an effective organization, and to shepherd projects from plan through to completion.

To be successful in reducing energy use, pollution, and costs, an energy management program must be carefully planned. Planning is a logical sequence of steps that begins with a commitment to positive change, evolves into carefully considered action, and continues with the

monitoring of results and additional enhancements. The basic steps in the planning process are as follows:

- Obtain the commitment and support of all those involved.
- Organize the energy management team.
- Provide a foundation of background information by evaluating energy purchases, establishing an energy use index (EUI), and assembling other data.
- Conduct an energy survey/audit to identify energy efficiency opportunities (EEOs).
- Develop the energy management plan by establishing priorities and formulating schedules, budgets, and goals.
- Implement, promote, and monitor the plan.

Details on most of the above described steps are provided in the following sections.

2.7 RECOMMENDED STRATEGY FOR ACHIEVING FAA ENERGY-USE REDUCTION GOALS

Energy managers should define a strategy for implemention of an energy management program which is designed to improve energy efficiency and eliminate energy waste. Under guidance from Headquarters, energy managers can establish the following priority energy programs to help FAA achieve energy-use reduction goals:

- ***Establish "energy awareness" programs.*** Awareness programs teach energy users to eliminate energy waste without diminishing the quality of their working conditions. Awareness encourages users to develop simple, cost-effective energy habits such as turning out lights, maintaining reasonable room temperatures, and keeping doors and windows closed. Such programs require no-cost and low-cost measures, yet offer a high energy savings potential and peak performance from the existing systems. See Chapter 8 for details.

- ***Retrofit energy systems.*** Retrofits provide technological improvements to existing buildings and equipment. Energy managers should implement installation of efficient lighting systems and equipment, and compile a database of quality information, equipment, and suppliers relevant to the area of jurisdiction. Detailed energy efficiency

opportunities (EEOs) for various energy systems are discussed in the following chapters.

- ***Replacement***. Replacement is the installation of high-efficiency equipment when existing equipment wears out. In addition, inefficient equipment should be replaced prior to its scheduled replacement time if economical.

- ***Load shifting***. Load shifting of electrical loads away from peak demand periods saves money when the local utilities impose "demand charges" based not just on total kilowatts per hour (kWhs) used, but also on the highest kilowatt (kW) demand over a certain period. Chapter 17 contains more details.

- ***Implement energy conservation investment projects***. FAA provides two different sources of funding for energy conservation projects which have either a rapid payback, or a simple payback of 10 years or less. The majority of the energy conservation program is funded from facilities and equipment (F&E) funds. Part of the energy conservation program is funded from OPS funds. See Chapter 3 for details.

- ***Participate in public utility programs***. FAA energy managers are strongly encouraged to participate in energy utility conservation programs known as demand-side management (DSM) when and where such programs are offered by regulated public utilities. See Chapter 7 for details.

- ***Implement energy savings performance contracting*** (42 U.S.C. 8287). Each FAA region is encouraged to initiate energy savings performance (ESP) contracts every year. Headquarters will address the policy of developing a simplified contracting process, including development of contractor prequalification standards and selection procedures in accordance with 10 U.S.C. 2865. See Chapter 6 for details.

- ***Increase use of alternative, renewable, and clean energy***. FAA energy managers are encouraged to use alternative, renewable, and clean energy sources wherever such use is cost-effective over the life of the facility. The use of solar and other renewable energy is encouraged by 10 U.S.C. 2394(a) and 10 U.S.C. 2857. All FAA regions are encouraged to participate in DOE demonstration programs when

participation is cost-effective and compatible with the FAA's mission. See Chapter 20 for details.

- ***Implement energy efficiency opportunities for various energy systems in the FAA facilities.*** Energy managers, under guidance from Headquarters, should assist development and implemention of a plan to reduce overall energy use in buildings. For the construction of new buildings and facilities, the minimum requirements for energy management systems and design standards outlined in 10 CFR Part 435, 110 must be addressed. Identification and implementation of energy efficiency opportunities (EEOs) for various building systems is dicussed in the following chapters.

- ***Procure energy efficient products.*** FAA regions, under guidance from Headquarters, should select for procurement the most efficient energy products (e.g., heating, ventilation, and air-conditioning (HVAC) components, lighting systems, and office equipment) based on their life-cycle-cost effectiveness.

- ***Implement preventive maintenance program.*** The goal is to improve operations and maintenance (O&M) for facilities and energy systems, and to provide related training to increase efficiency in the production and use of energy. Equipment maintained routinely runs more efficiently, with lower operational costs and maximum reliability. Chapter 12 provides details.

- ***Apply Energy Management and Control Systems (EMCSs).*** Congress has been particularly interested in the application of energy management and control systems at federal facilities. Energy managers ensure that this technology is given comprehensive application review, that all new and existing system expansion applications found to be cost-effective are diligently pursued, and that installed systems are provided necessary operations and maintenance support to maintain efficiency and resultant savings. EMCS implementation using ESP contracts, which provide continuous operations and maintenance through the contract terms, is an option to ensure adequate operations and maintenance support. A detailed explanation is provided in Chapter 19.

CHAPTER 3. ECONOMIC ANALYSIS AND BUDGETING

3.1 KEY CONCEPTS

- Low-cost and moderate-cost projects play an important role in an effective energy program.
- Ultimately, facilities can reach their full energy savings potential only by investing in retrofits and new equipment, particularly in administrative and industrial facilities.
- Experience has shown a tendency for actual savings to fall short of engineering projections.
- Energy Policy Act (EPAct) of 1992 recommends three separate funding mechanisms for meeting its goals: energy savings performance contracting (ESPC); the Federal energy efficiency fund (FEEF); and demand-side management (DSM) programs.
- The energy manager must understand how the budget process works in order to obtain the necessary funds to implement energy projects.

3.2 INTRODUCTION

Economics play a major role in determining which energy efficiency options will be included in an energy management plan. Economics also heavily influence the order in which the options will be implemented. Once the energy management program is in place, actual costs tend to be the primary gauge in determining the program's success.

This chapter explains life-cycle cost analysis and describes different ways to finance energy efficiency improvements.

Fiscal Elements of an Energy Conservation Program

Most conservation methods require some level of financing. Implementation of available cost-effective technologies for conservation range from low-cost to high-cost. For example, a retrofit program could include low-cost methods such as installation of compact fluorescents, water heater insulation, and minor weatherization. Moderate-cost programs could include attic insulation and infiltration reduction. The most costly measures include complete weatherization or installation of high-efficiency HVAC equipment.

Low-cost and moderate-cost projects play an important role in an effective energy program. Depending on their current status, incremental improvements to any existing system can often achieve potential savings of about 15 percent.

A number of more expensive projects are usually needed to reach a facility's full energy-saving potential. Once a facility has developed savings momentum with an effective awareness program, together with improved maintenance and the implementation of low-cost retrofit projects, the accumulated savings can provide the money needed for more substantial engineering projects.

Generally, the more resources devoted to energy efficiency the greater the savings. For example, evaluations of utility-sponsored energy conservation programs have found that awareness programs alone achieve relatively low levels of energy savings; they need to be followed up with retrofit projects, equipment replacements, and load-shifting. Information-only programs generally achieve energy savings of 2 percent or less. Audits alone, without the accompanying installation of energy saving measures, achieve savings of about 3 to 5 percent.[1]

While improved energy-user awareness can increase energy savings slightly, facilities can only reach their full savings potential by investing in energy-conserving retrofits and new equipment, particularly in administrative and industrial facilities.

The implementation of low to moderate-cost measures results in greater savings than information campaigns or audits alone. Thus, an awareness program must be accompanied by retrofits to yield substantial savings. For instance, utility experience has found that a program with rebates to customers averaging about 30 percent achieved savings of only 2 percent; a program that offered 75 percent rebates achieved a 12 percent savings rate; and a program with no-interest loans (equivalent to a 100 percent rebate) achieved 17 percent savings.[2] Additional differences in promotion and implementation may also have affected the savings rate differences.

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[1] S. Nadel, Electric Utility Conservation Programs: A Review of the Lessons Taught by a Decade of Program Experience," *State of the Art of Energy Efficiency: Future Directions*, American Council for an Energy-Efficient Economy (1991), pp. 61—104.

[2] Nadel, op. cit.

3.3 ECONOMIC ANALYSIS

Management can apply various quantitative tests to any prospective investment to help determine if it is financially worthwhile. The most common of these tests, life-cycle costing, includes analysis of savings-to-investment ratio (SIR), discounted payback period, and internal rate of return (IRR).

Life-Cycle Costing

For any energy efficiency project, life-cycle costs must be analyzed to determine the payback period. Life-cycle costing methods provide the major benefit of considering all costs of a product, device, or system that accumulate over its useful life and taking into account the time value of money. In other words, the analysis considers the cost over the life of the system, rather than just the initial equipment cost. Typical costs included in the analysis are those to purchase, install, maintain, and operate the energy efficiency option. By using life-cycle costing techniques, it may be shown that a product that is twice as expensive as another actually may be only half a expensive on a life-cycle basis.

Specific elements of life-cycle costing can be applied for different purposes. For example, it can be used to determine any of the following:

- Whether it is better to repair an old item or replace it with a new one.
- Which of two or more similar items is less expensive over the life cycle.
- Which of two similar energy-saving systems, such as different types of insulation, will be the most cost-effective (best buy for the money spent).
- Which of two similar energy conservation measures is the best investment, given a limited budget.

Life-cycle costing techniques must be used for energy-efficiency projects in federal government buildings, and life-cycle costs must be analyzed to determine if the payback will exceed 10 years. All options with payback periods of 10 years or fewer must be considered.

Several software packages have been developed to perform life-cycle costing analysis. The National Institutes of

Standards and Technology have developed the Federal Building Life-Cycle Cost (BLCC) computer program. It is available free of charge and is specifically written for Federal agencies (Contact the Computing and Applied Mathematics Laboratory, U.S. Department of Commerce, National Institute of Standards and Technology, Gaithersburg, Maryland 20899-1000; telephone 301-975-2000).

BLCC provides economic analysis of proposed capital investments that are expected to reduce long-term operating costs and maintenance of buildings or building systems. Two or more competing designs can be evaluated to determine which has the lowest total life-cycle cost. Or, a project can be compared against a "do-nothing" base case where no capital improvements are made.

BLCC is especially useful for evaluating the costs and benefits of energy and water management projects in buildings. It also calculates the following:

- Simple payback – calculated by dividing initial investment by annual savings after taxes. The smaller it is, the better.
- Savings-to-investment ratio – calculated by dividing savings over the life of an investment described in today's dollar value by initial investment. Savings-to -investment values should be greater than 1.
- Adjusted internal rate of return – the interest rate represented by the cumulative savings compared to the initial investment.
- Net savings-calculated by subtracting the life-cycle cost of the existing option from the life-cycle cost of the investment.

3.4 POTENTIAL ENERGY SAVING TARGETS

Estimates of potential cost-effective energy savings vary.[3] In addition, the range and variety of energy conservation technologies can seem daunting. Nevertheless, energy efficiency experts, including those at the EPRI, Lawrence Berkeley Laboratory, and the Rocky Mountain Institute, have reached consensus on some of the most promising areas for energy savings.

[3] S. Nadel, op. cit.

Electricity offers one of the most tempting targets for increased efficiency. For FAA, as for the United States in general, the biggest potential electricity savings are concentrated in the following few areas: lighting, motors, and space cooling.

Lighting Savings

Lighting uses about 25 percent of all U.S. electricity; light fixtures use 20 percent directly while cooling equipment uses another 5 percent to counteract unwanted heat. Efficient lighting hardware and lamps are now available that can save from 55 to 90 percent of that electricity. These devices produce the same amount of light as older systems while using less power. They can also provide less glare, less noise, and more pleasant color. Such improvements provide additional benefits in the form of improved quality of life and higher productivity. Additional lighting improvements include "daylighting" sensors that adjust lamp output in sync with daylight conditions and "occupancy" sensors that automatically turn off lights when rooms are vacated.

Motor Savings

Electric motors consume 65 to 70 percent of U.S. industrial electricity and offer the next best savings opportunity. Motor system retrofits and replacements are highly cost-effective because the typical capital investment cost of an electric motor is only a few percent of its total life-cycle operating cost; most of that latter cost is in annual electricity use. Modern electronic variable-speed drives and high-efficiency motors provide about half of the potential electric motor savings. The other half comes from improvements in the choice of motors, better maintenance, improved pumps, and other efficiency "tune-ups."

Space Cooling Savings

Administrative buildings use almost half of their electricity for space cooling and its associated air handling. Systematic efficiency improvements to existing cooling systems can reduce building energy use by as much as 50 percent. A side benefit of increased cooling efficiency is a reduction in peak load and thus lower demand charges. The greatest potential savings come from properly-sized, high-efficiency water pumps and fans. In particular, fans and fan motors in air-handling systems are often oversized. Leaky ducts, dirty filters, stuck dampers, and poorly-operating controls also

reduce fan efficiency. In addition, modern high-efficiency compressors exist that use 30 percent less energy than conventional compressors. Another approach to reducing cooling costs is to reduce cooling load. Cost-effective methods include modern glazing and window films that reduce solar heat gain inside the building. Efficient lighting also reduces cooling load.

Savings Projections

One must be careful about overly optimistic savings projections. Actual savings often fall below prior engineering estimates. It is almost a general law of energy conservation that engineering estimates overstate actual savings more often than not; apparently, it is easier for actual implementation to fall short of the theoretical savings level than for savings to exceed that level.

3.5 FINANCING OPTIONS

Although an investment in energy efficiency may make perfect economic sense on paper, budgetary concerns could stand in the way. In such cases, management assistance is needed to identify alternative financing strategies. Financing for energy efficiency improvements is available from a wide variety of sources. These include energy service companies, equipment manufacturers, management companies, leasing corporations, finance companies, investment brokers, and utilities.

The source of financing usually depends on the size of the project or the type of financing option being considered. Many different types of financing options are available.

A region has several sources of potential financing:

1. Internal financing from:

   - Facilities and Equipment (F&E) funding,
   - Operations (OPS) Funds

2. External funding from:

   - Energy Savings Performance Contract (ESPC).
   - FEEF (if funds are available), the energy grants program created by DOE's Federal energy management program (FEMP) office.
   - Utility demand-side management rebates or subsidies.

3.6 INTERNAL FINANCING: FAA BUDGETING FOR ENERGY PROGRAMS

Internal financing is usually used for relatively simple and inexpensive projects with payback periods of 2 years or less. With internal financing, costs and risks are assumed by the agency. At the same time, the agency reaps all benefits and savings. The energy manager contemplating using internal funds to finance a project should consider the availability of funds, the rate of return for the energy efficiency project versus the rate for alternative investments, and the risks involved.

Understanding the FAA Budget Process

The energy manager must understand how the budget process works to know how to plan and program energy projects to obtain the necessary funds. For their programs to survive the budget process, energy managers must develop strong justifications for those programs.

Each FAA organization (office, service, etc.) prepares a budget at least two years in advance of the actual appropriation fiscal year. The regions are given an opportunity to submit their budget requests each year. Once the regions submit their budget requests, the appropriate headquarters organizations review and approve the requests, and then prepare their own budget which contains the regional budget requests. This regional budget requests may be either changed, approved, disapproved, or deferred to future years by the appropriate headquarters organization.

The headquarters organizations forward their budget requests to the Office of Financial Services for review and approval. Again, many of the headquarters organizations budget requests will be scrutinized and either approved, changed, or dropped in the budget submittal to OST. This review and approval process is repeated by the OST and OMB staffs during preparation of the President's budget submission to Congress.

Congress has the final authority for approving DOT's/FAA's budget requests and for appropriating the funds. Once Congress authorizes funds, it is up to DOT/FAA to spend the money as it sees most appropriate, unless Congress specifically attaches conditions or instructions on the use of the funds. The authority to obligate or spend appropriations will in turn be delegated down to the organizations through the reverse order of the budget-building process.

In most cases, an organization's final funding appropriations are less than its initial budget request. Energy managers must work at both ends of the budget process to ensure adequate funding for energy projects. Energy managers must develop good economic justifications for energy projects during the budget-building stage as well as during the funding-disbursement stage. Normally, organization managers have the authority to decide how the appropriated funds are to be spent. This is one of the major reasons why a manager's support for energy conservation programs is so critical to their success.

Capital Investment Plan

The FAA's Capital Investment Plan (CIP) process provides a mechanism for defining plans and strategies that the FAA will pursue in addressing the primary concerns of the NAS. The Facilities and Equipment (F&E) Appropriation provides the resources for the modernization and improvement of air traffic control and airway facilities services as set forth in the CIP. Both the CIP and the F&E Appropriation Call for Estimates processes provide existing mechanisms for defining program activities and ranking/prioritizing among those projects.

Sources of Funding

There are several different funding sources available to support energy conservation projects. Specific procedures must be followed to obtain funds from each funding source. Detailed explanations of how to build the budget and how to do project programming for these funding sources are beyond the scope of this Handbook. These different funding sources give energy managers some idea about when and how to use a funding source given the nature of the project (e.g., scope of project, type of building, work classification, and payback potential). The funding sources are described in the paragraphs below.

Facilities and Equipment (F&E) Funds: The majority of the energy conservation program is funded from F&E funds. These are the same funds that pay for construction or renovation of facilities, purchase of equipment, occupational safety/health (OSH) and environmental compliance needs, etc. Organizations are allocated a portion of F&E dollars in the beginning of each quarter of a fiscal year to carry out assigned missions. Managers have authority and flexibility in deciding how these F&E funds are to be spent.

Even when F&E funds are earmarked for energy conservation efforts, managers can reallocate some of the funds to other priorities as they see fit. This is the primary reason for gaining the managers's strong support for energy conservation programs. In a declining budget environment, it is easy for F&E funding for energy retrofit projects to be deferred in favor of requirements which are more essential to mission accomplishment.

Operations (OPS) Funds: Some of the energy conservation program is funded from OPS funds. OPS funds pay for day-to-day operations of FAA organizations and facilities, and include such programs as air traffic control, systems maintenance, etc. As with F&E funds, OPS dollars are allocated to organizations in the beginning of each quarter of a fiscal year to carry out assigned missions; and managers can use their discretion in using OPS funds, or reallocating these funds to other priority mission requirements.

3.7 EXTERNAL FINANCING

Under external financing mechanism, energy savings performance contracts or leasing agreements are two options increasingly being considered for larger projects. In addition, many utilities are offering incentives for installing energy-efficient equipment. These include financing for feasibility studies, rebates and discounts, design grants/assistance and low-interest loans.

Energy Savings Performance Contracting

Energy Savings Performance Contracting (ESPC) provides an alternative funding source using private-contractor financing for initial investments in energy projects. Under an energy savings performance contract, an energy service company pays for virtually everything that is needed to make the building more energy efficient – including the facility survey and the purchase, installation, operation, and maintenance of equipment. The owner and the service company then share the energy cost savings that result from the implementation of these energy-saving measures. Based on an agreed-upon formula, the owner pays the service company a portion of the savings each month during the term of the contract, which many be up to 25 years. After the contract expires, the owner retains the equipment that was installed and keeps all the cost savings.

Energy savings performance contracting provides a means for federal government agencies to meet their energy-use

reduction goals without making any capital expenditures. The President's March 8, 1994, Executive Order encourages the use of innovative financing mechanisms such as ESPC. The Department of Energy has developed model procurement documents for use by federal agencies seeking these types of contracts.

From successful implementation of ESPC projects, participating regions can generate a substantial revenue from a share of savings paid by ESP contractors. The revenues from ESPC projects are then available to be re-invested for additional energy conservation projects. Earned ESPC savings can be an excellent supplemental funding source for generally under-funded energy F&E accounts. Many low-cost maintenance-related projects are good candidates for earned ESPC funding. Details are available in Chapter 6.

Federal Energy Efficiency Fund

Federal Energy Efficiency Fund (FEEF) was established by the Energy Policy Act of 1992 to improve energy efficiency in federal facilities, and is disbursed by DOE under its Federal Energy Management Program (FEMP). The fund provides grants to federal agencies to implement energy efficiency and water conservation projects. The FEEF budget was zeroed out for FY 96 and is unknown for future years. However, DOE has issued guidelines to agencies to explain how to submit proposals for funding if appropriations become available for fiscal years beyond 1996. Priority for funds is given to those agencies that have not received direct appropriations from Congress for projects. DOE conducts a competitive assessment based on cost-effectiveness, energy and cost savings, amount of agency funds allocated to energy projects, amount leveraged from non-federal funds and other factors set by DOE. Additional details are contained in Chapter 5.

Energy Utility Programs

Public utility-sponsored programs, such as demand- side management (DSM) programs, encourage energy-efficiency improvements by offering rebates and other subsidies to their customers for energy-efficient technologies. Many DSM programs are run by electric utility companies that see improved energy-efficiency or load shifting as a means of avoiding expensive new plant construction. Utilities subsidies are provided either as up-front capital costs

needed for a specific efficiency project in advance, or as a rebate once the technology has been installed.

Many utilities lower the initial cost of energy-saving equipment by offering rebates or discount coupons. The amount of the rebate depends on the type of equipment installed. Low-interest loans also are being offered by many utilities for procurements of energy-efficient systems and equipment. More details are provided in Chapter 7.

CHAPTER 4. ENERGY MANAGEMENT TEAM CONCEPT

4.1 KEY CONCEPTS

- Energy managers should recruit assistance for energy conservation tasks from various organizations or offices. Organizing a regional Energy Management Team (EMT) is the first step in sharing the workload.

- Before the active recruitment of members for the EMT, the regional energy managers (REM) should study the responsibilities of regional organizations and determine which organizations can be helpful to energy conservation.

- With approval from regional AF Division Managers and SMO's, energy managers can tap into the resources of regional and field organizations.

- Energy managers need to establish informal lines of communication with key staff members whose assistance is critical to implementing energy conservation projects.

- Using Federal Supply Schedules (GSA) for energy conservation equipment and material can streamline the procurement process.

4.2 TEAM-CONCEPT

Since the REMs alone cannot do all of the work required to achieve energy conservation goals, they must delegate tasks to others. Organizing an "energy management team" is the first step in sharing the workload.

Knowing how best to use the team is very important since very few facilities can afford to assign a dedicated, full-time facility energy coordinator. Also, there are energy conservation experts already available within existing facility organizations. Spreading energy conservation work among various organizations mainstreams the energy conservation program and makes those organizations more energy conscious. By using this team concept, REMs may orchestrate a successful energy conservation program.

4.3 REGIONAL ENERGY MANAGER

Selection of an REM is the first and most important step in building an energy management team. Behind any

successful energy conservation program there is usually one dynamic individual who takes the initiative to accomplish whatever is necessary.

Usually, energy management tasks are assigned as additional duties at the field level. REMs do not have staff of their own; therefore, they must rely on staff from various facilities to perform specific energy conservation tasks. Because of resource constraints and limited authority, an REM must gain strong support from facility managers. Without their support, it is almost impossible to implement a successful region-wide energy program; this requires broad participation from all organizations.

4.4 REGIONAL ENERGY MANAGEMENT TEAM

Each region has a clear organizational structure that defines authorities, spans of control, and responsibilities. Understanding a region's organization is important in communicating energy conservation program goals to the energy team because the REM must draw personnel from various organizations to support region-wide energy programs.

The function of the EMT should be an advisory one rather than a corporate decision-making one. The EMT is a good forum in which to propose and evaluate ideas. It acts as a kind of "sounding board" before decisions are made. Attempts to use the EMT as a decision-making body create an unnecessary administrative burden that will slow down energy conservation efforts. Through the energy management team channels, energy managers can have informal access to all levels of management to help support energy conservation efforts.

Energy Management Team Member Organizations

Before starting to actively recruit members for the EMT, the energy manager should study the responsibilities of regional organizations and determine which organizations can be helpful to energy conservation. Representation from the following organizations may be considered for the EMT:

- Accounting Division
- Budget Division
- Logistics Division
- Airways Facilities Division
- Air Traffic Division

RESPONSIBILITIES RECOMMENDED FOR REGIONAL ENERGY MANAGER (REM)
Manage and direct the implementation of the FAA Energy Program in the Region. Coordinate with facility energy coordinators (FEC) for assistance in accomplishing the roles and responsibilities of REM. Assist regional AF Division Manager in appointment of a regional energy management team (EMT). This team consists of personnel specializing in environmental, OSHA, and engineering, and acts as an advisory committee for the energy program implementation. Provide guidance on concepts and requisites to integrate the energy program with other FAA programs without endangering environmental, OSHA, and mission safety. Integrate energy conservation considerations as early as practicable into the planning and execution of all projects throughout the region. Interact with stakeholders to avoid mission conflict. Ensure that program and budget requests identify resources required to implement the energy program in accordance with the applicable Executive and FAA Orders. Assist Headquarters (HQ) in identification of regional facilities exempt from meeting the requirements of the energy program, based on criteria developed for categorical exemption from regulatory requirements. Recommend/assist HQ in the selection of facilities for energy surveys and audits. *continued.....*

- Management Systems Division
- Human Resources Management Division, and
- Major energy users.

4.5 SYSTEMS MANAGEMENT OFFICE (SMO)

SMO managers play a role in the implementation of energy and water conservation measures for the entire domain under their jurisdiction. In real life situations, the SMO manager has neither the time, nor the knowledge, to manage or oversee day-to-day energy and water conservation activities. The SMO manager may assign a facility energy coordinator (FEC) to track the progress of all energy conservation activities and periodically inform the REM.

RESPONSIBILITIES RECOMMENDED FOR REGIONAL ENERGY MANAGER (REM)

..continued

Provide technical information, guidance and advice to regional and field offices on all aspects of Energy Program compliance, including information on new developments and requirements related to energy issues.

Periodically monitor location and functional energy conservation goals, programs, progress toward achieving goals, and resources assigned to achieve goals.

Review monthly energy consumption and efficiency of each regional facility against standards. Investigate variations and identify unfavorable trends so that corrective action can be recommended.

Provide annual energy conservation recommendations to obtain challenging and achievable energy conservation goals for all locations and functions in the region.

Provide forecasts of energy conservation projects to HQ for input to long-range energy conservation planning for all regional locations.

Provide support to regional facilities for data compilation and reports generation in the Energy Management Reporting System (EMRS).

Identify, review, and advise HQ of potential Energy Savings Performance Contracting (ESPC) opportunities. Provide facility-specific information pertinent to ESPC at the request of HQ.

Ensure that energy program documentation meets applicable requirements, and review such documentation. Reviews include, but not limited to:

- Applications and associated documentation for Federal Energy Efficiency Fund (FEEF) grants from DOE.
- Documentation for requesting funds from HQ.
- Project plans and specifications.
- Annual report to the Secretary and Congress, as required by the Energy Policy Act (EPACT).
- NEPA documentation for major Energy Program related projects.
- Energy Savings Performance Contracting (ESPC) for efforts related to the region.
- Quarterly status report to HQ.
- EMRS reporting.

Participate in, or designate an alternate to attend, meetings convened to review and accept commissioning of energy projects. Serve as an advisor on questions related to compliance with the energy program.

Participate in monthly HQ telecon of all personnel participating in the energy program to share ideas and discuss problems/issues.

Provide input to quarterly national newsletter on energy program, highlighting current energy management activities in the regions, innovative energy conservation ideas, profiles of successful projects, etc.

The SMO manager sets the tone for energy conservation. Although the REM is responsible for coordinating and orchestrating energy conservation efforts, the SMO manager is the person who must make the sometimes difficult decisions to implement projects that will save energy. The SMO's strong support for energy conservation efforts will make a big difference in setting budget priorities.

The SMO manager should be informed and briefed about the energy program. To gain valuable support, REMs must convince SMO managers of the benefits of energy conservation.

4.6 FACILITY ENERGY COORDINATOR (FEC)

The SMO manager designates the FEC to implement the requirements of the energy and water conservation programs at the SMO and facility level. The primary function of the FEC is to operate in consultation with and under the guidance of the REM. However, the FEC reports to the SMO manager.

RESPONSIBILITIES RECOMMENDED FOR FACILITY ENERGY COORDINATOR (FEC)
Assist REM in implementation of the Energy Program at the facility level. Provide assistance to all field personnel in the implementation of the energy program requirements. Develop and communicate energy-saving techniques and ideas with the REM.
Develop, maintain, and update a file of agency energy policies and procedures, and advise the involved field level employees of any new or changed policy.
Assist REM in review and decision-making process. Conduct routine facility walk-throughs to gather information, as requested by REM, and compile it in the required format.
Organize documentation for applications and reports, and arrange for records retention.
Compile and maintain facilities' Energy Program records in a standard format.
Compile monthly EMRS report on energy consumption and efficiency of each facility according to regional standards. Assist REM in investigation of variations and identification of unfavorable trends.

CHAPTER 5. FEDERAL ENERGY MANAGEMENT PROGRAM (FEMP) OFFICE

5.1 KEY CONCEPTS

- Current Federal Energy Management Program (FEMP) agency-support activities include providing technical assistance, project financing, and assisting in new-technology demonstration.

- FEMP is continuously looking for new opportunities to improve Federal energy management through new initiatives such as solar and other renewable energy utilization, procurement of energy-saving products, and water conservation.

5.2 OVERVIEW

The Federal Energy Management Program (FEMP) office was established by the U.S. Department of Energy (DOE) in 1974 to provide direction, guidance, and assistance to federal agencies in planning and implementing energy management programs that will improve the energy efficiency and fuel flexibility of the federal infrastructure. Although important strides have been made toward energy efficiency since then, the potential for additional efficiency remains high.

5.3 APPROACH TO FEDERAL ENERGY MANAGEMENT: LEGISLATIVE REQUIREMENTS

The magnitude of the energy consumed and the potential for energy savings have been the basis for legislative and administrative efforts to increase energy efficiency in the federal sector. The legislative authority comes from the Energy Policy and Conservation Act of 1975; the National Energy Conservation Policy Act (NECPA) of 1978, as amended; and the Federal Energy Management Improvement Act of 1988. Several Executive Orders since 1976 give detailed direction to federal agencies.

Among the key legislative mandates for federal buildings are energy-efficiency standards and targets for reducing energy consumption. The current legislated goal is a 10% reduction from 1985 to 1995, but Executive Order 12759 issued in 1991 and the National Energy Policy Act of 1992 (EPACT) have set a new goal. The order and law require agencies to reduce energy use in federal buildings and facilities 20%

from 1985 levels by 2000. The Executive Order also requires agencies that operate fleets of 300 or more vehicles to reduce gasoline and diesel consumption 10% from 1991 levels by 1995.

To ensure that energy-efficient technologies are properly included in federal construction, procurement, and operations, the federal government is required to use life-cycle costing, allowing the evaluation of alternatives based on full life-cycle cost rather than merely on initial purchase cost.

5.4 CURRENT FEMP AGENCY-SUPPORT ACTIVITIES

Technical Assistance: FEMP helps agencies identify the best, most cost-effective energy efficiency, water-saving, and renewable energy projects through training, on-site audits, design assistance, and new technology applications. The FEMP program develops energy analysis and design tools to assist engineers and facility managers in evaluating energy-efficiency operations and establishing compliance with building standards. Such tools include computer-based models for building energy analysis and an analysis and design tool for lighting and large installation retrofits. FEMP also develops and conducts training courses for federal energy managers. Topics for these courses include life-cycle costing, financing, energy-efficient lighting, and integrated energy management techniques that consider both supply- and demand-side options and issues.

FEMP is establishing partnerships with energy industries, utilities, states, and organizations both within and outside DOE to increase the technical resources needed to meet program goals.

Project Financing: FEMP provides guidance to federal agencies on third-party financing and energy-saving performance contracting. In addition, it develops and documents methods for implementing shared energy savings programs based on pilot projects. An example of how federal agencies can help finance energy-efficiency improvements is the use of utility demand-side management programs.

FEMP uses three project-financing mechanisms to leverage existing Federal funds and private-sector resources to finance energy- and water saving projects.

- ***Energy Savings Performance Contracting (ESPC).*** ESPC is an alternative to the traditional method of making improve-ments in Federal buildings, which has been through the appropriation of capital funds. With an ESPC, Federal agencies contract with an energy service company that pays all up-front costs. In exchange the company shares the cost savings resulting from the energy improvements. Private companies will invest more than S1 billion in ESPC between 1995 and 2005.

- ***Federal Energy Efficiency Fund.*** The Fund was established by the Energy Policy Act of 1992 to improve energy efficiency in Federal facilities. The Fund provides grants to other Federal agencies to implement energy efficiency and water conservation projects. The grants enhance and leverage other funding sources. In fiscal year (FY) 1994, $6 million was available to agencies. In FY 1995, grants worth $8 million were set aside for agencies.

- ***Utility Incentives.*** FEMP works to ensure that Federal facilities served by public and private utilities receive financial and technical assistance from utilities. FEMP's utility incentive activities will provide more than $400 million for energy projects between FY 1995 and FY 2005 and may streamline procurement of energy efficiency technology.

New-Technology Demonstration: Usually, federal facilities managers will only install equipment that has been commercially available for several years. To hasten the penetration of energy-efficient technologies into the federal marketplace, FEMP is working with other agencies and equipment manufacturers to provide federal test bed demonstrations where operating performance can be evaluated in realistic applications that could lead to widespread use.

5.5 ANALYSIS & REPORTING

One of FEMP's primary responsibilities is to coordinate and report to Congress on interagency activities that achieve Federal energy management goals. FEMP serves as the lead for coordinating the activities of two interagency committees to address policy and technical issues associated with Federal energy management. To support agencies, FEMP collects data on energy use in Federal agencies and transfers information on energy and water

resource management within the Federal and private sectors to all Federal agencies.

Through publications and electronic media, reliable information helps facility managers make the best decisions on energy savings opportunities. FEMP also presents awards (with an interagency committee) to recognize outstanding contributions toward increased energy efficiency, renewable energy use, and water conservation within the Federal government. These awards are both ceremonial and financial to motivate Federal managers to implement additional projects.

5.6 NEW INITIATIVES

FEMP is continuously looking for new opportunities to improve Federal energy management. Through partnerships with other Federal agencies and public and private organizations, a continuing exchange of ideas results in identifying new opportunities to reduce Federal energy and water consumption. FEMP is committed to its partnerships and to creating and distributing its tools and information for sound energy use in the Federal government. New initiatives include the following:

- ***Solar and other renewable energy***. FEMP promotes implementation of solar and other renewable energy projects by connecting industry resources with Federal needs, training facility managers, and showcasing cost-effective applications.

- ***Water conservation***. Estimates show that the Federal government could save more than $240 million per year by installing cost-effective water-conservation measures. FEMP is teaming with other agencies and the private sector to implement water-saving projects and provide training and technical assistance.

- ***Mobility***. FEMP will be addressing transportation fuel usage in the Federal government, which accounts for most Federal energy use and cost. The emphasis would be on tapping the potential for $400 million in annual savings in planes, ships, and vehicles, improved operational performance of the equipment, and environmental benefits.

- ***Procurement of energy- and water-saving products***. FEMP identifies Federal market opportunities and

works with procurement organizations to aggregate purchases, reduce costs, and expand markets.

5.7 SUMMARY

The Federal Energy Management Program (FEMP) reduces the cost of government and makes it work better through energy efficiency, use of renewable energy, and water conservation. The technical, managerial and fiscal expertise of this program are available to facility energy managers. FEMP resources can multiply conservation opportunities by identifying conservation technologies, providing program-directed training, and acting as a proactive guide to fiscal resources.

For more information on FEMP, contact:

Mark Ginsberg, Director
Office of Federal Energy
Management Programs, CE-44
U.S. Department of Energy
Forrestal Building, Room 5E-080
1000 Independence Ave., SW
Washington, DC 20585

or call the FEMP Help Desk:
(800) 566-2877

CHAPTER 6. ENERGY SAVINGS PERFORMANCE CONTRACTING
(A.k.a. Shared Energy Savings Contracting)

6.1 KEY CONCEPTS

- Energy Savings Performance Contracting (ESPC) is a contracting procedure whereby a private contractor finances, installs, and maintains energy-saving equipment and shares the resulting dollar savings with the facility.

- The use of ESP contracting, or performance contracting, is one of the major objectives of FAA's energy management plan.

- ESP contracting is a sound alternative to F&E-financed projects when funding is unavailable, personnel and time are at a premium, or the required technology cannot be implemented by facility personnel.

- One essential factor for an effective ESPC program is the establishment of an agreed-upon baseline figure for energy use between the ESP contractor and the facility. The savings are measured relative to that baseline

6.2 BACKGROUND

Using the Private Sector to Finance Energy Savings

Energy savings performance contracting is a low-investment, low-risk contracting procedure that can significantly increase energy efficiency at FAA facilities. Under ESPC, private contractors finance and install energy savings measures at FAA facilities and are paid a share of the savings only if the promised level of savings actually occurs. The region/facility retains all of the savings not paid to the contractor. The concept – also known as shared energy savings (SES) contracting – has been widely and successfully applied in the private, state, and local sectors.

The ESPC concept was developed in response to the needs of energy users in both the public and private sectors of the economy. Despite their internal financing ability, many industrial and commercial energy users have difficulty achieving potential energy savings because they are

unfamiliar with available energy technologies or they expend their creative efforts on competing projects with higher priorities. State and local governments and nonprofit organizations (e.g., school boards and hospitals) see similar drawbacks; in addition, they often lack the necessary front-end capital. An ESP contract meets the needs of both the private and public sectors by providing technical expertise, financing, installation, and maintenance.

An ESP contract is an agreement between a building's owner (i.e., the FAA) and a contractor, an energy services company (ESCO). That contract identifies energy savings opportunities and requires implementation of efficiency measures. The ESP contracting concept has been summarized succinctly as follows:

". . . [ESCOs audit energy use in buildings to identify the optimal mix of measures for energy efficiency, then install and maintain these measures, often paying for the whole project at no up-front cost to the building owner. In exchange, they get a share of the savings that the project produces. The building owner is guaranteed to pay no more for the energy than would have been the case without the efficiency measures. This type of business arrangement —in which payment for goods and services rendered is contingent upon their successful operation — is called performance contracting."[1]

Many states have established full-scale ESPC programs, including New York, California, Iowa, and Michigan. The ESP contracting idea has created a successful industry composed of several firms that are able finance, install, and maintain energy efficiency measures on a performance-contracting basis. DOE has released a listing of pre-qualified ESP contractors who are qualified to bid for performance contracting with federal agencies.

Enabling Legislation for Energy Savings Performance Contracting

Congress revised the National Energy Conservation Policy Act (NECPA) in 1986 to enable Federal agencies to enter into ESP contracts for terms as long as 25 years. The law states, in part:

Such contract shall provide that the contractor shall incur costs of implementing energy savings measures, including at least the costs (if

[1] Shepard, M. and R Weisenmiller, "The Tool Kit: An Introduction to Financing Options for Energy Projects," Financing Energy Conservation. The American Council for an Energy Efficient Economy, Washington, DC, 1986, p. 2.

any) incurred in making energy audits, acquiring and installing equipment, and training personnel, in exchange for a share of any energy savings directly resulting from implementation of such measures during the term of the contract.[2]

Energy Savings Performance Contracting in the FAA

The use of ESP contracting is one of the strategies which the FAA will employ for funding energy conservation projects. The new ESPC strategy is to deliver simpler, more realistic projects. FAA is sometimes better off keeping all of the savings rather than paying a share of savings to an outside contractor if the region has funding available and the energy manager or other personnel understand the particular technology well. In many cases, projects with high paybacks can be funded internally through F&E funds.

Nevertheless, the ESPC program is a sound alternative when funding is unavailable, personnel and time are at a premium, or the required technology cannot be implemented by facility personnel. Under ESPC, the ESCO pays for equipment, personnel, and financing out of its share of the savings. Without access to a private contractor, the region/facility would bear all costs itself. In addition, the facility would have to furnish the up-front financing and would also bear the risk of nonperformance. Additional advantages of the ESPC approach are that ESCOs have the experience to recognize energy saving opportunities that hard-pressed energy managers might otherwise miss, and ESCOs perform O&M tasks that many facilities lack the resources to perform adequately.

6.3 ENERGY SAVINGS PERFORMANCE CONTRACTING

Due to the complexity, performance contracting requires good communication and effective coordination among engineers, technicians, contracting officers, lawyers, and associated personnel necessary to select likely sites, write requests for proposals (RFPs), and negotiate and monitor contracts.

Purchase Request Process and Bidding

The regional energy managers must decide whether their facilities are good candidates for performance contracting. Successful ESPC projects usually involve the contracting

[2] National Energy Conservation Policy Act, 42 U.S.C. 8287.

office early on - before the PR is formally submitted. The ESPC project planners also involve the local utility during the planning phase, to determine the utility's reaction. The utility may want to play a role in the project through its DSM program, if it has one (see Chapter 7). The PR package must contain enough information for the contracting office to issue a synopsis of it.

ESP contracts are usually bid through an RFP process rather than an Invitation for Bid (IFB) process because discussions with potential contractors are almost always necessary. Source selection is usually not necessary for ESPC but is recommended for large projects, including multiple-facility ESPC proposals. The ESCOs normally have many questions because their project's success is predicated on their intimate knowledge of the targeted facility and its operations. One of the best ways to accommodate those questions is through a pre-proposal conference and site visit. A good time to hold such a conference is about 2 or 3 weeks after issuance of the RFP. The proposal due date should be at least 60 days after the conference.

The RFP should require separate technical proposals and price proposals. The technical proposal details all planned energy savings measures, while the price proposal covers the ESCO's proposed cost savings. DOE has developed a model solicitation to establish uniform formats and standardized contract provisions recommended for federal agency use in ESP contracting. A copy of this model solicitation can be obtained from the Federal Energy Management Program (FEMP) office at the DOE.

Contract Selection and Negotiation

The proposal evaluation team should examine the technical proposal to make certain that it is feasible and practical relative to its potential impact on facility activities. The team should be wary of leading-edge technologies, although it should not dismiss them out-of-hand. The team evaluating the price proposal must examine its realism. Estimates of cost savings have a tendency to exceed what can be accomplished practically. The team must ask itself whether the cost savings make unrealistic assumptions about energy users' behavior and/or system reliability and performance. Neither people nor equipment operate at 100 percent efficiency all of the time.

The proposal evaluation team should also pay close attention to the bidders' relative financial strengths from the

point of view of their abilities to remain in existence for the life of the contract. Ideally, the team should look for a solid company with the financial ability to finance and operate the capital improvements necessary to achieve the promised energy savings. Under ESPC, bidder companies must be able to survive the period in which they receive no revenues: from the contract's start until the equipment is installed and energy savings begin to occur.

Resolving Contractor Disputes

Performance contracts should be written in a fashion that helps to minimize possible conflicts between non-energy maintenance contractors and ESP contractors. The ESCO is responsible for reducing energy use; if they do not, they forfeit all or part of their revenues. Therefore, they are likely to involve themselves in any and all aspects of building maintenance that affect energy use even if other contractors or facility maintenance personnel are involved. The key to reducing those concerns is good contract language and a reliable ESCO. Facilities can preserve their flexibility to make changes in building use if the ESP contract enables automatic adjustments to be made for minor mission changes and renegotiation for major mission changes. Selecting a reliable ESCO that is relatively easy to work with is important, albeit difficult. In addition, the contract must clearly spell out the ESCO's responsibilities for building maintenance and must place clear limits on those responsibilities.

6.4 CALCULATING SAVINGS AND CONTRACTOR PAYMENTS

Establishing the Baseline for Energy Use

One essential factor for an effective ESPC program is the establishment of an agreed-upon baseline figure for energy use between the ESCO and the facility. The savings are measured relative to that baseline. Depending upon the type of project, a baseline can be adjusted for various factors. For example, a chiller replacement or modification may require a baseline that is adjusted for variations in cooling degree days and/or in relative humidity. Installation of meters and submeters is usually essential, but can be paid for by the ESCO through the ESP contract. One key to getting a workable baseline is to choose a relatively simple project, such as lighting retrofits, boiler modifications, natural gas conversion, variable speed drives, or enhanced motor efficiency. For such projects, baseline energy use is relatively easy to determine.

Establishing the baseline is one of the most important issues in performance contracting because a facility uses that baseline to estimate energy savings and thus to calculate payments to the ESCO. Those payments are based upon the difference between actual measured energy use and the baseline – an estimate of what energy use would have been without the ESCO.

Ideally, a baseline provides a measure of only those energy reductions that result from a contractor's actions, not of those that result from changes in building use or from weather. In addition, a baseline must be simple enough to serve as a basis for billing payments to contractors.

Baselines for energy use should also be as flexible as possible to accommodate changes that occur after an ESP contract has been signed. The uses to which buildings are put often change. For example, a facility may add new energy-using equipment, increase occupancy rates, or add more lighting to a building. Ideally, the method used for calculating energy savings should enable prediction of the extent to which such changes affect energy use and adjustment of the baseline accordingly. When such adjustment mechanisms are included in the baseline development methodology, they are usually referred to as "adjustment indices." Adjustment indices may be formulas for adjusting the baseline based on occupancy rates, lighting output, weather factors, and other measurable changes. Similarly, if the changes are more radical or cannot be easily measured, the ESP contract should allow for negotiated baseline changes.

The energy-use baseline for a particular building must be developed from either historical or estimated energy-use data. Estimates may be based on a comparison with similar buildings or from a relatively detailed analysis of the building and its energy-using equipment. Most ESCOs prefer metered data because they believe it is both simpler to use and more reliable than using estimation techniques.

The energy services industry has not developed a standard approach to baseline determinations; a variety of approaches currently exist.[3] Nevertheless, most ESCOs use relatively simple baseline methodologies because they judge

[3] The data on industry baseline evaluation methods are based on a survey of ESCOs conducted by Lane and Edson, P.C.

that such methods give the best trade-off between development costs and accuracy.

The three basic methods for establishing a baseline are:

- Engineering calculations;
- Regression analysis; and
- Simulation.

Some ESCOs limit the type of work they accept to projects that fit the types of baseline estimating methods they have developed through their own experience. Each of the three baseline calculation methods is discussed below.

Engineering Calculations

Engineering calculations incorporate experience about the energy using characteristics of building properties and HVAC equipment. Such calculations can be used to establish a baseline when the conservation measures are fairly tightly defined. Lighting is a good example. The energy-use baseline for lighting is simply the electrical consumption per existing light fixture multiplied by the number of fixtures being used. A contractor who decides to install more efficient lighting can calculate the proportion of savings based on the difference between the energy efficiency of the new, and that of the old, lighting fixtures. The ESCOs use engineering calculations that vary from simple to sophisticated.

Regression Analysis

Regression analysis is a statistical technique that uses historical data derived from meters to isolate one or more of the variables that affect energy use. A regression analysis results in an equation that relates energy use to weather and/or building-use variables. Used as a baseline, a regression equation estimates what energy use would have been without the ESCO while eliminating the effect of variables not under the ESCO's control. ESCOs generally avoid regression equations with two or more variables. A simple regression using degree days[4] to estimate energy use appears to be the most common baseline method used by ESCOs.

[4] Degree days are a standard measure of the extent to which the outside ambient air temperature rises above (or falls below) the temperature at which it is no longer necessary to heat (or cool) a building.

When historical, metered energy-use data are available, regression equations define energy use relative to the entire building; thus, they afford contractors the most flexibility in proposing a variety of conservation measures without being limited to using specific types of equipment. Most ESCOs generally desire one to three years of energy-use data.

Simulation

The third method for establishing a baseline is simulation. In essence, a simulation of building energy use is a sophisticated set of engineering calculations that attempts to forecast energy use on the basis of a building's size and shape, its HVAC equipment, the levels of insulation, the types of windows and doors, and other salient characteristics. Baselines developed from simulations have a number of drawbacks in the eyes of the energy services industry: (1) they are perceived as being overly complex and thus expensive to use, (2) they are not well understood by either the ESCOs or their customers, and (3) the results are considered less accurate and less reliable than historical metered data. Unless and until ESCOs are convinced that simulations are accurate, inexpensive, and easy to use, they are likely to attribute additional risk to projects that rely upon simulated data and will demand a greater share of the savings to compensate for that risk.

6.5 PERFORMANCE GUARANTEES

Another issue related to baseline determination is the performance guarantee; that is, deciding how low savings must be to constitute contract nonperformance and how savings will be split between the facility and the ESCO when savings are greater (or less) than expected. Ideally, the performance guarantee of an ESP contract provides an incentive for the contractor to increase savings beyond the minimum forecasted and, conversely, should penalize the contractor if savings are less than forecasted. The most common ESPC procedure is a constant percentage split. For example, an ESP contract may give 50 percent of the total energy savings to the ESCO with 50 percent for the facility. If actual energy savings are 20 percent, then the facility earns 10 percent and pays 10 percent of the baseline dollar value to the ESCO. If actual savings are only 4 percent, the ESCO is paid 2 percent.

The question of how often to measure energy savings also arises. It appears to be a fairly standard practice to measure savings on a monthly basis since energy use is most often billed monthly. However, because the shorter the

measurement interval the more likely random events will affect energy use, FAA should require that a minimum amount of savings be achieved before making ESPC payments.

According to one experienced ESPC practitioner, ". . . *it is extremely important to recognize that random effects can cause variations in energy usage. Energy curves are rarely steady; even factoring in weather and all known variables, energy consumption can vary 5 to 10 percent for unknown reasons. Consequently, it can be expected that in some months, a 5 to 10 percent 'energy savings' may be measured without any effort from anyone. To eliminate the potential of paying for random energy savings, the contract should require a certain level of energy savings before any payment is due.*"[5]

[5] Yates, P., "Energy Agents for Local Governments." *Financing Energy Conservation*, op. cit., pp. 96–97.

CHAPTER 7. ENERGY UTILITY PROGRAMS

7.1 KEY CONCEPTS

- Demand-side management (DSM) programs are public utility-sponsored programs that encourage energy-efficiency improvements by offering rebates and other subsidies to their customers.
- Taking advantage of DSM programs should be one of the major objectives of the FAA's energy conservation plan.
- Energy managers should never proceed with a project before checking whether the local utility will partially or totally subsidize the project.
- Dual capability – the technology that provides the ability to switch from one fuel source to another – reduces dependence upon any one source of supply.

7.2 DEMAND-SIDE MANAGEMENT

Background

Demand-side management programs are public utility-sponsored programs that encourage energy-efficiency improvements by offering rebates and other subsidies to their customers for energy-efficient technologies. FAA facilities can, and should, take advantage of DSM programs if their local utility offers them. Many DSM programs are run by electric utility companies that see improved energy-efficiency or load shifting as a means of avoiding expensive new plant construction. However, many natural gas utilities are also offering DSM programs at the prompting of their public regulatory commissions.

Energy utility companies have traditionally concentrated on the supply side of the meter. They have focused on providing a reliable supply of electricity or natural gas to customers. Electric utilities, in particular, have viewed themselves as being in the business of building and operating power plants.

Demand-side management is a relatively new business approach used by energy utilities in which they take actions on the demand side of the meter, rather than solely on the supply side. Increased energy production costs and the difficulty of positioning new plants have led utilities and more importantly, utility regulatory bodies to place a new emphasis

on energy conservation as a way of extracting more kilowatts (kw). A kilowatt-hour (kwh) saved through efficiency is a kwh that does not need to be generated by a new plant. Because the electric power generation business is no longer a declining cost industry, energy-efficiency improvements are a cost-effective way to reduce the need for new generating capacity. Increased efficiency also satisfies customer needs by reducing their costs.

More and more public utility commissions (PUCs) are requiring their regulated utilities to implement DSM programs as part of their least-cost planning or integrated resource plans (IRPs). Such plans aim to minimize the cost of energy by comparing the cost of various efficiency measures with the cost of traditional sources of energy supply.

Depending on the utility's avoided cost – the cost that it avoids by eliminating or postponing the need for new generating capacity – and its load profile, the utility may promote overall efficiency measures or be primarily interested in technologies that shift demand away from peak demand periods. For example, thermal storage is a technology that uses energy during lower cost off-peak demand hours to create ice or chilled water at night, which then cools the building during the day with minimal daytime energy use. By reducing peak demand time energy use, the utility reduces the need for capacity to meet those peak energy requirements.

Demand-Side Management

For many FAA facilities, local electric or gas utilities may have programs in place that provide energy-efficiency services, including free or subsidized energy audits and subsidies or rebates for energy-efficient technologies. DSM programs are usually targeted toward specific energy-user groups. For example, residential programs include home energy audits and rebates on installation of compact fluorescent bulbs, hot water tank insulation, and similar measures. Commercial and industrial programs also provide audits and rebates for specific technologies. In addition, those programs provide financial incentives for measures proposed by the customer because energy use among commercial and industrial customers varies more than for residential customers; customer needs are more specialized.

Taking advantage of utility DSM programs should be one of FAA's major strategies. By taking part in such innovative utility programs, facilities can obtain partial or total funding

for lighting and certain other energy-efficiency measures. In addition to learning about, and taking part in, existing utility programs, most large facilities can negotiate customized programs with their local utilities. Such customized programs have the potential to achieve relatively large efficiency gains.

To take advantage of innovative utility programs, the facility energy coordinators should assist energy managers in identifying programs that are available from the local electric and gas utilities. Energy managers should never proceed with a project before checking whether the utility will partially or totally subsidize the project. However, energy managers should not stop at that point; it may be possible to develop a complete customized DSM program.

Negotiating Demand-Side Management Programs With Utilities

Utilities provide subsidies in the following two ways:

1. Subsidies providing the up-front capital needed for a specific project in advance, or
2. Subsidies providing a rebate once the technology has been installed.

When the utility provides the full capital costs for efficiency improvements, a portion of that capital cost must often be repaid later as separate direct payments or as additions to the facility's energy bill. Rebate programs, on the other hand, require the facility to provide the initial capital. Energy savings usually begin sooner under rebate programs.

FAA can negotiate to obtain customized DSM programs at the facilities. The aim of negotiations is to obtain maximum potential funding for energy-efficiency improvements. Rebates can be negotiated either as temporary reductions in the utility bill, or as refunds which may then be applied to the OPS accounts.

7.3 FUEL SWITCHING

Dual Capability

Dual capability is any technology that provides the ability to switch from one fuel source to another for generating energy. Dual capability reduces dependence upon any one source of supply. A facility with dual capability can switch relatively easily and quickly to a second fuel if the first fuel type is either unavailable or is more expensive per delivered Btu than the second fuel.

The main practical application of dual fuel capability is to support the purchase of natural gas on the "spot" market – an alternative contracting mechanism for purchasing natural gas. The spot market refers to the purchase of gas from the producer rather than the local gas utility. The end-user can make spot purchases either directly from the producer or indirectly via a gas marketer. Spot market transactions are usually short-term, "interruptible" purchases. Short-term contracts are normally 30-days long (although they can be extended for additional 30-day periods). "Interruptible" deliveries can be interrupted by any one of a number of contingencies: unusually cold weather, producer shutdowns, a temporary lack of pipeline capacity, or other problems. (Of course, when deliveries are interrupted, customer payments are too.)

Short-term, interruptible contracts make supplies less certain. In addition, while spot market gas is normally cheaper than gas purchased under long-term contracts, prices can increase more quickly. Both possibilities make dual capability almost essential when purchasing spot gas. When natural gas is unavailable or suddenly more expensive, a facility can switch dual-fuel boilers relatively quickly to burn fuel oil in lieu of natural gas. Such a facility can then switch back to natural gas when it pays to do so. Some local distribution companies will reduce the price of their natural gas if the FAA facility agrees to switch to an alternate fuel during a time when capacity has been curtailed. This type of arrangement can result in savings for both the local distribution company and the FAA facility.

Backup Capability

Backup capability is similar to dual capability. The most common type of backup is the emergency engine generator that provides security to a facility's most critical capabilities.

"Peak shaving" plants are a type of backup capacity that can reduce a facility's electric bills. A facility may be able to reduce its "demand" charges – the amount it pays the local public utility for providing uninterruptible electric power at peak periods – by reducing its interruptible load. Several ways exist to reduce peak load: overall energy conservation, moving electricity-intensive tasks to off-peak periods, and using peak-shaving to generate a portion of the facility's peak power requirements. Although engine generators are normally more expensive than utility-provided power, they can be cost-effective if used to avoid paying a premium for electricity at peak periods.

CHAPTER 8. ENERGY AWARENESS

8.1 KEY CONCEPTS

- Energy awareness attempts to eliminate energy waste by changing the attitudes of energy users and, through those changed attitudes, to change their behavior as well.
- An effective awareness program targets specific audiences and involves as many energy users as possible.
- The awareness program uses action-oriented messages to tell users what they can do and how to do it in the simplest, most direct way possible.
- Publicizing conservation information on a regular basis tends to increase the program's effectiveness by increasing and maintaining participation.

8.2 PROGRAM PURPOSE

The purpose of an energy awareness program is to eliminate energy waste by making energy users more energy conscious. An awareness program attempts to alter the attitudes of energy users and, through those changed attitudes, to change their behavior as well. An effective program targets specific audiences, involves as many energy users as possible, is widely publicized, and makes energy-saving actions and goals as concrete as possible. Sources of additional awareness ideas and information appear in Appendix K and Appendix H.

Awareness works through publicity and training. The program should be continuous - and fun. Because nobody likes to be told what to do; a good awareness program avoids a preachy, moralistic approach. Instead, it concentrates on reinforcing opinions that most energy users already hold: energy efficiency reduces pollution, it reduces dependence on oil imports, and it reduces costs. The program also adds information on exactly how to achieve those results. A subsidiary, but important, message is that energy efficiency does not mean doing without energy, it means achieving the same results using less. We no longer need to preach the virtues of wearing sweaters and taking shorter showers; energy users want bright, adequately heated and cooled spaces, but at less cost.

Awareness is the essential foundation for an effective energy program. First, it helps to change attitudes, thus encouraging users to seek out ways to save energy. Second, it changes behaviors, making sure that energy users take energy-saving actions and continue to use and maintain energy-saving equipment after it has been installed. That is, energy awareness helps to increase the "persistence" of energy-savings projects so that they continue to reap savings year after year.

8.3 AWARENESS BASICS

A good awareness program explains energy efficiency in simple terms, not because facility personnel cannot understand more complex messages- they will if they are interested enough-but because a simple message competes more effectively with the multitude of other messages being broadcast to energy users. The awareness program must tell users what they can do and how to do it in the most direct way possible. The energy awareness message must compete successfully with all other messages; furthermore, it must not contradict other mission messages, or counter other program goals.

An energy awareness program has a high potential for success. The basic elements for a successful energy campaign either exist already or can be readily created. As identified by sociologists, those elements are as follows:[1]

- ***Monopolization***. Almost everyone agrees that energy efficiency is worthwhile.
- ***Canalization***. Existing personnel who already practice energy efficiency can be potential allies to the energy manager in spreading the message.
- ***Supplementation***. The program must achieve contact with as many energy users as possible.
- ***Channeling***. The necessary materials and equipment must be made available for efforts requiring an investment. Other awareness efforts, such as turning off lights and shutting windows, for example, require little or no capital investment.
- ***Universality***. Everyone can use energy more efficiently. However, the message must be tailored to appeal to various user groups.

[1]Kotler, P., and R. L. Eduardo. *Social Marketing: Strategies for Changing Behavior*. The Free Press (1989).

8.4 PROGRAM DESIGN

To develop an effective energy awareness campaign, the energy manager should start by defining the audience or audiences. A different message is needed for certain facility personnel than for maintenance workers.

Energy managers should get as much help as possible from other region/facility personnel in developing an energy awareness program. Getting energy users and maintenance staff involved in the planning process not only increases their understanding of the program, it generates a greater sense of ownership leading to greater participation.

Having defined the audience, the awareness program should suggest the specific actions that each user group should take that can save energy. For example, one promotional campaign could be directed to operations personnel, another to office workers, and another to maintenance workers. The energy manager may want to start with a general, overall awareness program; however, such overall programs tend to be more preachy, less action-oriented, and therefore less effective than specifically-focused action campaigns. They can, however, serve as a useful foundation for the more narrowly-focused campaigns, which should follow the general campaign very quickly or parallel it.

8.5 ACTION-ORIENTED MESSAGES

As mentioned above, the best awareness programs are those that can be distilled into short, action-oriented messages. The energy manager can then communicate those messages in many ways. For example, a message like "Use energy wisely" is unlikely to achieve much savings by itself, although it can serve as a basis for more concrete messages. Slogans like "Turn off the lights" and "Switch it off when you leave" are more effective because they communicate a direct action that users can implement immediately. Such action oriented messages have a greater potential to change behavior as well as attitudes. Even better perhaps is a message like "Switch it off for the environment" because it combines an action with a generally desired consequence. The awareness program should target those action-oriented messages toward different audiences. Some examples of the kind of actions that an awareness program can emphasize are described below.

An awareness program targeted to office occupants can encourage the following (no-cost) actions:

- Turn off the lights (including fluorescent lights) when you leave the room.
- Turn off computers overnight.
- Do not use space heaters; turn up the thermostat instead (or have maintenance personnel fix the central unit).

An awareness program targeted towards maintenance personnel can be particularly effective because they are generally responsible for upkeep of the most energy-intensive systems. Awareness messages can recommend the following (low-cost) actions:

- Fix stuck dampers.
- Install low-flow washers in all hot water faucets.
- Clean steam traps.
- Check for torn or missing insulation and fix it.
- Clean condenser coils on cooling equipment.
- Wash lenses and luminaires on a regular basis.

The ideas presented above are only a sampling of the many possible messages that a good awareness program can promote. Appendix K provides additional awareness project ideas.

8.6 PUBLICITY TOOLS AND TECHNIQUES

Successful public outreach energy information programs continually present the "need for energy conservation" and "how to save energy" themes. Publicizing conservation information on a regular basis tends to increase the program's effectiveness by increasing and maintaining participation. Appendix K also lists publicity techniques that could be successful at various FAA facilities.

Posters, stickers, and other publicity materials get the message to the facility's personnel. Note: Contact headquarters' program office and the Federal Energy Management Program (FEMP) office to obtain the latest information and ideas. FEMP is eager to hear from all federal agencies.

Films, videos, slide presentations, and publications on energy and environmental topics are available from sources listed in Appendix H. Almost all gas and electric utility companies have public outreach programs that make utility

representatives available to give presentations. The FEMP office may also be able to provide energy awareness materials.

Appendix L provides some useful facts and "rules of thumb" for promoting energy awareness and conservation. These tips are provided as a starting point; energy managers should add others which, based on their experience, have been successful in the past.

Energy Awareness Month

"Energy Awareness Month" is a nationwide program that recognizes the importance of energy conservation. This national event takes place every October. Energy managers can leverage their own programs with the national attention generated by Energy Awareness Month to generate more attention from regional management and facility-level energy users.

October provides a good opportunity to demonstrate the Agency's progress on existing energy reduction goals and to introduce new goals, if any. Also, October is a good month in which to recognize particular groups and individuals that have done an outstanding job in energy conservation.

8.7 EVALUATING PROGRAM EFFECTIVENESS

Since the ultimate purpose of energy awareness is to use energy more efficiently, the most appropriate measure of success should be actual energy reduction. While it is difficult, if not impossible, to isolate those energy reductions due solely to energy awareness efforts, the facility should achieve some reductions in total energy consumption (or in Btus per square foot).

One way to measure an awareness program's effectiveness is to develop a set of subjective assessment criteria to gauge changes in users' energy habits. Those criteria can include the number of incidents where lights are left on after duty hours, where windows are left open during heating/cooling seasons, and the number of unauthorized space heaters in use. Those subjective criteria can be measured during periodic "walk-through" inspections.

During facility inspections, the following actions should be completed:

- Find out whether posters and other awareness materials are visibly displayed.
- Conduct interviews to determine whether energy users are familiar with proper energy conservation procedures.
- Evaluate whether there is a general conservation ethic in the workplace.
- Encourage those not yet committed to the program to get more involved.

CHAPTER 9. BACKGROUND INFORMATION COLLECTION

9.1 KEY CONCEPTS

- An electric bill usually includes energy use charges and demand charges, and may also include power factor charges and fuel adjustment charges.
- A comprehensive, accurate energy use index provides a baseline against which future energy management actions can be evaluated.

9.2 OVERVIEW

For achieving a successful audit/survey, it is important to provide a foundation of background information by evaluating energy purchases, establishing an energy use index (EUI), and assembling other relevant data. Before undertaking a close-up look of all energy-related aspects of the facility, the energy management team should have certain information on hand. Typically, this information includes:

- Utility rate schedules
- Base-year energy use data
- Energy consumption data for the 3 years previous to the base year
- Weather data
- Facility data
- O&M logs, equipment manuals, and warranty information on equipment that may be modified
- Local building codes
- Other relevant information, such as modifications already under way and future plans for the facilities

This background material is discussed in the following sections.

9.3 ENERGY PURCHASES

A key element of the energy survey is an analysis of energy purchases from utilities. (It is also an important part of program monitoring.) Most of this analysis will relate to electricity because the electric bill is likely to be the most complex utility bill and because the complexity of the bill reflects the complexities sometimes associated with a facility's electrical system.

Utility Rate Schedule

Electric utilities have many different rate schedules, depending on the type of service involved. By reviewing the rate schedule for the facility, the team can determine if the facility is obtaining the best rate or if modifications could result in a better rate. In some cases, the purchaser may have a choice between schedules and special riders, as for an all-electric building. Although most facilities are on the right schedule, it may pay to verify this for each building.

A review of past rate schedules will help the team knowledgeably compare energy use and costs between one year and another. To get a true picture of changes in energy expenditures, dollar factors will need to be adjusted to reflect whatever rate changes occurred in the past.

Representatives of the local electric utility can provide more information about rates and rate schedules. For planning purposes, the team should ask utility representatives (as well as fuel suppliers) to indicate likely future rate changes.

Elements of a Utility Bill

It is important to understand each element of the electric bill. The electric bill usually comprises two and sometimes as many as four or more different charges: energy use charges, demand charges, power factor charges, and fuel adjustment charges. Some of these are imposed by the utility; others are charged by the utility on behalf of state or local authorities.

Energy Use Charges. Electrical energy consumption is measured in kilowatt-hours (kWh) and is measured by a kilowatt-hour meter. Many utilities use time-of-day metering to determine energy use charges. This involves the use of metering equipment that records energy consumption for certain defined portions of the day. Energy used during certain daytime hours – the peak period of demand – is charged at a higher rate. In this way, utility customers are encouraged to use electricity during other periods, when overall utility demand and rates are lowest.

Demand Charges. Another important element of an electric utility bill is the demand charge, which is determined by the rate at which electricity is consumed. It is designed to assign customers a fair share of the utility's fixed investment in the production, transmission, and distribution systems needed to meet each customer's maximum

electricity requirements. The more electricity used at any given time, the more the utility must invest in these systems.

Power Factor. Many utilities impose a charge based on a building's power factor. A utility must invest in equipment to provide reactive power. It can obtain a return on its investment in one of two ways: by averaging it out to all customers, or by charging more to customers with poor power factors. Utilities that charge for poor power factor usually define it as a power factor less than 0.9. Customers therefore pay for the difference between 0.9 and the actual power factor.

Fuel Adjustment. In many areas, utilities have imposed a fuel adjustment charge to reflect the rapidly rising costs of the fossil fuels used in generating electricity (as opposed to established rates based on historical costs of fuel). Because the procedures involved in changing utility rates are so complex and time-consuming, public service commissions have permitted utilities to pass additional costs for fuel on to customers as variable fuel adjustment charges.

Other Charges. A utility bill may also reflect other charges, including city or state sales taxes and county or other municipal surcharges.

Other Purchased Utilities

Other purchased utilities used in a facility may include natural gas, oil, steam, hot water, and chilled water.

The natural gas bill is similar to an electrical bill. Some gas utilities impose a demand charge to reflect the larger equipment needed to meet higher demands. Some also impose a purchased gas adjustment (PGA) charge similar to the fuel-adjustment charge imposed by electric utilities. The PGA is imposed in response to changes in the price of gas that the gas utility pays to its supplier.

Oil is purchased directly from a fuel oil supplier who charges for the oil itself, a certain percentage for overhead and profit, and applicable sales taxes and other surcharges.

Steam is purchased from an electric utility or, a district system, a private source, such as a building complex that produces waste steam as a byproduct of its boiler plant. When steam is purchased from a utility, a demand charge

may be imposed. When it is purchased from some other source, there may or may not be a demand charge.

Chilled water, when purchased, usually comes from a nearby larger facility that has excess capacity it is willing to share. Pricing arrangements vary from contract to contract. Chilled water may also be purchased from District Energy Systems or Community Energy Systems, and these systems should always be considered as a source of supply

9.4 ENERGY USE INDEX

Establishing a facility's energy use index (EUI) is a basic step in developing any energy management plan. An EUI measures how much energy a facility consumes, in British thermal units (Btu) per gross conditioned square foot per period of time (usually 1 year). The worksheet included in Appendix Q can be used to determine an EUI. Before getting into the specific steps involved in developing the data, a few facts should be made clear:

- The EUI should not be used as a measure of energy efficiency or inefficiency. Its primary purpose is to compare a facility's energy consumption from one period to another, such as 1993 to 1994 or June 1993 to June 1994.

- Comparing the EUI of one facility to another can be misleading, because the facilities may be used for completely different purposes or they may be affected by different climatic conditions.

- A facility's EUI may actually increase, even though the facility's energy efficiency increases, because of changing climatic conditions. For example, a very hot summer or very cold winter will still increase energy use; energy management will only reduce the rate of the increase. This points out a very important concern: The EUI should be adjusted to reflect changing weather conditions. Methods of doing this are discussed below.

- The total cost of energy may increase, even though consumption decreases, because of energy price increases. For comparison purposes, indicate what energy costs "would have been" had the prevailing costs of the base year been in effect or, alternatively, what base year costs would have been had current energy costs been in effect during the base year.

- Not all cost factors to be considered relate to energy consumption. Demand charges for electricity, natural gas, and steam relate to the rate at which energy is consumed. Demand and demand charges can be reduced considerably without a comparable reduction in the amount of energy consumed. Nonetheless, lower demand does help save energy in the long term because it reduces a utility's standby requirements and, therefore, its energy consumption.

- For Federal facilities, results obtained from the GSA's Energy Usage and Analysis System may be applicable to the EUI.

The Energy Use Index Worksheet in the Appendix Q can be used to determine the EUI for most facilities. The worksheet does not include space for certain types of energy consumption – for example, propane or purchased chilled water. If the facility uses these energy sources, either convert a column that does not apply to the facility or add a new column.

9.5 OTHER INFORMATION

In addition to collecting information about utility charges and base-year energy use, the energy management team should also obtain the following:

- ***Energy consumption data for years previous to the base year.*** Although not critical to the energy management program, it is suggested that energy consumption data for the 3 years prior to the base year also be collected and presented in a format that makes comparison easy.

- ***Weather data.*** The team should obtain weather data for each year for which energy consumption data are collected. Weather data usually are available from the local electric utility. Otherwise, they may be obtained from the National Climatic Center, Federal Building, Asheville, North Carolina 28841. In analyzing energy use patterns, the team will need to account for the fact that the amount of energy a facility consumes depends substantially on climatic conditions. If this year's winter is extremely cold as compared to last year's, an accurate comparison of energy data is possible only if it is adjusted to reflect the same climatic conditions. In other words, last winter's

figures should be adjusted upward or this year's figures downward to obtain an accurate comparison.

- ***Building data***. The team should try to obtain original building plans and specifications, along with as-built plans from the facility owner or manager or from the original consulting engineers or general contractor. If none of these sources can provide what is needed, single-line diagrams will need to be drawn to indicate the equipment in place, connected loads, and other major details.

- ***O&M logs, equipment manuals and warranties***. O&M logs and equipment manuals help indicate how equipment is being operated and maintained and how changes in O&M routines have affected equipment performance. Valid warranties and guarantees on equipment that may be modified must also be on hand.

- ***Codes and Regulations***. When the time comes to consider options, the team must be aware of a number of factors that could affect the way EEOs are implemented. Government legislation, codes, and other regulations are of critical importance. Depending on the locality, the following are among the many regulatory factors that must be considered: building codes, electrical codes, mechanical codes (heating, cooling, ventilation, and so forth), plumbing codes, fire-prevention codes, elevator codes, health codes, Occupational Safety and Health Administration (OSHA) regulations, public utility commission regulations (electricity, steam, gas, water. sewer, and telephone), and air and water pollution regulations. In addition, asbestos-containing materials and indoor air quality must be carefully considered. While representatives of each of the regulatory agencies involved can provide assistance, it may be far easier if a team member is already familiar with most of these concerns.

- ***Other***. Other information that may be available could be useful. For example, in-house personnel may already have initiated certain energy efficiency modifications. If so, details should be obtained, along with plans for any future modifications. Consult with management for information about any changes planned. Particular importance should be given to such anticipated changes as turnover of major

tenants or physical modifications such as renovation, remodeling, or expansion.

Information from each source should be reviewed separately and as it interrelates with other sources, including utility bills and the EUI. The most obvious correlation is that between energy consumption data and climatic conditions. Are certain trends evident? Can any major changes in consumption not be explained by the weather? If so, do O&M logs reveal a possible cause? For example, do the logs indicate a change in procedures? Do these changes account for the lack of correlation between the energy-consumption data and the climatic data? What about electrical demand? Do peaks and valleys occur in a somewhat uniform pattern, or are there unexplained phenomena that bear investigation?

The questions and concerns raised by this review should be discussed with management or the head of O&M before the energy survey begins.

CHAPTER 10. ENERGY AUDITING

10.1 KEY CONCEPTS

- Energy audits help form the foundation of an energy program by identifying energy conservation and cost-savings opportunities.
- Depending on the objectives and circumstances of the energy audit, the energy manager should develop an audit strategy to maximize the use of time and resources.
- It is important, although difficult, to set audit priorities among the many opportunities for energy savings.
- Putting together a qualified audit team is crucial.
- Checklists are effective tools for ensuring that an energy audit obtains all of the necessary information.
- An important function of an energy audit is to inform facility managers about the findings and to convince them to allocate the necessary resources to correct any deficiencies.
- Audits should be performed only to the level needed for determination and justification of energy conservation measures. Energy conservation is achieved by the implementation of energy conservation measures.

10.2 PURPOSE OF THE ENERGY AUDIT

The primary purpose of an energy audit is to identify energy conservation and cost savings opportunities among "energy-using" systems such as lighting fixtures and HVAC equipment. The goal of the energy audit is to evaluate the overall efficiency of facility energy systems as well as the efficiency of individual components comprising those energy systems.

Most FAA buildings were designed and constructed prior to the energy crisis of 1973 when there were sharp increases in energy prices and utility rates. Prior to those increases, architects and engineers lacked the incentive to use electricity and gas efficiently, particularly since energy-efficient equipment usually required greater initial

capital investment. Also, little in the way of energy-efficient equipment or systems was available due to limited technology and market demand. Consequently, many old FAA buildings were designed to use lighting, HVAC equipment, and auxiliary fan motors that are inefficient by today's standards.

Although many FAA buildings have been improved over the years by retrofits, most old buildings still offer energy-saving and cost-saving opportunities. Retrofitting entire old energy systems can be an attractive investment because the simple payback for many of these projects is less than two years. However, the initial capital outlay is often substantial and may require the entire building to be vacated for some period of time. Initial capital requirements often kill good energy conservation proposals. To encourage good energy conservation projects, energy managers may have to compromise by implementing a partial or phased upgrade of energy systems.

An energy audit should also determine the performance and efficiency of each individual component of an energy system. Although the components of many energy systems have been replaced since they were first installed, many are still not energy-efficient by today's standards. With advances in technology, more energy-efficient replacement components are available today. Most of those components can be replaced relatively easily. For example, replacing an entire HVAC system requires significant capital investment. However, numerous no-cost or low-cost opportunities can be identified through a productive energy audit program. For example, high-efficiency fluorescent lights with electronic ballasts can replace old-style fluorescent or incandescent lights without major modifications.

Many buildings have never been audited to ascertain energy efficiency. In addition, functional changes have taken place in many buildings that were audited in the past. As FAA slowly downsizes, decommissions old equipment, installs new equipment, and consolidates operations, many of the facilities will have to readjust their energy use to accommodate those changes. It would be wise to determine if the original energy system designs have become obsolete.

Although many energy cost-saving measures can be identified during an energy audit, some measures will help reduce total energy cost but may not help reduce energy consumption. An example of this cost reduction would be the shifting of loads away from peak periods. By

understanding energy requirements and alternative energy sources, energy managers can pick the most economical energy resources to save money. For example, switching an electric heater to a gas-fired heater may not reduce energy consumption, but can save money since gas is cheaper per Btu than electricity. A comprehensive energy audit can identify the best cost-saving opportunities.

Energy audits can also follow up on operating energy conservation projects to determine if the expected savings have been achieved. That type of audit becomes increasingly important for energy savings performance (ESP) contracts (or other shared energy savings contracting). Installing metering devices makes audit follow-up results more credible.

10.3 AUDIT STRATEGY

Most energy audits can be classified into three categories: walk-through, mini-audit, and maxi-audits.[1] Each is described below.

- *Walk-through*. This type of audit is the least costly and identifies preliminary energy savings. A visual inspection of the facility determines maintenance and operations energy savings opportunities. Information is collected to determine the need for a more detailed analysis.

- *Mini-audit*. This type of audit requires tests and measurements to quantify energy uses and losses, and to determine the costs associated with changes.

- *Maxi-audit*. This type of audit goes a step further than the mini-audit. It requires evaluating the quantity of energy used for each energy function, such as lighting or industrial processes. It also requires model analyses, such as a computer simulation, to determine energy-use patterns and predictions on a year-round basis (taking into account such variables as weather data).

Depending on the objectives and circumstances of the energy audit, the energy manager should develop an audit strategy to maximize the use of time and resources. The usefulness of the different types of audits depends upon the

[1]Albert Thuman, Plant Engineers and Managers Guide to Energy Conservation, 5th Edition, Liburn, Ga., The Fairmont Press (1991). p. 4

purposes of those audits. The appropriate level of audit depends upon the type of economic justification required to obtain funding. Large-scale projects like demand-side management (DSM) and ESPC programs usually require extensive audits to ensure accurate calculation of appropriate payments to DSM or ESP contractors. For small F&E projects where approval authority is within the scope of the region or facility, detailed economic justification is often unnecessary. Therefore, for these projects, a walk-through audit may be sufficient. Comprehensive maxi-audits or even mini-audits that require outside technical experts can be quite expensive.

System-Based Audit Versus Solution-Based Audit

Basically, there are two different strategies for energy audits: the "system-based" approach and the "solution-based" approach. Each strategy has its pros and cons; the best strategy depends upon the audit objectives.

The system-based strategy requires the isolation of an entire energy system and its evaluation as a unit. Also, the efficiency of each element within the energy system must be evaluated. A maxi-audit is usually required to obtain the needed data. Standard "reference points" are used for comparing energy system performance. For example, the system-based strategy for conducting an energy audit of a commercial building would assess the building's "shell" for its insulation value, lighting level, heating and cooling efficiency, kitchen appliances, hot water, and other electrical equipment. The major standard reference points are temperature settings (e.g., hot water temperatures), lighting levels, and so forth. The system-based approach allows energy managers to minimize the total energy consumption of a building.

The following are examples of system-based energy audits:

- Building a cogeneration plant based upon a facility's power needs and waste-to-heat recovery economic analysis,
- Consolidating individual air-conditioning units into one centralized unit,
- Installing energy management and control systems (EMCSs) to maximize energy efficiency, and
- Sizing appropriate heating and cooling units.

The solution-based strategy is relatively easy to implement. This strategy takes advantage of proven energy

conservation techniques and applies those techniques where opportunities exist. Normally, walk-throughs and mini-audits are sufficient to obtain the data needed. For example, in any building without adequate ceiling insulation, installation can be cost-effective and easy to implement. The solution-based strategy attempts to increase the energy efficiency of each energy-using system component.

The following are examples of a solution-based approach:

- Replacing incandescent lights with more efficient lights such as fluorescent, mercury vapor, metal halides, or high-pressure sodium lights;
- Weatherstripping cracks and openings in the building's structure; and
- Insulating the building envelope by replacing single-pane glass windows with double-glazed windows or by adding a layer of insulation to exterior walls and ceilings.

One of the shortcomings of the solution-based approach is that suboptimizing a piece of equipment does not necessarily optimize overall system efficiency. This is particularly important for doing HVAC audits. Energy managers should audit HVAC systems as a whole, rather than component by component.

Using a solution-based energy audit, energy managers can target specific energy conservation opportunities without the time-consuming task of preparing a trend analysis of base energy-consumption patterns. Energy managers can use the solution-based approach to start identifying the most attractive energy-saving options.

Based on past experience, certain energy conservation opportunities consistently offer very attractive economic payback. These areas are: fine-tuning HVAC equipment, properly-sizing electric power auxiliary equipment, and retrofitting lighting. Although economic payback from these projects depends on the cost of the projects, potential energy savings, and the cost of capital, a good portion of these projects will have a payback of less than two years. Appendix M provides over 100 solution-based energy conservation opportunities. Energy managers may need to conduct a mini-audit to calculate economic payback.

10.4 PREPARING FOR AN AUDIT

One of the most difficult tasks for the energy manager is setting energy audit priorities among the many opportunities for energy savings. Reviewing past energy consumption patterns provides an historical trend that may identify where most energy is consumed, if the facility is sufficiently metered.

Gathering the necessary energy cost and consumption information can be tedious. However, to prioritize the energy systems audit schedule (based on highest potential energy and dollar savings), collection and analysis of that information is essential. The information analysis helps management to focus and prioritize the workload. Also, that information is needed for calculating the savings-to-investment ratio (SIR) for energy conservation projects. It is important to plan the contents of the final audit report before carrying out the audit in order to ensure that the audit gathers the data needed.

Many facilities were audited for energy conservation during the mid-1980s. Those old audit reports can provide good insight into the extent of prior energy conservation efforts, progress made to date, and the remaining opportunities for conservation. If any projects were implemented as a result of those previous audits, those early audit reports become a good basis for conducting follow-up energy savings audits.

10.5 ORGANIZING THE AUDIT TEAM

Once the scope of an energy audit has been defined, the next crucial task is putting together a qualified energy audit team to perform the audit. It is often difficult to pull qualified engineers and technicians away from their full-time jobs to perform energy audits. This is where management commitment is paramount. If management is committed to energy conservation, organizing the team members will be easier.

Although many regions will contract-out energy audit tasks (for many different reasons), those contracting actions still take time and resources to manage. Many utilities now offer free or subsidized audits to their customers; however, region/facility personnel must still manage this process.

Selecting and training in-house qualified engineers and technicians to perform energy audits can pay off when it comes time for project implementation. The personnel

should be sent to energy training courses. Their ideas for developing energy conservation projects must be obtained. Also, ideas from other regions can be obtained by contacting the program office for energy management and conservation.

Examples of areas where in-house personnel can participate on the audit team are as follows:

- *Lighting analysis*: The staff electrical engineer or technician can assist in conducting lighting surveys.
- *HVAC systems and controls*: This area is highly technical. Well-trained personnel are essential. If available, mechanical engineers can provide help. If not, outside help from headquarters or contracting sources may be available.
- *Building envelope*: Civil engineers and architects can help in identifying potential energy savings opportunities.

10.6 PERFORMING THE AUDIT

The most important requirement of an energy audit is to ensure that the actual checks of energy systems for inefficiencies are made by qualified engineers. Audit teams should be organized based upon the types of energy systems being audited.

Checklists are effective for ensuring that an audit has obtained all of the necessary information. Basic checklists are provided at the end of this chapter for various energy-using systems. These checklists can be modified to meet a facility's specific needs.

Facility maintenance personnel should be part of the audit team. They should be familiar with the workings of different energy systems. More importantly, they must learn how to operate those systems at peak efficiency.

Energy-user involvement is another important part of the energy audit. End users can provide useful information about the past performance of energy systems.

In order to ensure that energy consumption data is correct, quality control is critical when conducting an energy audit. The proper tools and instruments needed to help accurately evaluate energy systems must be purchased. Appendix N

lists the names of tools used for measuring energy consumption and efficiency in an energy audit.

10.7 THE AUDIT REPORT

To get the full potential from an energy audit, the results must be documented. At a minimum, the energy audit report should record the types of equipment used in the audit, energy consumption patterns, and potential areas for saving energy. That information will be useful in the future for calculating actual energy savings (by comparing historic consumption data with new data obtained after taking corrective actions). Preparing reports takes time, but it is necessary to ensure that good conservation projects are implemented.

An important function of an energy audit report is to inform decision-makers about the audit findings and to convince them to allocate the necessary resources to correct any deficiencies. Using briefing slides to show why the decision-makers should commit resources to energy conservation is often an effective way to communicate audit findings. Rather than describing the audit itself, the energy manager should concentrate on the actions to take and explain deficiencies and proposed corrective actions, supporting them with an economic justification.

10.8 ENERGY AUDIT CHECKLISTS

Energy audit checklists can be used by facility energy managers to inspect and identify the energy efficiency, safety, and environmental soundness of lighting, steam systems, chilled and hot water systems, and so forth. These checklists are provided on the following pages.

ENERGY AUDIT CHECKLISTS

LIGHTING CHECKLIST

ITEM	COMMENTS
Measure footcandles at workplaces to ensure that illumination levels meet standards. Note: The Illuminating Engineering Society (IES) has recommended foot candle levels by type of workplace. Other lower lighting standards exist, including one promulgated by the U.S. Department of Energy (DOE).	
Ensure type of lighting (e.g. fluorescent, incandescent, mercury, sodium, and quartz) is the most appropriate for the application. Record type of lighting.	
Reduce illumination level by removing lamp. Ensure that wattage of each lamp is appropriate. Evaluate whether there are too many unnessary lamps. Record.	
Increase the efficiency of existing lighting by periodic cleaning of light fixtures (lenses) or adding reflectors. Last date cleaned: __/__/__.	
Determine areas with special lighting requirements. Evaluate whether current lighting arrangements are adequate.	
Turn off lights when not needed. Check for lights which are left on when they are not needed. Investigate the feasibility of installing automatic sensors to control lighting in these areas.	
Reduce the lightings' hours of operation.	
Evaluate whether work stations are organized and located to take maximum advantage of existing lighting.	
To minimize glare and ceiling reflections, the light source should be to one side of the worktask area rather than directly in front of, or over it.	
Evaluate whether the maintenance of lighting systems has been effective.	
Identify large work areas that are uniformly lit for the entire space. Investigate whether "spot" lighting can replace unnecessary lighting of an entire work area.	
When lamp removal is appropriate, first remove lamps over nonessential task areas.	
Consider removing the inner two lamps in four-lamp fluorescent fixtures and/or in every other luminary in the row.	
Disconnect the ballast on fluorescent and high-intensity discharge (HID) fixtures after lamp removal.	
Remove lamps directly affecting the task areas, as necessary.	
Find areas where more efficient lighting components can replace inefficient original lighting system designs or fixtures.	
Color code lighting fixtures from which lamps have been removed so that maintenance crews do not replace those removed lamps.	

ENERGY AUDIT CHECKLISTS

LIGHTING CHECKLIST (continued)

ITEM	COMMENTS
Check and (as appropriate) disconnect light switches where the associated fixtures are not needed.	
Check and, if needed, install switches for selective control of illumination where (1) spaces require different lighting levels for different activities, or (2) daylight can be used to supplement or replace electric lighting.	
Check and, if needed, install timer switches or electronic personnel sensor switches in areas used infrequently or for only a few minutes at a time.	
Check and, if needed, install photoelectric cells for turning outside lighting on and off.	
Make maximum use of daylight. Encourage workers to use natural lighting by using windows and skylights. Using daylight helps lessen heat requirements. Natural sunlight should cross perpendicular to the line of vision.	
Group many light replacement projects together.	
Consider lowering light fixtures so that they are closer to task work areas in high bay areas and other spaces. Lighting intensity at the task varies as the inverse square of the distance between source and task.	
Remove lenses from luminaries in corridors, storage areas, high ceiling spaces, equipment rooms, etc. and other spaces if the resulting glare will not be a problem. Lenses cut out light, removing them may allow use of fewer lamps.	
Remove or lower room wall partitions where they are not needed, or use low partitions with glass.	
Relocate or remove light fixtures when the light is blocked by over-stacked materials or other obstructions.	
Where possible, replace two small wattage incandescent lamps with one large incandescent lamp (of lower total wattage). For example, replace two 60-watt lamps with one 100-watt lamp.	
Evaluate the use of several types of reflective incandescent lamps to produce the light needed, but using fewer watts (depending upon type and application). For example, in recessed "tophat" fixtures, elliptical reflector (ER) bulbs or screw-in fluorescent lamps usually can be used at a lower wattage than regular flood lights, yet they provide equal amounts of usable light.	
Check and, if appropriate and practical, convert incandescent fixtures to fluorescent (by changing fixtures or replacement lamps) or to HID (by the addition of a ballast plus the lamp). Mercury vapor fixtures often can be converted directly to high-pressure sodium (HPS) or to metal halides. Note: Payback for lamp conversion will vary depending on wattage reductions, electricity rate structures, and the number of hours electric lighting is used in a particular location.	

ENERGY AUDIT CHECKLISTS

LIGHTING CHECKLIST (continued)

ITEM	COMMENTS
Replace existing fixtures with more efficient types. Check and, if possible, replace lamps with T-8 lamps and electronic ballasts.	
When replacing ballasts in fluorescent fixtures, use 430-milliampere (mA), high-power factor, low-wattage ballasts with appropriate lamps. Note: Reduced wattage electronic ballasts are also available that use less electricity, last longer, and operate at lower temperatures than standard types.	

STEAM SYSTEMS CHECKLISTS

Learn how a central system actually operates. Get operations manuals and review them.	
Check for excessive consumption of boiler makeup water. This indicates steam leaks or bad traps.	
Check whether condensate return systems are functional. Condensate return should be at least 85 percent.	
Check for steam leaks and condensate leaks.	
Check all traps and tag bad steam traps.	
Check for uninsulated steam and condensate lines and tanks.	
Determine what steam is used for and if a cheaper substitute (e.g. natural gas) is available.	
Understand boiler/burner controls. Record settings.	
Perform a "flue gas" analysis to determine boiler combustion efficiency and whether a tune-up is required. If the boilers are already tuned, have less than three passes, and the flue gas temperature is above 400 degrees Fahrenheit (°F), consider installing turbulators in firetube boilers.	
Record boiler capacity and operating pressure.	
Determine steam requirements to see if boilers can be staged or if one or more boilers can be fully loaded while shutting down another.	
Determine if blowdown systems can recover the energy lost from hot boiler water and steam generation during blowdown. Note: By piping the vent off a blowdown unit's recovery unit to the deaerator, steam normally lost to the atmosphere can be recovered. By installing heat recovery coils in the heat recovery unit, heat from boiler blowdown to the drain can be recovered and used to preheat boiler makeup water, combustion air, and domestic hot water.	
Study water treatment; analyze boiler/ makeup water.	

ENERGY AUDIT CHECKLISTS

STEAM SYSTEMS CHECKLISTS (CONTINUED)

ITEM	COMMENTS
Consider installation of stack heat recovery units, such as economizers, if stack gas temperatures are high. Economizers should only be considered if all other recommendations have failed to reduce stack gas temperatures below 420°F for low load (200 to 600 horsepower) boilers.	

CHILLED WATER SYSTEM CHECKLIST

Understand chilled water systems and determine the capacity of auxiliary equipment.	
Check for chilled water leaks.	
Determine the proper chilled water operating temperature.	
Raise the chilled water supply temperature. Note: The temperature of leaving chilled water in centrifugal chillers is usually maintained at 42°F to 45°F by a chilled water thermostat. This may be lower than required to meet the cooling demand of the building air-handling systems, particularly in moderate weather. Chilled water supply temperatures of 50°F or higher can be used if humidity control and other comfort requirements are satisfied.	
Consider manually raising setpoint of the chilled water thermostat to the highest possible temperature while still satisfying humidity control and other comfort requirements. Install controls which reset the chilled water supply temperature based on the return chilled water temperature. Note: This allows the supply chilled water temperature to rise as the return chilled water temperature drops. The chiller follows the actual building load more efficiently, rather than supplying chilled water according to design conditions.	
Install controls that reset the chilled water supply temperature according to the cooling coil with the highest cooling demand. In this manner the chiller delivers only as much cooling as is actually required.	
Determine condenser water temperature. Lower the entering condenser water temperature as much as possible.	
Determine the condition of cooling towers on installations with a cooling tower bypass valve. Ensure that the bypass valve closes completely before the cooling tower fans operate. If chilled water is not needed during the winter, close the tower bypass valve permanently.	
Determine the condition of forced draft cooling towers. If chilled water is not needed in the winter, make sure the fan discharge dampers are kept completely open or remove them, if possible.	

ENERGY AUDIT CHECKLISTS

CHILLED WATER SYSTEMS CHECKLIST (CONTINUED)

ITEM	COMMENTS
Determine the condition of induced draft towers. Replace sections of fill that are damaged or deteriorated.	
Check whether hot gas bypasses are operating properly. Sometimes bypasses are not needed and can be discarded.	
Check controls to ensure that they are calibrated and functional.	
Determine whether heat transfer surfaces on the evaporator and condenser coils are clean.	
Determine whether the refrigerant level is too low.	
Investigate whether units can be shut off when not needed.	
Determine whether lights in walk-in coolers and freezers can be shut off automatically upon exit.	
Check whether time clocks are installed on window air conditioners. Verify that the most efficient EER units are used.	
Check for ways to control solar gain to reduce the cooling load on buildings.	
Investigate whether computer center cooling demands are the basis for setting the entire facility chilled water temperature. Consider using separate cooling units for computer rooms.	

SERVICE (DOMESTIC) HOT WATER CHECKLIST

Measure and compare existing water temperature versus required temperature (e.g. 105 °F from faucets). Lower the water temperature when appropriate.	
Measure the flow rate from showers and sinks. Consider using water flow restrictors.	
Determine the method of hot water generation. Investigate the feasilbility of installing decentralized water heating.	
Inspect circulating pump controls. Consider using variable-speed pumps.	
Inspect the hot water system for any leaks. Repair them if required.	
Inspect insulation on hot water pipes. Re-insulate if required.	
Check for any waste heat that can be used for water heating.	

BUILDING ENVELOPE CHECKLIST

Verify that outside wall insulation is adequate,	

ENERGY AUDIT CHECKLISTS

BUILDING ENVELOPE CHECKLIST (CONTINUED)

ITEM	COMMENTS
Verify that ceiling/roof insulation is adequate. About 40 percent of energy loss can occur through poor ceiling insulation.	
Check the type of windows used. Determine the feasibility of replacing single-pane windows with double-glazed window.	
Identify areas with infiltration or wind draft problems. Seal leaking areas if possible.	
Determine if any passive measures can be taken to reduce solar loading on buildings. The use of passive measures depends on the orientation of the building and its surrounding shrubs and trees.	
Check the type and number of doors on the building. Ensure that these doors are appropriate for their intended purpose. Consider installing revolving doors for high traffic areas.	
Check for ways to minimize heat loss (or heat gain) from loading dock doors or hangar doors.	

ELECTRICAL MOTOR CHECKLIST

Check whether motors are properly sized for their loads. Load motors fully where possible. Replace or switch motors as necessary. A 50 percent reduction in motor size results in an over 80 percent energy use reduction.	
Ensure that the highest practical power factor is used for electric motors.	
Consider shutting down elevators during unoccupied hours in buildings.	

HVAC SYSTEMS AND CONTROLS CHECKLIST

Study blueprints and determine the type of HVAC system being used.	
Determine the operations areas being served by all fans (i.e. supply, return, exhaust).	
Study control drawings and develop a design control strategy.	
Perform at least one inspection of all mechanical equipment.	
Sketch each air handling unit (as actually seen) showing the exact location of their sensors, fans, filters, coils, and dampers.	
Determine if the controls are installed as shown on the original manufacturer's drawings.	
Determine if the controls are functioning correctly.	

ENERGY AUDIT CHECKLISTS

HVAC SYSTEMS AND CONTROLS CHECKLIST (CONTINUED)

ITEM	COMMENTS
Determine the percentage of outside air being used.	
Determine the actual supply Cubic Feet per Minute (CFM).	
Determine if there are capacity reduction possibilities. Determine if there are adjustable sheaves.	
Determine the actual amount of power drawn by each fan system.	
Determine if modifications to controls are possible to conserve energy.	
Check whether HVAC systems are operating when the spaces they serve are not being used.	
Note: Often large capacity HVAC equipment is kept running to serve a relatively small area requiring continuous conditioning. In these cases, separate smaller HVAC units may be more efficient.	
Check for HVAC systems that draw in excessive outside air or recirculate more air than necessary. Readjust the air mix if required.	
Check whether the central heating and cooling plants are partially loaded most of the time because they were originally sized according to maximum-use design conditions that seldom occur. Large boilers and chillers operate at their peak efficiency only at full load. Consider installing smaller boilers or variable speed drive motors for chillers.	
Identify any HVAC systems that simultaneously heat and cool the same air to produce a desired temperature since that method of operation wastes energy.	
Reduce peak electricity demands by installing load limiters to turn off non-essential loads upon reaching a preset demand level. Load shedding reduces the demand charge assessed by utility companies.	
Consider using duty cycling that turns off a compressor, pump, or air handler for a brief period every hour or half hour; and that regulates HVAC systems by turning off the maximum number of units that can be turned off at any given time. Duty cycling can reduce peak energy demand without sacrificing the comfort of the facility occupants.	
Consider installing temperature controls that allow the HVAC system to use fresh air for ventilation.	
Note: These controls monitor the outdoor temperature and signal the HVAC system to use outdoor air depending on whether outside air temperature is cooler or warmer than indoor air.	
Shut down air-handling units or exhaust fans during unoccupied periods.	

ENERGY AUDIT CHECKLISTS

HVAC SYSTEMS AND CONTROLS CHECKLIST (CONTINUED)

ITEM	COMMENTS
Minimize outdoor air intake during building-occupied periods to eliminate the unnecessary heating and cooling of outside air. Note: Outside air brought into and exhausted from a facility uses a majority of the heating, and a significant portion of the cooling, energy consumed by HVAC systems.	
Determine the minimum number of outside air changes required per hour for each space served by an air handler.	
Reduce the cubic feet per minute (cfm) moved by exhaust fans by restricting flow or changing sheaves. Adjust the minimum position of outdoor air dampers on air handling units (AHUs) to meet minimum requirements.	
Install time clocks to shut down unnecessary exhaust fans and to close ventilation air dampers during unoccupied hours.	
Determine the present cfm being delivered by the air-handling unit and reduce the cfm as appropriate. Note: Many fans circulate more air than necessary to satisfy space requirements. Reducing air flow dramatically reduces the brake horsepower (bhp) used by the fan motor.	
Determine the volume of each area served by the air-handling units and the cfm delivered to those areas. Using this information, determine the total cfm required from the air-handling unit. Size fan motors accordingly.	
Consider installing a mixed air controller. Most AHUs are designed to maintain a constant mixed air temperature of 55°F. When outdoor air has a higher heat content than return air, the economizer should change over to minimum outside air and maximum return air. The general practice is to approximate heat content by changing over when the outside air temperature reaches 70°F	
Check for any stratification of outside and return air occurring in ducts or mixing plenums.	
Check controls on the economizer. Find out whether the controls are based on dry-bulb temperature or on enthalpy. Note: At low outside temperatures, the economizer should admit only the minimum amount of outside air required. This is often not the case with parallel-blade dampers. During cool weather, the economizer should mix outside and return air to supply air at a temperature no lower than needed to cool the area with the greatest cooling demand.	
Consider installing a set of relief dampers or a gravity ventilator to vent return air to the outdoors for fixed air handlers.	

ENERGY AUDIT CHECKLISTS

HVAC SYSTEMS AND CONTROLS CHECKLIST (CONTINUED)

ITEM	COMMENTS
Check humidity sensors for damage and for sensors out of calibration. Note: In most AHUs, humidification is accomplished by spraying steam into the supply air stream. AHUs are usually controlled by maintaining the desired relative humidity (RH) of supply air, by resetting supply air RH (by return air RH), or by maintaining the desired RH in one area.	
Find out whether humidification is required when the AHU is set in a mode other than "cooling only."	
Check the steam control valve on the humidifier. If the valve fails to close completely, it may leak steam through the humidifier into the air stream.	
Ensure that load optimization with reheat systems occurs by leaving at least one reheat coil off (which minimizes the amount of reheat in other areas). Note: Most central HVAC systems are designed to provide sufficient cooling and/or heating to satisfy the worst condition in any one area. By supplying an air temperature that satisfies the area with the greatest energy demand, energy wasted is reduced to an absolute minimum.	
Consider installing nonelectric thermostatic steam valves with wall-mounted thermostats. Sometimes it is practical to control all radiators in an area with an automatic valve on the steam supply line.	
Minimize electrical reheat by adjusting thermostats and reheat setpoints and balancing the air system. Note: Much of the required heat output is then shifted from the electric reheats to the steam and hot water heating coils located at the air handling units. During the summer, power can be shut off to all electric reheats within a selected AHU area.	

CHAPTER 11. ENERGY MANAGEMENT PLAN

11.1 KEY CONCEPTS

- The energy management plan provides a blueprint for action and a baseline with which to measure progress in energy conservation.
- The effectiveness of the program is monitored by carefully tracking energy consumption and cost data to determine if predicted savings are achieved.

11.2 DEVELOPMENT OF THE ENERGY MANAGEMENT PLAN

The central element of an effective energy management program is the energy management plan. A logical outgrowth of the survey report, the plan not only identifies energy efficiency opportunities but also indicates what is going to be done, by whom, and when. In short, the plan is the energy management team's blueprint for action and a baseline with which to measure progress. But it must be a flexible blueprint, one that allows for changes based on experience.

The more detailed an energy management plan is, the better it is likely to be. By providing details about every single action, a detailed plan shows that thorough consideration has been given to all important factors. Potential conflicts and problems can and should be identified and resolved *before* the plan's implementation, not during.

Establish Priorities

The heart of the plan relates to the specific energy efficiency opportunities (EEOs) to be used and the order in which they will be implemented. In most cases, numerous options will be identified, perhaps enough for three or more years of activity.

In most cases, it is practical to concentrate on the low-cost and no-cost EEOs that provide the greatest energy and cost savings immediately, and then schedule the low-cost and no-cost EEOs with less dramatic savings as soon as possible. Several moderate-cost EEOs also could be implemented the first year, with more in the second year, and so on. Options requiring substantial investment could be started soon after the people involved have gained good experience with the energy management program.

Initial emphasis usually is placed on the simplest measures (such as adding caulking and weatherstripping and insulating pipes and ducts) and on remedial maintenance (bringing devices up to design conditions unless slated for immediate replacement or substantial modification). In some cases, the improved efficiency resulting from remedial maintenance may suggest that a proposed EEO should be changed.

Clearly, a method is needed to rank EEOs in terms of priority – to identify which should be implemented first, which second, and so on. Not everybody will use the same criteria for establishing priorities; individual circumstances and attitudes vary. However, three types of considerations generally influence the ranking of each option:

- *Technical considerations*. Does the EEO require the prior implementation of a different option?
- *Financial considerations*. Is the EEO cost-effective? Does the implementation of one EEO affect the cost of another? Is funding available now? If not, when can funds be budgeted?
- *Energy considerations*. How much energy will be saved by implementing the EEO?

Prepare a Schedule

Once the EEOs are prioritized, the energy management team should make a preliminary schedule for implementation of the changes. The schedule should indicate the time required for each task and who will perform it. For a successful schedule, follow these two guidelines:

- *Scheduling must be realistic*. How long will it take to implement an EEO? What problems are likely to be created in the process? For example, if work is performed after hours to avoid office disruption, cost factors such as overtime pay for workers and additional light, heat, and ventilation must be considered. The same applies if work must be performed by outside contractors instead of in-house personnel. In that case, also allow additional time for preparing plans and specifications and taking bids.
- *Tasks should be organized according to their various subtasks*. By doing this, the skills required for each subtask can be identified, along with the time each is likely to take. The scheduler also should be familiar

with the capabilities of each employee and additional factors, such as vacation schedules, as well as the capabilities and availability of contractors.

Examine high-priority EEOs to determine time requirements associated with each. Some EEOs can be implemented in an hour or a day. Others may require as much as several months. To determine time factors, list each modification into its component elements. By knowing exactly how long it will take to go from start to finish, one will be able to identify various important benchmark dates.

One also will be able to coordinate planning with vacation schedules and schedules of others who are needed to help ensure that actions go as planned.

Based on the time requirements of each EEO, create a schedule for the first 18 months, showing what will occur on a week-by-week basis. Check the schedule carefully to ensure that conflicts are eliminated. Do not make the plan so tight that a 1-week delay in completing one option will throw off the entire balance of the plan.

Provide data on each of the EEOs to be implemented during the first 18 months. These data include:

- Identification of the specific change, including location
- Estimated cost of the change
- Estimated energy savings
- Estimated annual dollar savings
- Related financial data required by management (for example, simple payback, discounted payback, and savings-to-investment ratio)

Additional details that should be provided on EEOs to be implemented in the first 18 months include what is required in terms of work and material, when that work and material will be required, and how much it will cost to implement the EEO. By providing this information in as much detail as possible, potential problems can be identified and eliminated before they become real problems.

The elements of the plan that take place after the first months would be covered in less detail, especially since experience with the first months may suggest revisions to subsequent elements.

Develop a Budget and Goals

An understanding of how the FAA budget process works is essential in order for the energy manager to successfully plan and program energy projects, and to obtain the necessary funds. For their programs to survive the budget process, energy managers must develop strong justifications for those programs. A description of this process is provided in Chapter 3.

Because the energy manager knows what is going to be done, and approximately how much each change will cost and save, a budget and a goal can now be developed. The budget represents the amount of money required, in terms of capital investment for equipment, materials and labor, or operations and maintenance. Goals identify the amount of energy and money that will be saved. They help ensure that the people involved with implementing the plan have a common "cause." The simplest method of setting a goal is to total the estimated savings from implementing the different EEOs. However, several important considerations must be taken into account:

- *Be realistic*. It generally is best to make goals attainable to prevent the frustration of being unable to meet a goal that was set too high to begin with. By the same token, it would be unwise to set a goal too low, because early accomplishment of the goal could result in a "slackening off."

- *Estimate savings cautiously; some changes affect others*. For example, by removing lamps, one will save money on lighting. If the heating system is made more efficient, one will save money on heating. If, however, both are done, then the heating system may have to work harder to compensate for the heat that the lamps provided.

  In a similar manner, installing a heat recovery unit to reuse heat from exhaust air may save $6,000 worth of energy. Lowering the ventilation rate may also save $6,000. But doing both will not save $12,000 because less heated air is exhausted.

  The costs and savings associated with each EEO should be estimated accurately. In this way, the plan is as effective as possible and goals and budgets are as realistic as possible.

- *Consider when EEOs will be implemented.* Savings usually are stated in annual terms. Thus, an EEO projected to save 50,000 kWh per year will save less than that amount during the year in which it is implemented (unless it is in place on October 1). Consider, too, the nature of the system and the way it is to be used. A cooling system modification implemented in September may save nothing at all during the year in which it is implemented because the cooling system may not be used for the balance of the year.

- *Make adjustments for climatic conditions.* The amount of energy a facility consumes depends substantially on climatic conditions. If this year's winter is extremely cold compared with last year's, an accurate comparison of energy data is possible only if the data are adjusted to reflect the same climatic conditions. In other words, last winter's figures should be adjusted upward or this year's figures adjusted downward to obtain an accurate comparison.

- *Take energy rate changes into account.* To get a true picture of cost factors between one year and another, dollar factors should be adjusted to reflect whatever rate changes have occurred.

Obtain Management Approval

After the preliminary plan is complete, it should be reviewed with management. If management has a preferred type of presentation format, use it. It will make the entire process of approval that much simpler, since management will be able to find the information it wants by looking where it expects to find it.

Once the energy management plan is approved by management, the plan becomes final. The final plan includes details that identify the persons responsible for each function, the time factors involved, and the schedule. It also includes the budget and goals. For the final schedule, use a calendar, flowchart, or a similar aid so one knows what is supposed to happen at any given time and who is supposed to make it happen.

11.3 IMPLEMENTATION OF THE PLAN

Implementing the plan simply means doing what has been planned. In some cases – such as where obvious waste could be reduced or eliminated at little or no cost – common sense would dictate that elements of the plan be implemented even before the plan is finalized. Specific details about the technical aspects of implementation are provided in the following chapters, but three more general considerations are addressed here: selecting contractors, promoting the plan, and monitoring progress.

Select Contractors

Whenever a contractor is needed, certain steps should be taken to help ensure a good working relationship.

In most cases, it is advisable to prepare *building plans* that indicate the specific changes involved. Plans usually can be prepared easily, by in-house personnel or by an outside source. Working with plans minimizes the possibility of costly misunderstandings. Specifications also are required. These can be performance-based or prescriptive. Specifications should also indicate the warranties and guarantees sought, the time available to perform the work, applicable local building codes, and related concerns. Be aware that while they should be specific, specifications should not be so specific as to preclude changes or alterations.

To provide a sound basis for comparing proposals, all estimates must be based on the same set of plans and specifications. Do not necessarily select the lowest bidder. Be certain that the contractor selected is equipped to do the job as specified and has a reputation for good service.

Promote the Plan

Modifying both energized systems (such as boilers and chillers) and non-energized systems (such as the building's windows and insulation) can save significant amounts of energy and money. But how much is saved and at what cost depends on the effectiveness of the plan – which depends on the human systems. No matter how much time and effort are spent on modifications, the understanding and support of the facility community are crucial to obtaining the best results.

The entire facility community should be made aware of the energy management plan, its purpose, and its benefits from the very outset so everyone feels that they are part of the process. If the plan is explained to all involved, most will be ready to help put it into action and ensure that its goals are achieved. Use memos, signs, and other techniques to acquaint all facility occupants about impending changes. Tell them what they can do to help, who they can report problems to, and who to contact with their ideas and suggestions. One might also want to set up an incentive system for rewarding promising energy-saving ideas. Be especially careful to give people advance notice about any inconveniences that may be involved. People generally do not mind an inconvenience when they understand it is for a good purpose.

Promotion should not end once the plan is announced. Through posters, meetings, newsletters, and so forth, keep people informed of the program's progress and how their cooperation is helping. By keeping energy management on their minds, they will become more thoughtful in their use of energy.

Not everyone needs to have the same level of understanding and support for the plan. This will vary according to what they do and how they do it. In some cases, people will be asked to modify their habits – for example, turning lights off when leaving a room or securely closing outside doors. This understanding and support will be required throughout the life of the program. In many cases, the "new way of doing things" will develop into good habits, just as energy-wasteful habits were developed when energy was inexpensive and considered plentiful and when its effects on the environment were not well understood.

Monitor Progress

The energy management team must monitor two distinct aspects of the program: the *quality of implementation* and the *effectiveness of the program*. In both cases, the keys are careful observation and recordkeeping. Do not rely on memory alone. Records that should be kept include all energy bills and consumption data, along with costs and other factors associated with making changes. These records will allow one to compare the energy costs from month to month and with similar periods in other years, assuming one makes climatic or dollar adjustments as necessary for accurate and meaningful comparison. Information recorded and stored by energy management

systems can be helpful in monitoring both the quality and the effectiveness of the energy management program. As discussed in Chapter 19, many systems can record and print reports on daily energy consumption patterns, and even energy consumption by specific pieces of equipment. After reviewing the results of the monitoring, consider modifying the program to correct any deficiencies that may be present.

Quality of Implementation The energy management team should evaluate how long it takes for various tasks to be completed and how well they are performed. If a given change has gone over budget, determine why. If the energy savings forecast is not realized, determine why. Thorough and accurate records can lead to identification of issues that need further study.

When a contractor is retained to perform certain work, a qualified individual should inspect the work to ensure that it has been completed in a satisfactory manner. When maintenance schedules are revised, one should check with O&M personnel to ensure that the revised schedule can be managed adequately. Check to ensure that new maintenance procedures are being followed. In essence, this approach involves nothing more than following basic procedures of good management, making sure that responsibilities for specific functions are completed in the most effective manner.

Effectiveness of the Program

The effectiveness of the program is monitored by carefully tracking energy consumption and cost data to determine if predicted savings are achieved. The Energy Use Index Worksheet will provide information on any system or subsystem that is the sole user of a certain form of energy. In most cases, however, subsystem information cannot be extracted easily from that worksheet, nor is there any great need for subsystem information to be determined precisely. If determination of exact consumption of specific subsystems is imperative – such as lighting, elevators, heating, or cooling – the information can be obtained either through submetering or by conducting an empirical survey.

Submetering involves metering the power supplied by the various electrical feeders to the subsystem. In more contemporary buildings, where individual subsystems are supplied power independently, installation of submetering is relatively simple. In older facilities, where several systems operate from one feeder, the task is far more difficult, if not

practically impossible. Even when installation is simple, the cost of submetering can be high.

The alternative to submetering is an empirical survey. A professional is retained to survey the facility and its various subsystems to establish data on all connected loads, their usage and load factors, and to determine subsystem energy consumption. The larger the facility involved, the more difficult and expensive the task becomes.

An investment in subsystem monitoring will result in the ability to know how much energy is consumed by each system. In some cases, this may enable management to recapture energy costs or a portion of energy costs from tenants. In such cases, tenants have an added incentive to cooperate with the energy management program.

Plan Modification

The overall monitoring process, and the information that results from it, should be used to keep the energy management program as effective as possible. By analyzing the data obtained through monitoring, one will be able to make improvements, to undertake alternatives that have not as yet been attempted, and to revise goals where revision seems warranted. Monitoring, in short, helps ensure that the program continually reflects current realities.

By monitoring and analyzing results, one can incorporate lessons learned from experience into the energy management plan. The energy management team should meet as often as necessary (for example, monthly) to examine everything related to the plan that has occurred during the month. If elements of the plan are not realized, the team should make appropriate adjustments to the plan – such as dropping or modifying approaches to measures that are ineffective. Once the plan has been in effect for 6 months or so, the team should make adjustments for the next 6 months. The procedure involves repeating many of the steps used to make up the first year's plan. In this way, at the end of the first year the plan's elements for the following year will be filled out, fine-tuned, and ready to implement, complete with budget and goals. Updating also provides an opportunity to develop and issue a year-end review that compares energy consumption and costs to consumption and costs of previous years. This procedure helps keep everyone involved interested in the program.

CHAPTER 12. IMPLEMENTING A PREVENTIVE MAINTENANCE PROGRAM

12.1 KEY CONCEPTS

- To be most effective, preventive maintenance should be included in a carefully planned program that includes documentation, scheduling, and training in addition to the maintenance itself.
- The preventive maintenance coordinator should establish the program, formulate schedules, and follow up to ensure that work is being performed as scheduled.
- Schedules should include the type of maintenance needed, the frequency of the maintenance, who should do the maintenance, and how should it be done.

12.2 OVERVIEW

Preventive maintenance is an essential component of any energy management program. Improperly maintained equipment and systems needlessly cost money – they waste energy, usually result in downtime, are always more expensive to repair than they would have been if they were properly maintained, and generally need to be replaced sooner.

All facilities will benefit from a preventive maintenance program. This is primarily because preventive maintenance minimizes the need for expensive "breakdown" maintenance and repairs, in which equipment and systems are repaired only when they fail. Equipment routinely maintained runs more efficiently, with lower operational costs and maximum reliability. In addition, good preventive maintenance will extend the usable life-cycle of most equipment and, combined with good operating practices to keep building systems running at peak efficiency, will increase the value of the facility itself.

A well organized preventive maintenance program is an important follow-on to all of the energy efficiency opportunities chosen for implementation as part of the energy management program. However, it should also include systems that are scheduled to be upgraded in the later stages of the program. These systems should be

incorporated into the preventive maintenance program from the beginning.

12.3 ELEMENTS OF A PREVENTIVE MAINTENANCE PROGRAM

The checklists at the end of this chapter contain numerous preventive maintenance actions that can be performed at any time in almost any facility. However, to be most effective, preventive maintenance should be included in a carefully planned program that includes documentation, scheduling, and training in addition to the maintenance itself. The program should be scheduled to coincide with implementation of the energy efficiency opportunities outlined in this manual, but systems that are not upgraded or are scheduled for upgrades later in the energy management program should not be overlooked.

An effective preventive maintenance program should consist of the following:

- Establishing a single person to be responsible for the preventive maintenance program.
- Establishing a reference library that contains a complete inventory of equipment plans, flowcharts, diagrams, instruction manuals, parts lists, and so forth. These materials should be readily available at all times.
- Setting up and maintaining a master maintenance schedule and some type of work processing system.
- Reviewing operations logs and service logs to track the performance of systems. Use these logs to identify specific maintenance needs and adjust the frequency of maintenance activity according to equipment performance, thus eliminating superfluous inspections.
- Keeping a record of preventive maintenance and emergency repairs, including the costs and time required. Use these records, which will provide a history of all equipment (and thus eliminate dependence upon memory), to evaluate equipment and material and determine if equipment is operating efficiently or should be replaced.
- Familiarizing all operations and maintenance (O&M) personnel with the facility, its systems and

equipment, and maintenance requirements. Establish routines and procedures for maintenance, ensuring that the workload is distributed evenly. Keep records of the skills and hours required for preventive maintenance, which can be used to develop an O&M staffing pattern.

- Providing on-the-job training and ready reference material for new O&M personnel.

- Providing a formal, ongoing training program that integrates all aspects of a facility's operating and maintenance systems as well as environmental, energy conservation, and safety issues.

- Establishing, advertising, and operating a functional awards and suggestion program, one flexible enough to allow awards across functional lines.

Computer programs are available to assist in setting up and tracking a preventive maintenance program, including many of the activities listed above. In addition, energy management systems – automated controllers, often computerized – can provide valuable information on the condition of equipment and systems. More information on energy management systems, many of which can monitor conditions and adjust equipment operations accordingly, can be found in Chapter 19.

The next section describes how to establish a preventive maintenance program. Following that are some general guidelines for preventive maintenance and some recommended preventive maintenance actions for various facility systems.

Establishing the Program

One of the most important factors in establishing a formal preventive maintenance program is the need for supervision. The energy manager, or the preventive maintenance coordinator in charge, should establish the program, formulate schedules, and follow up to ensure that maintenance is being performed as scheduled. They should also serve as training coordinators. The preventive maintenance coordinator's responsibilities in developing the program will probably encompass the following:

- Assembling the library of O&M documentation.
- Establishing a library of training material.

- Developing the preventive maintenance schedule and reviewing and updating it regularly.
- Ensuring that the O&M staff receives adequate training.
- Conducting periodic inspections to ensure that proper maintenance procedures are being followed.

Specific tasks related to each of these responsibilities are described in the remainder of this section.

Documentation

A library of O&M documentation will be very important as one establishes and implements the preventive maintenance program. The library should include the following items:

- An up-to-date inventory of all systems and equipment, organized by maintenance task or by trade (depending on how you organize the preventive maintenance program).
- All operations and maintenance manuals for each type of equipment.
- Information on manufacturers' warranties and guarantees.
- Up-to-date versions of the building's architectural, mechanical, and electrical drawings.
- A complete set of building specifications, including addenda and all approved changes.
- Up-to-date versions of as-built drawings for each system.
- Single-line diagrams showing the function and operation of all major systems.
- Equipment operations logs, maintenance records, and complaint logs.
- Local building codes and other applicable laws, codes, standards, and guidelines.
- If an energy management system exists, documentation for the system and any system logs or printouts that may be on file.

All O&M personnel should be able to extract information on the facility and its systems from any of these sources. Once the preventive maintenance program is established, be sure to keep the documentation in the library up-to-date.

Scheduling

When one is ready to prepare a schedule for the facility's preventive maintenance program, equipment inventory and other documentation can be used to determine specific requirements. The schedule should include the following information for each system or individual piece of equipment:

- Type of maintenance required.
- Frequency of the maintenance.
- Who will do the maintenance.
- How the maintenance will be performed.

Many manufacturers can provide recommended preventive maintenance procedures and schedules for their equipment.

A master schedule that enables one to see all of the work that needs to be done in a given period is helpful. This can be done in a log book, through a computer program, or on a wallboard. List weeks or months across the top and the equipment or system down the first column. Use an appropriate mark to show when maintenance should be done and then another type of mark to indicate that the maintenance has been completed.

After developing the schedule, there is a requirement to assign preventive maintenance tasks. One way to do this would be to prepare work order forms that can be assigned to various personnel as required. The forms record the equipment, its location, the person assigned to the task, the time allotted and actually required to do the work, materials used, and any comments the person doing the work may need to record. They can be assigned to three categories: work to be done, work in progress, and work completed.

The preventive maintenance coordinator uses the work to be done file to assign tasks and the work in progress file to keep track of how the work is progressing. The forms in the work completed file make up a complete and accurate record of all maintenance performed.

Training

It is vital that O&M personnel be well-trained, fully understand all facility systems, and also understand their roles in the preventive maintenance program. The preventive maintenance coordinator should 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 O&M procedures for all systems.

The preventive maintenance coordinator should maintain a log that contains 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. This log should be reviewed regularly to ensure that all personnel have been properly trained.

For the preventive maintenance program to be effective, O&M 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 (O&M 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 facility has an energy management system, training is essential to 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 the system.
- 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.

12.4 PREVENTIVE MAINTENANCE ACTIONS

This section provides suggested preventive maintenance actions that can be taken for the various types of equipment typically found in most buildings. The descriptions are somewhat general by necessity; each action should be reviewed in light of manufacturers' recommendations for the equipment involved.

The following items should be included in the instructions for any preventive maintenance operation:

- Scope of Work
  - Inspect, clean, adjust, or other tasks specific to the equipment.

- Tools Needed
  - Standard shop tools normally kept in a central location (temperature gauges, ammeter, testing manifold for refrigeration system, stethoscope, control test kit, ladder, and so forth).
  - Special tools needed to make adjustments and perform remedial maintenance (may be determined during inspection).

- Special Instructions
  - Observe all safety precautions while working around moving, high-temperature, or pressurized equipment.

- Beware of automatic or remote-controlled equipment.
- Be alert to safety of other personnel, tenants, and the public at all times.
- Notify appropriate personnel in all cases where tenants will be affected.

- Procedures
  - Look at and listen to the equipment.
  - Secure power, steam, air, or water where applicable.
  - Place "Danger" tag on power source before proceeding.
  - Complete inspections, cleaning, adjustments, and remedial maintenance of equipment.
  - Restore power source and test operation.
  - Notify supervisor of any additional work required.
  - Complete the work order.
  - Clean up the entire area.

One may wish to develop a similar format for each piece of maintained equipment or for each type of maintenance (for example, routine cleaning, lubrication, and overhaul).

At a minimum, the maintenance actions presented on the following pages should be done at least once to bring systems up to efficiency. However, they also should be continued on a regularly scheduled basis, depending on factors such as the nature of the system and frequency of operation. Inspection of many of the items mentioned also will provide some idea about the effectiveness of the present maintenance program and the condition of the equipment, some of which may need adjustment, repair, or replacement. All the preventive maintenance tasks presented involve minimal expense.

Realize that these guidelines are general only. Whenever possible, the manufacturer of the equipment involved should be contacted to obtain pertinent literature describing the maintenance procedures suggested. Failure to perform maintenance as specified by the manufacturer may void warranties and could damage equipment. If the manufacturer's guidance is unavailable, a contractor who regularly installs such equipment or who designs heating and cooling systems should be asked to provide maintenance manuals or prepare guidelines.

PREVENTIVE MAINTENANCE CHECKLIST

BUILDING ENVELOPE

Windows and Skylights

- Replace broken or cracked window panes.
- Replace worn weatherstripping and caulking.
- Replace defective sealing gaskets and cam latches.

Doors

- Replace worn weatherstripping and caulking.
- Check automatic door closers for proper operation.
- Replace defective gaskets on garage doors and other overhead doors.

Exterior Surfaces

- Replace worn weatherstripping, caulking, and gaskets at exterior joints and at openings for electrical conduits, piping, through-the-wall units, and outside air louvers,

Stairwells and Shafts

- Replace worn seals and weatherstripping in stairwells, on penthouse machine room doors, in elevator shafts, in vertical service shafts, and on basement and roof equipment-room doors when they are connected by a vertical shaft that serves the building.

HVAC—Air-Conditioning Equipment

Refrigerant Circuit and Controls

- Inspect the moisture-liquid indicator to ensure that no moisture is in the system.
- Check for and repair refrigerant and oil leaks around the shaft seal, sight glasses, valve bonnets, flanges, flare connections, and the condenser assembly relief valve.
- Check for and repair leaks at pipe joints on equipment, valves, and instrumentation
- Check for and repair the source of oil spots on connections or under equipment.
- Inspect the liquid line leaving the strainer.
- Listen to the system operate for a few minutes and determine the cause of any unusual sounds.
- Check all gauges frequently to ensure that design conditions are being met.
- Inspect the tension and alignment of all belts and adjust as needed.
- Lubricate motor bearings and all moving parts.
- Inspect the insulation on suction and liquid lines and replace as necessary.

Compressor

- Check for unusual compressor operation, such as continuous running or frequent stopping and starting.
- Listen to the compressor operate for a few minutes and determine the cause of any unusual sounds.

PREVENTIVE MAINTENANCE CHECKLIST

HVAC—Air-Conditioning Equipment (continued)

- Check to see that the compressor and motor are securely fastened to the base.
- Check all compressor joints for leakage.
- Inspect instrumentation frequently to ensure that the operating oil pressure and temperature agree with manufacturer's specifications.

Air-Cooled Condenser

- Check the fan-belt drive and motor to see if they are properly aligned and lubricated.
- Be sure that refrigerant piping connections to the condenser coil are tight. Check for leaks.
- Clean the face of the condenser coil.
- Determine if hot air is being bypassed from the fan outlet to the coil inlet.

Evaporative Condenser

- Inspect piping joints and check for leaks.
- Check for dirt on the coil surface.
- Inspect the air inlet screen, spray nozzles, water distribution hoses, and the pump screen.
- Check to see if the local water supply leaves surface deposits on the coil.
- Follow the manufacturer's guidelines for fan and pump maintenance.

Water-Cooled Condenser

- Clean condenser shells and tubes.

Cooling Towers

- Conduct a chemical analysis to determine if solid concentrations are being maintained at acceptable levels.
- Check the overflow pipe's clearance from the normal operating water level.
- Listen to the fan and determine the cause of any unusual noise or vibration.
- Inspect the V-belt and the alignment of the fan and motor.
- Follow the manufacturer's guidelines for fan maintenance.
- Check to see if the tower is clean.
- Check to see if the intake strainer is clean.
- Determine if air is bypassed from the tower outlet back to the inlet.
- Inspect spray-filled and gravity-distributed towers for proper nozzle performance. Be sure the nozzles are clean.
- Inspect gravity-distributed towers for even water depth in the distribution basins.
- Monitor the effectiveness of any water-treatment programs.

Chillers

- Clean as necessary.
- Inspect for clogging.
- Keep water-side tubing clean and the refrigerant-side free of noncondensables.

PREVENTIVE MAINTENANCE CHECKLIST

HVAC—Air-Conditioning Equipment (continued)

Absorption Equipment

- Clean the strainer and seal tank regularly.
- Lubricate flow valves regularly.
- Follow the manufacturer's instructions for proper maintenance.

Self-Contained Units (window and through-the-wall units, heat pumps, etc.)

- Clean evaporator and condenser coils.
- Clean air intake louvers, filters, and controls.
- Keep airflow from units unrestricted.
- Replace worn caulking in openings between the units and windows or wall frames.
- Check the voltage to ensure that unit is operating at full power.
- Follow applicable maintenance guidelines for compressors, condensers, and fans.

HVAC—Heating Equipment

Boilers (General)

- Tune boilers at least annually.
- Inspect boilers for scale deposits, accumulation of sediment, or boiler compounds on water-side surfaces. The rear of the boiler is the area most susceptible to scale.
- Inspect the fire-side of the furnace and tubes for deposits of soot, flash, and slag. Pay particular attention to the fire-side refractory surface. Check the temperature at the gas outlet. Adjust the air-to-fuel ratio for a clean-burning fire.
- Replace door gaskets that do not provide a tight seal.
- Keep a daily log of pressure, temperature, firing rate, and other data. Look for variations as a way to determine the need for tube and nozzle cleaning, pressure or linkage adjustments, and related measures.
- Keep stacks free of haze. Adjust the burner if necessary.
- Tighten linkages when slippage or jerky movements are observed.
- Observe the fire when the unit shuts down. If the fire does not cut off immediately, the solenoid valve may need to be repaired or replaced.
- Clean nozzles or cutoffs on oil-fired units as necessary.
- Check the burner's firing period. If it is too long or too short, controls may be faulty.
- Check the boiler's stack temperature. If it is too high (more than 150°F above the steam or water temperature), clean the tubes and adjust the fuel burner.
- Inspect all boiler insulation, refractory, and brickwork and the boiler casing for hot spots and air leaks. Repair and seal as necessary.
- Replace all obsolete or little-used pressure vessels.
- Clean mineral or corrosion buildup on gas burners.

Boilers (Fuel Oil)

- Repair oil leaks at pump glands, valves, and relief valves.

PREVENTIVE MAINTENANCE CHECKLIST

HVAC—Heating Equipment (continued)

- Replace dirty oil-line strainers.
- Inspect oil heaters to ensure that oil temperatures are being maintained according to the manufacturer's or oil supplier's recommendations.

Boilers (Coal-Fired)

- Inspect coal-fired stokers, grates, and controls for efficient operation. Ashes with an excessive amount of unburned coal are usually a sign of inefficient operation.

Boilers (Electric)

- Inspect the electrical contacts and working parts of relays and maintain in good working order.
- Replace dirty heater elements as necessary.
- Adjust controls as necessary.

Central Furnaces, Make-Up Air Heaters, and Unit Heaters

- Clean all heat exchanger surfaces. Adjust the air-to-fuel ratio as necessary.
- Inspect burner couplings and linkages.
- Seal air links in casings as necessary.
- Repair or replace insulation as necessary.
- Follow the manufacturer's suggested guidelines for fan and motor maintenance.

Radiators, Convectors, and Baseboard and Finned Tube Units

- Remove obstructions in front of all units whenever possible. Ensure that air movement in and out of the connector unit is unrestricted.
- Be sure that air collected in the high points of hydropic units is vented to enable hot water to circulate freely throughout the system.
- Clean heat transfer surfaces in radiators, convectors, and baseboard and finned-tube units.

Electric Heating

- Keep the heat transfer surfaces of all electric heating units clean and unobstructed.
- Keep the air movement in and out of the units unobstructed.
- Periodically inspect heating elements, controls, and fans.
- Check reflectors on infrared heaters for cleanliness and proper beam direction.
- Determine if electric heating equipment is operating at the rated voltage.
- Check controls for proper operation.

HVAC—Humidification and Dehumidification Equipment

- Remove lint and dust from air dampers, fan parts, the spray changers and diffusers, control starters, and eliminators.
- Check equipment for carryover. Maintain carryover by adjusting eliminator seal gaps, altering damper positions, or changing air velocities.

PREVENTIVE MAINTENANCE CHECKLIST

- Follow the manufacturer's suggested guidelines for fan and motor maintenance.

HVAC—Air-Handling Equipment

- Seal leaks in ductwork by taping or caulking and repair or replace ductwork insulation as necessary.
- Check ductwork access openings for obstructions, such as loose hanging insulation (in lined ducts), loose turning vanes and accessories, and closed fire dampers. Adjust, repair, or replace as necessary.
- Inspect for buildup of water, condensation, or moistness on insulation and on equipment walls and floors of airhandlers. Ensure drip pans and drains are kept clear and free-running.
- Inspect damper blades and linkages. Clean, oil, and adjust regularly.
- Inspect air valves in dual-duct mixing boxes to ensure full seating and minimum air leakage.
- Inspect mixing dampers for proper operation.
- Clean or replace air filters regularly.
- Clean air heating, cooling, and dehumidification coils regularly.
- Seal leaks around the coils and casing.
- Keep all room air outlets and inlets (diffusers, registers, grills) clean and unobstructed.
- Inspect air washers and evaporative air-cooling equipment for proper operation. Clean damper blades and linkages. Inspect nozzles and clean as necessary.
- Check electronic air cleaners for excessive accumulations on the ionizing and grounding plate section. Replace filter media as necessary. Follow the manufacturer's instructions whenever adjustments or maintenance are required.
- Keep humidifier and dehumidifier air dampers, fan parts, spray changers, diffusers, controls, strainers, and eliminators free of dirt, lint, and other foreign particles.
- Adjust variable air volume boxes so they operate precisely to prevent overheating or overcooling.
- Follow the manufacturer's guidelines for fan maintenance.

HVAC—Motors, Engines, and Turbines

Motors

- Check the alignment of the motor to the equipment it drives. Align and tighten as necessary.
- Check for and repair loose connections and bad contacts regularly.
- Determine the cause of and repair excessive vibration and repair as necessary.
- Clean motors regularly.
- Lubricate the motor and drive bearings regularly.
- Replace worn bearings.
- Tighten belts and pulleys.
- Check for overheating. If overheating is present, check for functional problems or inadequate ventilation and repair as necessary.

PREVENTIVE MAINTENANCE CHECKLIST

HVAC—Motors, Engines, and Turbines (continued)

- Balance three-phase power sources to motors.
- Check for overvoltage or low-voltage conditions and correct as necessary.

Engines

- Follow the manufacturer's recommended maintenance procedures.
- Check fuel consumption and compare it with the designed fuel consumption. If fuel consumption seems to be excessive, determine the cause and correct.
- Record and check cooling-water temperatures daily. If they exceed the manufacturer's recommendations, check the temperature controls and correct as necessary.

Turbines

- Follow the manufacturer's recommended maintenance procedures.
- Record steam pressure and check turbine speed daily.
- Check the oil level, packing, and governor and throttle valve operation regularly and correct any problems as necessary.
- Record and check bearing temperatures and oil cooler temperatures. If they exceed the manufacturer's recommendations, check the temperature controls and correct as necessary.
- Check for vibration weekly and correct as necessary.

HVAC—Fans and Pumps

Fans

- Check for excessive noise and vibration and correct as necessary.
- Clean fan blades.
- Inspect and lubricate bearings regularly.
- Inspect drive belts for proper tension. Adjust or replace as necessary to ensure proper operation.
- Keep inlet and discharge screens on fans free of dirt and debris.

Pumps

- Check for packing wear and repack as necessary. Replace glandular packing with mechanical seals.
- Inspect bearings and drive belts for wear and binding. Adjust, repair, or replace as necessary.

HVAC—Pipes

Hot- and Chilled-Water Piping

- Inspect and test all controls for proper operation and leakage at joints. Adjust, repair, or replace as necessary.

PREVENTIVE MAINTENANCE CHECKLIST

HVAC—Pipes (continued)

- Check flow measurement instrumentation for accuracy. Adjust, repair, or replace as necessary.
- Repair or replace insulation as necessary. Replace any insulation damaged by water. Determine the source of the water and correct.
- Clean strainers regularly.
- Inspect heating and cooling heat exchangers. Temperature differences may be an indication of air binding, clogged strainers, or excessive amounts of scale. Determine the cause of the condition and correct.
- Remove clogs from vents.

Steam Piping

- Repair or replace insulation on all mains, risers, and branches as well as economizers and condensate receiver tanks as necessary.
- Check the automatic temperature-control system and related control valves and accessory equipment to ensure they are regulating the system properly in the various zones.
- Inspect zone shutoff valves and shut off steam going into unoccupied spaces.
- Adjust, repair, or replace any faulty steam traps.
- Adjust, repair, or replace pressure-reducing and -regulating valves and related equipment as necessary.
- Adjust, repair, or replace condensate tank vents as necessary.
- Check the accuracy of recording pressure gauges and thermometers.
- Inspect the pump for satisfactory operation, particularly for leakage at packing glands.
- Correct sluggish or uneven steam circulation.
- Correct any excessive noise in the system, particularly water hammer.
- Repair leaks in the vacuum return system.

HVAC—Pneumatic Air Compressor for Controls

- Repair any air leaks, particularly at connections.
- Note compressor operation. If it seems to run excessively, there could be pressure loss at the controls or somewhere in the piping system. Determine the cause and correct.
- Inspect the air pressure in the supply tank and pressure-regulator adjustment in the supply line for proper limits.
- Check belt tension and alignment.
- Clean or replace air compressor-intake filter pads as necessary.
- Lubricate electric motor bearings according to the manufacturer's recommendations.

PREVENTIVE MAINTENANCE CHECKLIST

LIGHTING

- Wipe lamps clean at regular intervals. Lamps that are exposed to substantial amounts of dirt, dust, grease, or other contaminants should be cleaned more frequently than lamps in a relatively clean atmosphere.
- Maintain luminaire efficiency by properly cleaning the reflecting surfaces and shielding media.
- Replace lens shielding that has yellowed or become hazy with a clear acrylic lens with good non-yellowing properties. A clear glass lens can be considered if it is compatible with the luminaire and does not present a safety hazard.
- Clean ceilings, walls, and floors frequently to improve reflective qualities.
- If daylighting contributes to lighting, wash windows frequently to maintain illumination levels.
- Replace all lamps used for area illumination after they have been in service for a substantial portion (approximately 70 percent) of their rated life, instead of simply replacing lamps one at a time as they burn out.

SERVICE HOT WATER

- Inspect pipes and tanks frequently. Repair or replace loose or hanging insulation. If insulation is water-damaged, locate the source of the water, repair it, and install new insulation.
- Repair all leaking faucets.
- Flush the water heater during seasonal maintenance of the heating system.
- Repack circulating pump packing glands to reduce hot water leakage. Replace glandular packing with mechanical seals.
- In the case of oil- or gas-fired water heaters, routinely check for smoky exhaust, high stack temperatures, and high levels of carbon dioxide. Adjust the air-to-fuel ratio to optimum levels (proper settings can be obtained from local utilities and suppliers.)
- Be sure that boiler water covers service hot water coils (if applicable).

ELECTRICAL SYSTEMS

Electrical Distribution System

- Conduct a load survey of the building's electrical distribution system. Check for low-voltage conditions, overvoltage, loose connections and bad contacts, unbalanced voltages, and power leaks to ground.
- Check voltage at the terminals of power and lighting circuits regularly.

Electric Motors

- Lubricate the motor and drives regularly.
- Replace worn motor bearings.
- Keep motors clean.

PREVENTIVE MAINTENANCE CHECKLIST

ELECTRICAL SYSTEMS (continued)

- Check the alignment between the motor and the equipment it drives and adjust if necessary.
- Tighten belts and pulleys at regular intervals.

CHAPTER 13. ENERGY EFFICIENCY OPPORTUNITIES IN BUILDING ENVELOPE

13.1 KEY CONCEPTS

- No-cost and low-cost measures can reduce general infiltration around windows, skylights, doors, and exterior surfaces, regardless of the building's height or configuration.
- Where the existing roof is sound and accessible, additional insulation provides a good investment in energy efficiency.
- Proper use of interior devices such as draperies, roll shades, and venetian blinds will reduce summer heat gain and winter heat loss.
- Clear double-glazed windows on southern exposures may be effective for locations with long, severe winters; reflective single-glazed windows are more appropriate for locations with long, hot summers.

13.2 OVERVIEW

A building's envelope consists of its roof, exterior walls, windows, doors and other openings, and exposed floors. A significant amount of energy can be wasted by infiltration and exfiltration through the building envelope.

Infiltration occurs when unconditioned air outside the building leaks in; exfiltration occurs when conditioned air inside the building leaks out. When conditioned air leaks out, it must be replaced by newly conditioned indoor air; when outdoor air leaks in, it must be conditioned. Infiltration and exfiltration occur through cracks and other openings around windows, doors, dampers, window and through-the-wall airconditioning units, skylights, and open doors and windows.

Infiltration increases with wind velocity, as air penetrates the windward side of the building. High-wind conditions often create negative pressure on the side of the building sheltered from the wind, which may induce air into the building even if the windward side of the building is windowless or "tight." Wind effects can also affect air pressure relationships within and between rooms in a building.

In tall buildings, *stack effect* also induces air leakage through cracks and openings. This condition exists whenever there is a difference in indoor and outdoor air temperature, but becomes stronger as the temperature difference increases. It is always a potential problem in vertical spaces such as service shafts, elevator shafts, and staircases. During the heating season, warm air has a tendency to rise, pulling conditioned air up through vertical spaces and allowing it to escape from the upper levels of a building. This air is replaced by colder outdoor air, pulled into the building at the lower floors, which must be heated.

13.3 NO-COST / LOW-COST OPPORTUNITIES

The following no-cost/low-cost measures can reduce general infiltration around windows, skylights, doors, and exterior surfaces, regardless of building height or configuration:

Windows and Skylights

1. Replace broken or cracked window panes.
2. Install weatherstripping on operable sashes if cracks are evident.
3. Caulk around window frames (exterior and interior) if cracks are evident.
4. Rehang misaligned windows.
5. Ensure that all sealing gaskets and cam latches are working properly.

Doors

1. Replace any worn or broken weatherstripping.
2. Install weatherstripping where it has not been installed previously.
3. Caulk around door frames.
4. Re-hang misaligned doors.
5. Ensure that all automatic door closers are functioning properly. Consider adjusting them so doors close faster.
6. Inspect the gasketing on garage and other overhead doors. Repair, replace, or install as necessary.

Exterior Surfaces

1. Install caulking, gaskets, or weatherstripping at all exterior joints, such as those between the wall and foundation or the wall and roof, and between wall panels.
2. Install caulking, gaskets, or weatherstripping at all

openings, such as those provided for entrance of electrical conduits, piping, through-the-wall cooling and other units, and outside air louvers.

3. Where practical, cover all window and through-the-wall cooling units when not in use. Covers specifically designed for this purpose are relatively inexpensive.

The following measures will reduce infiltration due to stack effect:

1. Reduce the temperature in stairwells. (If necessary, protect pipes from freezing.)
2. Seal elevator shafts at the top and bottom. Install weatherstripping on penthouse machine-room doors and be sure they are kept closed.
3. Seal vertical service shafts at the top and bottom and, in tall buildings, at every sixth floor.
4. Install weatherstripping on basement and roof equipment-room doors when they are connected by a vertical shaft that serves the building and be sure they are kept closed.

☞ *Be certain to comply with building code ventilation requirements. Check the fire resistance ratings of materials used. Skylights or smoke-relief vents may be required.*

Once these initial energy efficiency opportunities have been implemented, be sure that periodic inspections of windows and skylights, doors, exterior surfaces, stairwells, and shafts are incorporated into the preventive maintenance program.

13.4 MODERATE-COST AND CAPITAL-INTENSIVE OPPORTUNITIES

The energy required to offset infiltration and exfiltration can be substantial; an infrared thermographic survey can locate problem areas and their severity.

The two most common moderate-cost options to reduce heat gains and losses through the building envelope are adding more insulation and installing solar shades such as venetian blinds, drapes, and window films. A third, more capital-intensive option, is to replace existing windows with those having a higher thermal resistance efficiency.

Add More Insulation

Where the existing roof is sound and directly accessible from an attic or ceiling void, additional insulation provides a good investment in energy efficiency. Polyurethane foam or mineral fiber can be sprayed on the underside of the roof, and rigid batt or other applicable insulation can be added to the inside surface. In addition, fiberglass batt can be laid on the top of a ceiling as long as light fixtures are not covered.

In general, insulating the exterior of the roof is practical only when the roof needs to be replaced. In this case, rigid insulation can be installed as part of the reroofing project. When reroofing low-rise buildings with large roof areas, a reflective roof membrane can be effective in preventing heat infiltration.

In many cases, more energy can be saved by insulating the ceiling rather than the roof in buildings with attics. However, to avoid problems such as excessive heat transfer or freezing in the attic, be sure that ducts and pipes are insulated. The attic should also have adequate ventilation.

Adding insulation to other components in most large buildings may not be cost-effective.

Install Solar Controls

Unlike insulation, modifying windows by adding relatively inexpensive solar controls is almost always cost-effective. However, before undertaking a window upgrade, consider the effect of the upgrade on other building systems. For example, reflective glass and window coatings keep solar heat out of the building. This is a plus in the summer, but the loss of solar heat increases the building's heating load in winter.

Window modifications fall into three general categories: interior devices, exterior devices, and glazing.

Interior Devices. Proper use of interior devices such as draperies, roll shades, and venetian blinds will reduce summer heat gain and winter heat loss. When an interior device is installed in a manner that provides tight closure, air is trapped between the window and the device, providing additional insulation.

Interior devices are easily accessible, and thus provide for effective control as outdoor conditions change. They also

absorb and radiate heat into the building's interior. This is a plus in the winter, but creates a cooling load in summer.

Exterior Devices. Exterior devices are part of the window, wall, or roofing system. Used mostly for shading, they include louvered sun screens, blinds, awnings, and roof overhangs.

Exterior devices offset certain climatic conditions before they affect the building. Some also provide secondary benefits. For example, sunscreens provide shade in the summer and in winter preserve an air film at the exterior surface of the glass, which reduces heat losses. External roll blinds create a trapped air space, thus acting like storm windows to reduce heat losses in winter while affording protection from solar heat in summer.

Replace Existing Windows

The type of glass installed in a window determines the amount of sunlight that enters a building and the amount of heat that escapes to the outside. Insulating glass, multiple glazing (storm sash), and special reflective films or coatings can be used to reduce heat transmission through glass. Reflective or tinted glass also reduces the amount of sunlight entering a building.

When considering a window replacement, note the ratio of windows to total wall area on the building, the physical surroundings of the building and the orientation of the windows, the severity of climate where the building is located, and interior heat gain from lighting, equipment, and people. Clear double-glazed windows on a southern exposure may be effective for locations with long, severe winters; reflective single-glazed windows are more appropriate for locations with long, hot summers.

Windows with more than one layer of glazing conduct less heat (see Table 13-1). In colder climates, windows with two or three layers of glazing are recommended. Approximately 5/8-inch of air space is recommended between each layer of glazing. Increasing the air space beyond this value does not substantially reduce thermal transmission.

Glazing materials most commonly used in buildings include clear glass (single or multiple layers), heat-absorbing glass, reflective glass, insulating glass, and glass block.

Table 13-1. Characteristics of Various Glazing Materials

Description	Thickness	U-Value (winter)	U-Value (summer)	Visible	Solar	S.C.
Single, Clear	1/8"	1.16	1.04	.90	.84	1.00
	1/4"	1.13	1.04	.89	.78	.95
	3/8"	1.11	1.04	.88	.72	.90
	1/2"	1.09	1.04	.86	.67	.86
Single, heat absorbing	1/4"	1.13"	1.10"	.52	.96	.71
Double	3/16" air space	.62	.65		.71	.88
	1/4" air space	.58	.61			
	1/2" air space Low e coating	.49	.57	.80		.82
	e = .20	.32	.38			
	e = .40	.42	.49	.14		.25
	e = .60	.43	.51			
Triple	1/4" air space	.39	.44			.71
Acrylic, single glazed	1/4" air space	.96	.89	.92	.85	.98
Acrylic, with reflective coating	1/4" air space	.88	.83	.14	.12	.21

Clear glass one-eighth-inch allows approximately 84 percent of solar heat and radiation directly into the building, depending on the angle of the sun. Single-pane transparent glass any thicker does not significantly reduce heat or radiation.

Heat-absorbing glass reduces solar heat and radiation without substantially reducing visibility. The glass selectively absorbs radiant heat energy and then reradiates a portion of it either to the building's interior or to the outside.

Reflective glass (glass coated with a thin metallic film) reflects a much larger portion of solar heat and radiation than clear, uncoated glass. It is best used on buildings in areas with long cooling seasons because it eliminates the need for customary interior shading devices such as

venetian blinds. Reflective glass can cause significant heat gain in neighboring buildings.

Insulating glass modifies the amount of solar heat and radiation transmitted into the building. The exterior pane should be selected for its heat-absorbing or reflecting characteristics.

Glass block, specified for its radiation-absorbing or reflecting qualities, can reduce radiant heat gains to the interior by 35 to 75 percent.

When selecting glazing materials, consider how much solar heat gain is desirable in the heating season and how much of a reduction in natural lighting one can tolerate. Both of these decisions will affect interrelated systems such as lighting and heating and cooling.

Several recently introduced glass products are designed to accommodate the diverse needs for light and heat in various commercial buildings and climates. Most of these new products use coatings that permit only the desired portions of the solar spectrum (ultraviolet radiation, visible light, shortwave radiation, or infrared radiation) into the building. Two such examples are *antireflective coatings* and *low-E coatings*.

Antireflective coatings increase both daylight and solar heat gain in a space by reducing the amount of solar energy (visible and shortwave infrared) reflected from the glazing. They also block ultraviolet light better than other coatings.

Tiny, needlelike protuberances on the antireflective coating eliminate surface reflection losses, increasing both light and energy transmission (98 to 99 percent of visible light and 93 to 96 percent of solar energy). Because antireflective coatings let more energy in but do little to stop heat loss, they are typically combined with either two or three panes of clear glass with air space in between to provide added insulation.

Low-emissivity (Low-E) coatings reflect most longwave radiation back into a space for winter heating and reflect longwave radiation from outside surfaces back for summer cooling. The glass absorbs the longwave radiation it does not reflect. As with antireflective coatings, insulation can be added by combining the low-E surface with multiple layers

of either tinted or non-tinted insulated glass. Low-E coatings also block ultraviolet light.

Two types of low-E coatings, generally referred to as hard- and soft-coat, are available. Soft-coat is vacuum-deposited and generally applied to a thin-film material. It is generally more effective than hard-coat, but is extremely fragile to both moisture and touch. It cannot be handled, cut, or stored like ordinary glass. Hard-coat is manufactured by a pyrolitic process in which a hot, thin, metallic oxide coating is sprayed onto the ribbon of hot glass coming off the basic production line. It will not dull with age, has an unlimited shelf life, and can be handled, washed, and cut like normal glass. However, it is incompatible with some sealants.

One manufacturer offers three varieties of low-E coatings: one for cold-climate buildings with large heating loads; a second, with lower relative heat gain, for cooling-dominated buildings; and a third for moderate climates where daylighting is desired but heat gain is not.

Another new product being used in commercial buildings is an *airflow window*. This type of window usually has double-pane, insulated glass on the outside, single-pane glass on the inside, and an air space large enough to accommodate venetian blinds and airflows between. Air flows through the middle space from the sill to the window head; from there, in the cooling mode, it is either exhausted to the outside or, in the heating mode, sent to the heating, ventilation, and air-conditioning (HVAC) system for distribution to other parts of the building or, potentially, to thermal storage for later use.

Airflow windows are typically installed in buildings that employ concrete or other building materials that can provide thermal storage. In the heating mode, the venetian blinds serve as solar collectors. Because most of the direct solar energy is transported to the mechanical system, there is no overheating. This is also true in the cooling mode; the inside pane remains at a comfortable, controlled room temperature.

Because the angle of incidence between the sun's rays and the glass also affects the amount of radiation transmitted into a building, tilting windows can also be highly effective in reducing heat gain and loss. In summer, the angle of incidence to the south usually exceeds 57 degrees, so tilting the glass increases the amount of radiation that is reflected. In winter, when the sun's altitude is lower, the same tilt increases solar; heat gain.

CHAPTER 14. ENERGY EFFICIENCY OPPORTUNITIES IN HEATING, VENTILATION, AND AIR-CONDITIONING

14.1 KEY CONCEPTS

- Many HVAC systems are designed to meet extreme conditions that seldom occur. Accordingly, many systems are oversized and therefore perform inefficiently.
- Some facilities are ventilated at levels far greater than those recommended by local building codes. The more outside air brought in, the more energy used for heating, cooling, and humidifying the air and powering fans.
- Economizer controls save cooling energy by taking advantage of cool outside air when it is available.
- HVAC equipment at or near the end of its useful life should be replaced with equipment that operates efficiently at both design and part-load operating conditions.

14.2 OVERVIEW

This chapter describes many energy efficiency opportunities that can be applied to the heating, ventilation, and air-conditioning (HVAC) systems in a facility.

In the 1970s and early 1980s, the HVAC systems in many buildings were designed only with initial costs in mind-not energy efficiency. Moreover, most were also designed to meet extreme conditions that seldom occur. Accordingly, many systems are oversized and therefore perform inefficiently.

There are many ways to make HVAC systems more efficient. This chapter describes inexpensive alternatives related to operations as well as more substantive measures that involve retrofits and replacements. In addition, the preventive maintenance procedures described in Chapter 12 of this volume can also improve the overall efficiency of facility heating and air-conditioning systems.

Before changing HVAC operating practices, be aware that these modifications may cause minor changes in accepted

standards of comfort in the facility, some of which may be more noticeable than others. In addition, it is a good idea to obtain professional guidance before instituting any significant operational change. For example, in certain situations lowering the thermostat setting to 68°F during the heating season could activate the cooling system, wasting more energy than is conserved. Likewise, raising the thermostat setting to 78°F during the cooling season could trigger heating or reheat systems. Remember, each facility is unique; the guidelines presented in this chapter are general, and each must be tailored to the facility involved, preferably with professional guidance.

Ventilation systems typically have more of an impact on a facility's energy consumption than any other system. Although they consume relatively little energy directly (primarily to drive ventilation fans and damper motors), the ventilation systems' interrelationships in large measure determine how much energy is needed to heat, cool, and humidify a facility. Why? Because ventilation systems determine how much outside air must be brought into a building, and every cubic foot of outside air brought into the building must be conditioned. The more outside air brought in, the more energy used for heating, cooling, and humidifying the air and powering ventilation system fans. Consequently, the energy and dollar savings that can be obtained by implementing ventilation system energy efficiency opportunities can be substantial. However, one should be aware that ventilation is regulated by local building codes, and any modification to a ventilation system must conform to these codes.

Recent indoor-air-quality surveys of office buildings, schools, colleges, and health care facilities conducted by the National Institute for Occupational Safety and Health (NIOSH) showed that 52 percent of the 450 buildings investigated suffered from poor indoor air quality, primarily caused by inadequate ventilation. Problems commonly encountered involved inadequate outdoor air supplied to the occupied space; poor air distribution and mixing, leading to stratification, draftiness, and pressure differences between office spaces; temperature and humidity extremes or fluctuations (sometimes caused by poor air distribution or faulty thermostats); and air filtration problems caused by improper maintenance of the building's ventilation system.

Given the importance of the ventilation system and the need to comply with local codes and standards for ventilation and indoor air quality, here, too, it is a good idea to rely on a

consulting engineer to identify appropriate ventilation system energy efficiency opportunities for a facility. The consultant will be familiar with local codes and can identify existing ventilation rates, analyze system operating practices, and determine if any of the problems listed above are occurring in the system. In addition, one should incorporate ventilation systems into a preventive maintenance program as described in Chapter 12.

14.2 NO-COST / LOW-COST OPPORTUNITIES

No-cost and low-cost energy efficiency opportunities for HVAC systems are primarily related to operations. The following pages briefly describe many such opportunities.

Improve General Operations

General steps to save energy include the following:

1. Reduce heating and cooling in spaces used infrequently.
2. Turn the heat off during the last hour of occupancy.
3. Shut off all heating in garages, docks, and platform areas.
4. When appropriate, consider closing supply registers and radiators and reducing thermostat settings or turning off the electric heaters in lobbies, corridors, and vestibules.
5. If sill-height electric heaters are used, adjust thermostats so the heat provided is just sufficient to prevent cold downdrafts from reaching the floor.
6. Curtail humidification for areas such as hallways, equipment rooms, lobbies, laundry areas, and similar spaces.
7. Turn off portable electric heaters and fans when not needed.
8. Run self-contained units, such as window and through-the-wall units, only when needed. Turn them off when the space will be unoccupied for several hours.
9. In mild weather, lower the cooling effect by running room cooling fans at lower speeds.
10. Turn off reheat in all areas during the summer, except where equipment requirements necessitate humidity control.
11. On cloudy days during the heating season, close interior shading devices to reduce radiation from body heat to cold window surfaces.
12. Develop an after-hours equipment operation checklist

for custodial and other facility personnel as well as occupants who may use various spaces after normal hours.

13. Schedule maintenance work during the daytime, if possible.
14. Reduce internal heat generation as much as possible during the cooling season. Typical sources of heat generation include lighting, people, machines, and cooking equipment.
15. Eliminate gas waste by turning off gas pilot lights when combustion equipment is not going to be used for an extended time.

Reduce the Operating Hours of Local Exhaust Systems

Local exhaust hoods are commonly used in areas with concentrated smoke or fumes (such as labs, darkrooms, and lavatories). To maintain satisfactory capture velocities, they must exhaust substantial quantities of air. This air must be replaced by outside air, which usually must be conditioned.

Unnecessary use of an exhaust hood (that is, running the fan when there is nothing to exhaust) wastes energy. Therefore, shutting down exhaust systems when they are not needed can provide substantial savings. No cost is involved, except for the time required to identify the problem initially and work with service personnel to ensure adherence to new procedures. An alternative to depending on a human system to shut off the exhaust fan would be to install an inexpensive timer.

Shut Down the Ventilation System During Unoccupied Hours

Ventilation systems in many facilities run far more than necessary. In most cases, the ventilation system is needed only during occupied hours, sometimes even less. For example, for an office building occupied from 9 a.m. to 5 p.m. on Monday through Friday, the ventilation system should be operated for just 40 hours. But even 30 hours probably would be acceptable, assuming that the system can be shut off during the first and last hours of occupancy and that it is not used for economizer cycle cooling or morning warmup or cooldown routines.

☞ *Any reduction in ventilation system use must be in accordance with local code requirements, must be approved by a consulting engineer retained for that purpose, and must ensure that the quality of the air remaining in the facility*

fully meets the needs of persons staying after hours or arriving early.

Reduce Ventilation Rates During Occupied Hours

Some facilities are ventilated at levels far greater than those recommended by local building codes. Adjusting ventilation rates while the facility is occupied to the minimum allowable under local codes can provide significant energy and cost savings. Most local codes are based on consensus standards developed by the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE). ASHRAE Standard 62-1989, *Ventilation for Acceptable Indoor Air Quality*, specifies minimum ventilation rates and acceptable indoor air quality criteria. ASHRAE 62-1989 stipulates a minimum of 15 cubic feet of air per minute per person (cfm/person) in a building. Table-2 of ASHRAE 62-1989 defines the amount of outdoor air needed for well-mixed conditions in an occupied space. A ventilation system's effectiveness is defined by the percentage of outdoor air that reaches and is available to mix with existing air in an occupied space. This mixing in the occupied space can be improved through recirculation or by actively mixing the air in the space.

ASHRAE 62-1989 recommends the following techniques to reduce ventilation during occupied periods:

1. Lower the ventilation rate by adjusting outdoor air dampers until the desired volume of air is flowing. Before doing this, it is important that dampers be working properly and are correctly calibrated. Be sure that minimum outdoor air requirements are not jeopardized.

2. Cycle the ventilation system by turning it off for 15 to 20 minutes every hour. In this way, the building "coasts" on its existing air.

   ☞ *Use this practice with caution when air in some spaces may contain contaminants.*

3. Discontinue ventilation to spaces that do not require ventilation. For example, warehouses, which generally are large and lightly occupied, seldom need ventilation. High-ceiling rooms such as auditoriums need ventilation only when they are occupied.

4. Be aware of a facility's occupancy patterns. For example, the ventilation rates in a facility may be based on a peak occupancy that occurs only 10 to 20 percent of the time.

5. Close outdoor air dampers during the first and last hours of occupancy, when the air is most likely to require heating or cooling.

   ☞ *This step is not appropriate for facilities using an economizer cycle.*

6. Establish a schedule for the ventilation system, ensuring that exhaust systems operate only when they are needed most.

7. Reduce exhaust air quantities as much as possible ensuring that minimum exhaust requirement by code is not violated.

Increase Solar Heat Gain in Winter

Solar heat gain is usually beneficial in areas where heating requirements are significant. The following measures will increase the benefits:

1. Keep windows clean to permit maximum transmission of sunlight.

2. Install blinds, drapes, or shutters on windows that do not have them to control the rate of heat flow into and out of the facility.

   ☞ *Check the fire code for prohibitions against certain types of materials.*

3. Open blinds, drapes, and shutters to let sunlight in through windows during the winter. Move desks or workstations out of the direct path of sunlight to avoid occupant discomfort. Close blinds, drapes, and shutters at night and during periods of heavy cloud cover to reduce heat losses through windows.

4. If direct sunlight leads to excessive window brightness, causing discomforting glare, add a light-translucent drape that casts glare but still allows solar heat to enter.

5. Allow the temperature in spaces to rise so that some of the direct solar radiation will be stored in the structure and its furnishings. This will help offset nighttime heating requirements. Note that there is considerable diffuse radiation even on cloudy days.

6. Readjust blinds if overheating occurs.

7. Where possible, treat the site. For example, in the winter, trim all foliage shading the southern, eastern, or western facades of the facility; reduce any evergreen foliage grossly blocking the sun; and remove shading devices and any other objects that cast shadows on facility surfaces.

Adjust Indoor Temperature Settings

Adjusting thermostat settings is the easiest way to reduce heating and cooling requirements. However, it must be done with care. In many larger facilities, heating and cooling are often provided simultaneously. For example, perimeter areas of the facility need heat while central or core areas need cooling to offset heat gains from people, lights, and office equipment. Depending on the location of the thermostat and related system design factors, a setting of 68°F in the winter could activate the cooling system for interior portions of the facility. Even if this cooling is provided from outside air (as opposed to mechanical refrigeration), the additional outside air introduced into the facility will add to the heating load around the perimeter.

Adjusting thermostat settings changes the comfort conditions people are used to. Being that HVAC systems are designed and intended to provide comfort, occupants must be informed about any thermostat setting changes, and be advised to dress appropriately.

Because some occupants may not cooperate, it is a good idea to protect thermostats from unauthorized adjustment. The least expensive way to do this is to cover the thermostats. Covers can be installed quickly, and many can be locked.

If covers are susceptible to tampering, consider moving thermostats to ceiling return plenums close to the space to be conditioned, but out of reach. Alternatively, select thermostats that require a key to adjust the temperature. These approaches require changing the thermostat, which can be expensive. However, special key-operated

set-back/set-up thermostats will be required anyway if one decides to implement automatic night set-back and set-up procedures.

Lower Set-Back Temperature in Winter

During the heating season, substantial amounts of energy can be saved by lowering the thermostat during unoccupied periods, either manually or by adjusting automatic controls. The recommended set-back temperature is 60°F. Climate, type of HVAC system, and building construction determine when the system should be restarted to attain desired daytime temperatures. Experiment to determine the optimal set-back temperature and start-up times. In extremely cold weather, the heating system may not be able to raise the temperature back up by the time the building opens. Therefore, when extremely cold weather is forecast, adjust the set-back to a temperature higher than 60°F.

☞ *Be sure to check relevant local codes related to freeze protection for plumbing, fire sprinkler systems, and standpipes before implementing any extreme temperature reductions. Public utilities may set temperature requirements for their equipment rooms. Occupational Safety and Health Administration (OSHA) regulations also may apply.*

Some additional techniques for saving energy by temperature setback are listed below.

- Shut off radiators or registers in vestibules and lobbies during unoccupied periods and in areas without a separate thermostat.

- Shut off heat in corridors and stairwells. Close all doors between unheated corridors and heat spaces.

  ☞ *Be sure that the temperature does not fall below 55°F.*

- If thermostats are unavailable in spaces that are either heated by adjacent areas or receive solar heat through windows, shut off radiators, registers, fan coil units, and any other terminal heating devices until desired temperature levels are maintained.

- If the facility has large heated spaces, such as storage areas, that are occupied only by one or two people, lower the temperature to a level sufficient to

prevent damage to sprinklers and other systems and provide space heaters for the occupants.

- Reduce temperatures in retail areas to levels comfortable for heavily dressed patrons. Encourage staff to dress more warmly.
- When facilities are used after hours, consolidate activities to fewer spaces; reduce the temperature and turn off humidifiers in other parts of the building.
- Reduce hours of occupancy during severely cold weather.

Avoid Radiation Effects to Cold Surfaces

The temperature of the interior surface of a cold exterior wall or window is far lower than room temperature. People located near these surfaces radiate heat toward it, even if the room temperature is 70° to 75°F. To keep warm, these occupants may want the room thermostats to be set higher, but this can cause overheating and increase both heat loss and energy consumption. Remedies that will save energy and enhance comfort include using drapes and blinds, encouraging occupants to wear warmer clothes, and moving desks away from the cold surfaces.

Reduce Relative Humidity Levels

Humidification systems vaporize water into dry ventilation air to increase its moisture content. This provides comfort, protects the health of occupants, and prevents wood, furniture, and facility contents from drying and cracking. Humidification requires a heat input of approximately 1,000 British thermal units (Btu) to vaporize each pound of water.

Because moisture increases the *dewpoint* temperature of air, condensation will be found on any interior surface with a temperature lower than the dewpoint temperature of the air it comes in contact with. Accordingly, the maximum permissible relative humidity that can be maintained without condensation is influenced by the thermal properties of the enclosure and the interior and exterior environment.

Where preservation of materials is not a factor, maintain relative humidity at the level required for occupants, generally at least 20 percent in all spaces occupied more than 4 hours per day. Shut off humidifiers completely in all areas at night and during other unoccupied periods. If this

causes dryness and discomfort, raise the humidity level in each area of the facility in 5 percent increments until the appropriate levels are determined. If higher relative humidity levels are necessary to reduce static electricity and eliminate shocks, raise the humidity levels to 30 percent during those times when shocks are a problem.

Shut Down HVAC Systems

Examine the facility for actual HVAC system use to determine measures that will allow energy-consuming equipment to be shut down when the facility has few or no occupants—nights, weekends, and vacation periods. Only a small portion of a facility actually requires nighttime or 24-hour HVAC operation. Often a small unitary air-conditioning system designed to serve a room or few rooms will permit substantial shutdowns of large central systems.

Sometimes (several times a year) the central air system provides the heat for a facility. In these instances, a low-limit night thermostat can start the system on a full heating mode, with all outdoor air dampers closed, and keep it operating as required to maintain a specified temperature, such as 60°F. This type of thermostat is controlled by a time clock that starts and stops selected fan units or opens or closes automatic water or steam valves at predetermined times to maintain the desired temperature. In many cases, it will operate the system infrequently because of the facility's thermal storage capacity. As a result, separate connector or radiation hot-water systems, if a facility has them, normally can provide adequate heat during unoccupied periods and avoid the need to operate the central air system at all. And, depending on the facility's envelope, amount of glass, wall construction, and so forth, these radiation systems often can be completely shut off at temperatures above 35°F.

When the HVAC system is shut down during unoccupied periods, outside air dampers must be closed tightly. Inspect dampers to ensure tight seals, and repair or replace as required. Likewise, exhaust fans that interlock with outside air fans also should be closed. The only exceptions to these guidelines are when a nighttime economizer cycle, which uses cooler outside air instead of the mechanical cooling system to lower indoor temperature, is used during the cooling season.

If, after shutdown, the cooling system cannot achieve and maintain temperature and humidity conditions during hot

spells, install controls to activate it a few hours before occupancy rather than running the system all night or for the entire weekend. Shut down the boiler during the spring, summer, and fall when temperature control is not needed.

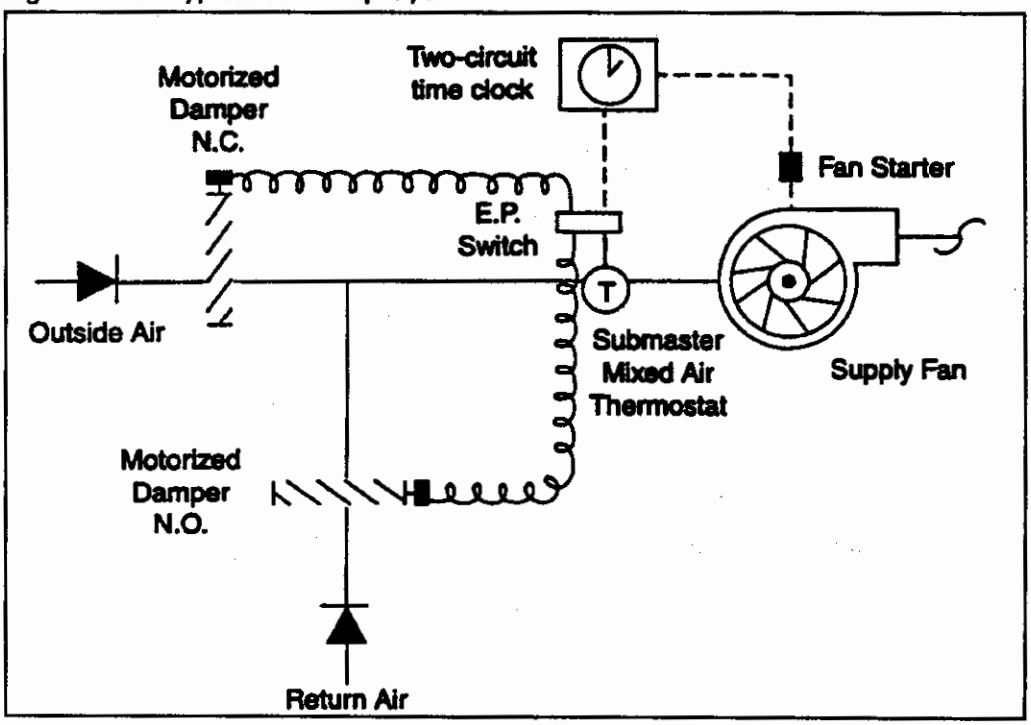
Add a Warm-Up or Cool-Down Cycle

If a facility's air-handling unit uses an outside air intake, one may be able to incorporate a warm-up or cool-down cycle into the system (Figure 14-1 depicts a typical warm-up cycle). The added cycle keeps the outside air dampers closed during morning warmup or cooldown. Thus, only the air already in the facility is heated or cooled; there is no need to treat the air that normally would be brought in through the open ventilation system. In the schematic, a two-circuit timeclock controls the outside air damper and fan operation.

Reduce Chiller Head Pressure or Coolant Temperature

Allowing the condensing pressure or temperature in vapor-compression cycles or the coolant temperature in absorption cycles to drop as outside temperatures fall, as described below, can provide substantial energy savings. Generally, anything that raises chilled water temperature or lowers condenser water temperature sufficient to meet loads will save energy. Consider automating these "reset"

Figure 14-1. Typical Warm-Up Cycle



functions. Normally, condenser water temperature is lowered by running the tower fan more, but as this too requires energy, additional study is required for each machine. Consider recovering heat from condenser water to preheat domestic water, but use caution in humid climates.

Vapor-Compression Cycles

One can save energy in typical vapor-compression cycles by allowing the 105°F refrigerant condensing temperature and the 95°F leaving-water temperature to drop as outside temperatures drop (provided the chiller's operating characteristics allow it). This saves the energy used for the cooling tower bypass that maintains entering-water temperatures at 85°F and also allows the chiller to run more efficiently because it does not have to work as hard to maintain the condensing pressure required for the lower temperature.

It is important to understand the chiller's operating characteristics because the condensing pressure in some chillers is always the same regardless of the entering-water temperature; thus, temperatures substantially lower than 85°F may force the chiller to work harder to maintain adequate condensing pressure, offsetting the energy saved by avoiding the cooling tower bypass.

Absorption Cycles

Many older chillers that use cooling tower bypasses set at 85°F for entering-water temperature have enough tolerance to allow entering-water temperatures as low as 70°F. Newer absorption chillers can tolerate entering-water temperatures as low as 45 to 55°F, and some of these do not require bypass valve controls at all. When the entering-water temperature is permitted to fluctuate with ambient conditions, the steam rate (pounds of steam per hour per ton) is reduced substantially. Consider running absorption machines at as high a pressure as possible; higher pressures mean higher temperatures, which increase capacity. With the capacity held constant, the steam rate (use) will drop. If so equipped, operate the absorption machine in a free-cooling mode.

Maintain Minimum Condensing Temperature by Cleaning and Purging

To maintain the best chiller performance at any given entering-water temperature, keep water-side condenser tubing clean and keep the refrigerant free of non-

condensables. A tremendous amount of energy is wasted as a result of high condensing pressures caused by non-condensables, fouled tubes, dirty strainers, poor cooling tower performance, and poor water treatment.

Consider installing automatic tube cleaners to reduce condensing temperatures and maintain low fouling factors. One such device, a cylindrical brush in each tube that is periodically forced from one end of the condenser tube bundle to the other by reversing waterflow direction, can be very effective in keeping condenser tubes clean. Depending on the extent of condenser tube fouling, energy savings from this energy efficiency opportunity (EEO) can be substantial.

Keep Chiller Leaving-Water Temperature High

Unnecessarily low chilled water temperatures waste energy. Raising the chilled leaving-water temperature raises the chiller's operating temperatures and thus reduces its workload. Every 1-degree rise in chilled leaving-water temperature can reduce the chiller's power requirements by approximately 1.25 percent.

A consulting engineer can determine an appropriate leaving-water temperature through a combination of HVAC system analysis and field testing. This will ensure that required room temperature and humidity is maintained while keeping supply air requirements at a minimum. Many system designs and installations can tolerate a substantial variation between full-load and part-load leaving-water temperature. When leaving-water temperature variation is feasible, the following techniques can be applied to control the temperature:

- Leaving-water temperature can be set automatically based on outside air temperature (within set limits) to take full advantage of heat load reductions. Room temperature or humidity requirements can override the setting if necessary.

- The temperature setting can originate from a sensor that monitors system part-load conditions. In systems that use cooling coils with valve controls, the temperature can be set by a signal from a select number of valves (or all valves, when necessary) that sense reduced coil loads. In systems that use coils without valve controls, the temperature can be set from the temperature of the water leaving the coil. In

either case, the reset chilled water temperature may be overridden by room high-limit humidistats, which should be set to the highest setting that maintains adequate comfort.

Operate Multiple Chillers Efficiently

When multiple compressors or chillers are used for cooling, operate one compressor at full load rather than two or more at part loads. Although this can be done manually, automated controls will provide optimal loads.

Reset Heating Supply Water Temperature

Heating supply-water temperatures are generally set higher than necessary, mainly to ensure comfort during infrequent cold periods. Resetting the temperature to match anticipated demand (determined by outdoor air temperature) can save as much as 14 percent in heating energy costs, including savings from reduced transmission line losses and poor control. It also improves occupant comfort levels because heat is distributed according to active needs instead of in high-temperature bursts.

For best results, experiment with various water-temperature settings and establish a schedule indicating the appropriate settings for different outdoor temperatures.

☞ *It may be appropriate to maintain significantly lower boiling-water temperatures during the first and last months of the heating season, when facilities experience substantial internal heat gains from lighting, business equipment, motors, occupants, and so forth.*

Use Oil Additives for Better Combustion

Oil additives improve fuel efficiency both directly, by lowering the ignition temperature and improving combustion efficiency, and indirectly, by keeping the boiler clean. Experience with oil additives indicates that they can increase the boiler's efficiency by approximately 2 percent by reducing excess-air levels and reducing fouling of heat-transfer surfaces.

Oil additives that can be used include sludge solvents, particulate and water dispersant, slag modifiers, and high-temperature and cold-end corrosion-control agents.

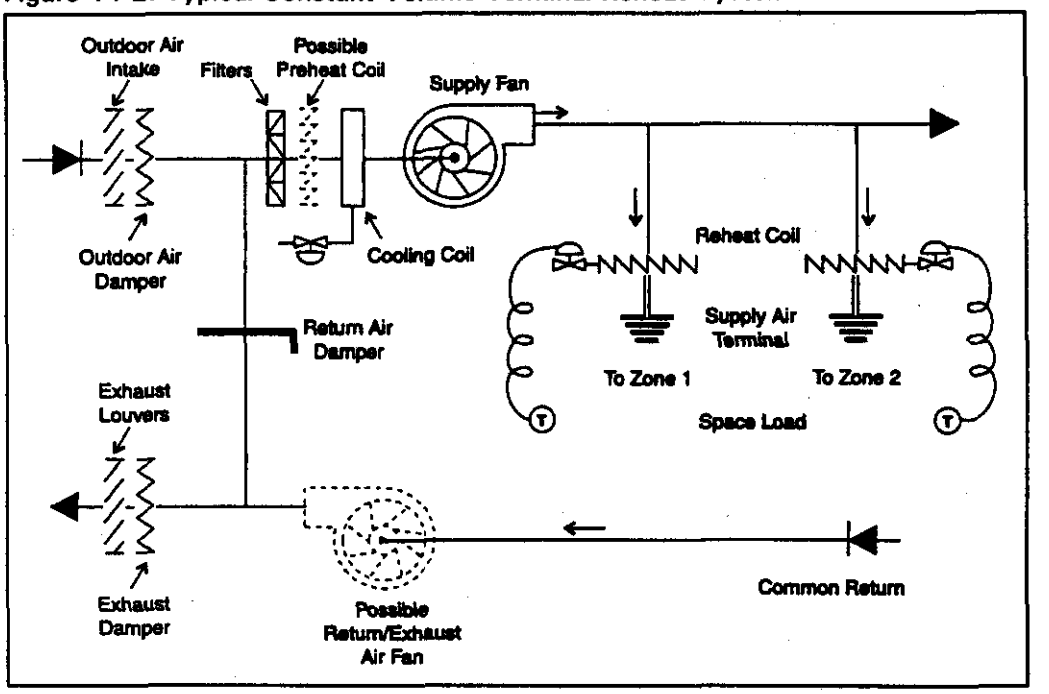
The slag modifier indirectly contributes to energy efficiency by reducing the insulating deposits on the boiler's fire side. Deposits as thin as 0.1-inch can decrease heat transferability by 10 to 50 percent, depending on their composition and the extent of coating on walls and convection tubes. Sludge solvents also allow the otherwise-wasted Btu content of the sludge to be used.

Reset Mixed-Air Temperature in Terminal Reheat Systems

Although terminal reheat systems allow a high degree of temperature and humidity control, they consume a substantial amount of energy in the process. In the system shown in Figure 14-2, supply air is passed through a cooling coil, which reduces supply-air temperature to approximately 55°F. The cooled supply air then flows through ducts toward each of the spaces served. Before entering the space, the cooled supply air passes through a terminal heating coil, which warms the air to the temperature set by the thermostat in the space. In so doing, cooling energy is wasted because the air is chilled more than necessary, and heating energy is wasted to compensate for the unnecessary cooling.

To reduce this waste during the cooling season, deactivate the reheat coils and manually adjust the temperature of the air leaving the cooling coil to meet comfort requirements. A temperature setting of 60 to 70°F usually is adequate,

Figure 14-2. Typical Constant Volume Terminal Reheat System



depending on facility characteristics and cooling loads. If there is a substantial change in cooling load each day, the air temperature setting may need to be adjusted frequently. Those who have used this approach report that comfort levels are satisfactory, as long as relative humidity levels do not rise substantially above 50 percent.

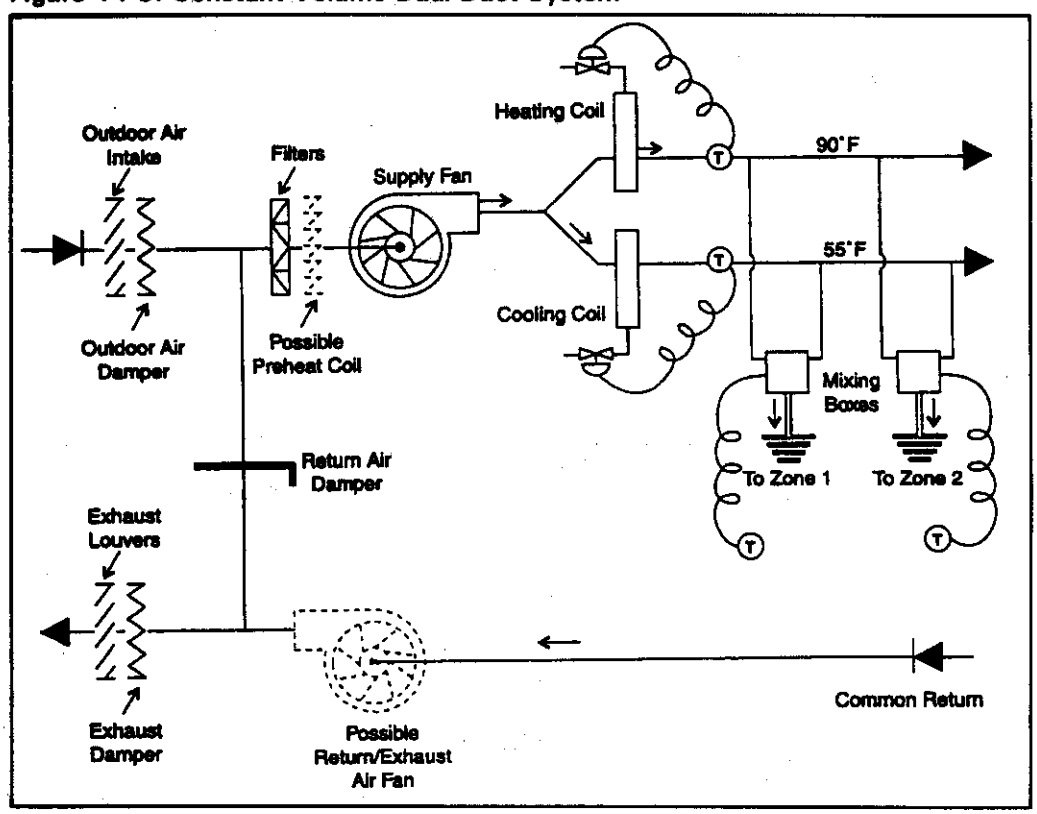
During the heating season, adjust the outside air and return air dampers slightly so that the supply-air temperature is between 64°F and 70°F, instead of the usual 55°F, depending on the conditions in the area served. Ensure that minimum outside air requirements are not violated.

Reset the Deck Temperature in Dual-Duct Systems

Dual-duct constant-volume systems (Figure 14-3) also consume a considerable amount of energy because each space is provided with both heated and cooled air. Before it enters a space, the air passes through a mixing box that regulates the amount of heated and cooled air to attain the desired mixed temperature.

This system can be modified during the heating season to be more energy efficient by allowing the cold-deck

Figure 14-3. Constant-Volume Dual-Duct System



temperature to rise to 60° or 70°F. During the cooling season, the hot-deck temperature can be reduced since less heat will be needed to achieve space temperature settings.

Improve Central Plant Operations

The following major steps can improve the operating efficiency of central cooling and heating plants:

Chiller Plant

- Use lower condenser water temperatures.
- Select and operate chillers to maximize their operating time at full-load conditions.
- Use higher chilled-water temperatures when humidity permits.
- Operate chilled-water pumps and cooling tower fans only when necessary.

Boiler Plant

- Operate steam boilers at lower pressures and hot water boilers at lower temperatures.
- Consider eliminating hot standby boilers.
- Operate water heating pumps only when necessary.

Improve Combustion Efficiency

All boilers, furnaces, and burners suffer from heat loss. For example, industrial boilers are likely to convert only 80 percent of their heat input into useful heat output. The remaining 20 percent is lost because of incomplete combustion, radiation and convection from boiler surfaces, blowdown, and flue gas.

Losses due to radiation and convection are likely to be 1.5 percent or less at full output. Additional insulation may reduce some of this loss.

Blowdown losses (if any) are a function of blowdown frequency and quantity. The loss depends on the boiler water makeup rate, the quality of the makeup water, and the treatment being used. If the system design requires frequent blowdown and blowdown losses appear to be excessive, install an exchanger system that can recover most of the loss.

Flue gas loss can be substantial. In the combustion process, ambient air in the boiler room is heated and converted into

flue gas as it flows over the internal surfaces of the boiler and eventually is discharged into the atmosphere through a stack. Factors that affect the amount of heat loss are the temperature and quantity of the gas going up the stack and the condition of the boiler's heat-transfer surfaces. To reduce flue gas losses, provide better control over the conditions that affect combustion efficiency and monitor combustion to ensure that the amount of air used is minimal. Keeping the quantity of excess air low will minimize both the weight and temperature of the flue gas going into the stack.

The temperature of the gas leaving the boil normally is significantly higher than the water being heated in the boiler. The exact difference depends on the amount, arrangement, and condition of the boiler's heating surface. Keeping the heating surface clean through sootblowing or brushing on the fire side and proper chemical treatment on the water side will ensure optimum heat transfer and low flue gas temperatures.

Some firetube boilers are characterized by relatively low flue-gas velocity through the tubes. These boilers usually are of two-pass design, and use large-diameter (3-inch-or-greater) tubes, a great number of second-pass tubes, or both. Heat transfer can be improved in some of these boilers by using tube inserts to accelerate gas flow. Consult the boiler manufacturer before making any modifications.

Another cause of flue-gas loss is the quantity of gas flowing into the stack, which is determined by the air-to-fuel ratio, which in turn depends on supply – air temperature, barometric pressure, humidity, specific gravity and viscosity of the fuel, and even boiler linkage wear. If any of these conditions change, adjust the burner controls to maintain the highest combustion efficiency possible with minimum smoke emissions.

Keep the level of excess air low-the more excess air in the combustion zone, the higher the boiler flue-gas temperature. Coupled with an increased quantity of gas, this higher temperature creates greater heat loss and reduces boiler efficiency. Air that is not part of the combustion reaction also decreases boiler efficiency by increasing the flow of hot gas up the stack.

Moisture or water vapor in the combustion process also decreases boiler efficiency. Water absorbs heat at twice the

rate of dry flue gases. It absorbs heat in the combustion chamber, thus decreasing the amount of energy available to the boiler surfaces, and then carries the heat into the atmosphere.

Keep Boiler Tubes Clean (Water Side)

The scale that forms on boilers can waste substantial amounts of energy, depending on its thickness and chemical composition. Typically, scale reduces steam output, resulting in excessive fuel consumption, and increases stack temperature. Boiler tubes should be inspected regularly to ensure that scale deposits are not building up.

If scale is a problem, consider modifying the feed-water treatment or the schedule of chemical additives. The cost of these remedies can vary widely, depending on factors such as the type of water treatment already available and any existing chemical problems. The advice of a consultant or a vendor of water treatment chemicals may be helpful.

Check Flue for Improper Draft

Proper draft is important in ensuring good combustion efficiency. A blocked flue restricts combustion air, which not only results in poor combustion efficiency (because of the high fuel-to-air ratio) but also causes potentially dangerous operating conditions. Conversely, overdraft causes a high air-to-fuel ratio, which also results in poor combustion efficiency. To avoid these situations, the chimney of the combustion equipment should be periodically checked for blockage or overdraft. Also, an oxygen sensor in the flue line can determine the exact level of the combustion efficiency in the boiler and the amount of excess air needed to maximize it.

Check for Air Leaks

Primary and secondary air should be allowed to enter the combustion chamber only in regulated quantities and at the proper locations to ensure an optimal fuel-to-air ratio. Air leaks in the combustor allow uncontrolled and varying quantities of air to enter the system, which increases the fuel-to-air ratio and lowers combustion efficiency. If stack-temperature or oxygen-content readings are questionable, inspect for air leaks. Repair or replace defective gaskets, cracked brickwork, broken casings, and so forth.

Reduce Pumping Flow

Chilled- and hot-water pumps commonly maintain a predetermined water flow regardless of cooling and heating loads. Many systems compensate for reduced load and flow requirements with three-way modulating control valves that detour the chilled or hot water around the coil and send it back unused. Consequently, pumps continuously operate at full load. This situation is most common in chilled-water systems where a specific minimum flow is required through the chiller.

In a pumping system where 3-way valves are used, energy can be conserved by simply replacing the 3-way valves with 2-way shut-off valves. This allows the pump head to increase when the units are satisfied, thereby forcing the pump to ride its curve and consume less energy. It is advised that several units at the end of the piping system be allowed to continue their operations with 3-way valves so that minimum flow can be maintained throughout the system at all times. This retrofit will normally result in pumping energy reduction of approximately 25 percent.

Also consider installing variable speed drives on motors of secondary loop water heating and chilled water pumps. Such pumps reduce pump energy requirements as well as the amount of hot and chilled water required to serve the actual load.

Adjust and Calibrate Controls

The original controls in many facilities were probably selected on the basis of low initial cost, not energy efficiency. Even with good maintenance, it is difficult to obtain a high degree of accuracy from relatively low-quality controls. Inadequate maintenance can cause calibration problems for even the best controls.

A well-planned program of adjusting and calibrating or, where necessary, replacing controls is an important part of any energy management program. It will not only save energy, but also improve the comfort level and reliability of the HVAC systems in the facility. The program should include the following:

1. Inspection and testing for proper operation.
2. Calibration of thermostats and gauges.
3. Adjustment of controllers.
4. Adjustment of air dampers to ensure tight closing.

After these EEOs are implemented, they should be incorporated into the preventive maintenance program.

14.3 MODERATE-COST AND CAPITAL-INTENSIVE OPPORTUNITIES

Moderate-cost and capital-intensive energy efficiency opportunities for HVAC systems are combined in this section. They are briefly described below.

Recirculate Filtered and Clean Air To Reduce Ventilation Load

Air cleaning devices that clean recirculating air can reduce the amount of energy required for ventilation. No single air-cleaning process can remove all three major types of contaminants (particulate, vaporous, and gaseous). Therefore, if different pollutants pose air quality problems in a facility, multistage cleaning is required. In all cases, particulate contaminants should be removed before vaporous and gaseous. Filters and electronic air cleaners are designed to remove airborne particulates; biological particles are usually removed by special filters, electronic air cleaners, or wet collectors. Sorption devices are used to clean vaporous and gaseous contaminants. It should be noted that building codes require a minimum flow of outside air which must be maintained at all operating times.

Activated carbon and alumina impregnated with chemicals that work on specific contaminants are effective air-cleaning media. Air-cleaning systems for recirculating air should be located in the recirculated air stream or in the plenum, where outdoor and return air mix.

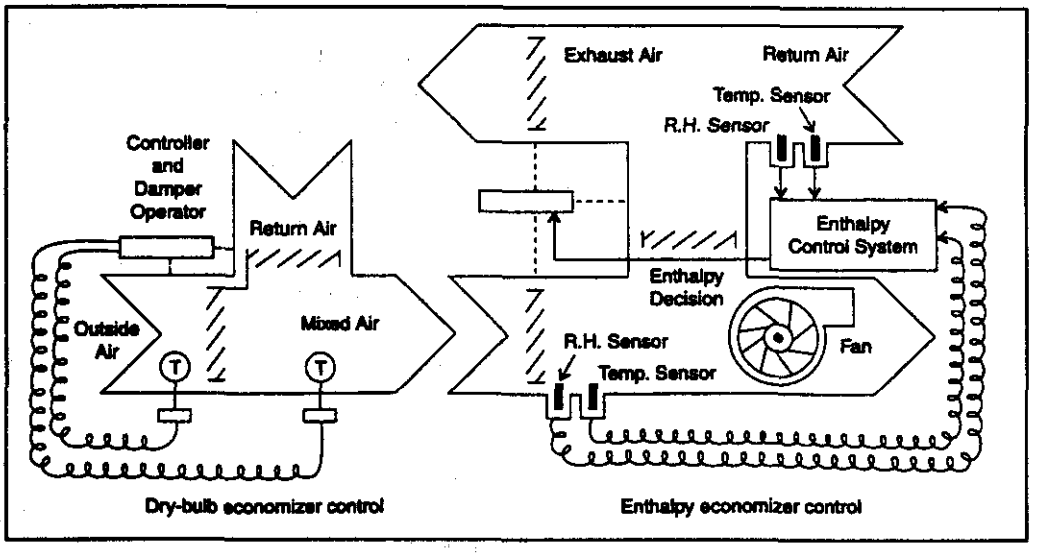
Add an Air-Side Economizer

Economizer controls on air-handling units that condition outside air save cooling energy by taking advantage of cool outside air when it is available. Mechanical cooling may not be needed when the outside temperature is in the 50° to 60°F range—conditions that may prevail for many hours each year in central and northern climates. Dry-bulb or enthalpy economizer cycle controls (see Figure 14-4) enable the HVAC system to take advantage of this cool outside air.

A *dry-bulb economizer cycle* is regulated by an outdoor dry-bulb temperature sensor. It is suitable in areas where there are fewer than 8,000 wet-bulb degree-hours above 66°F per year. A dry-bulb economizer cycle discontinues compressor operations when the outdoor temperature falls

below the design supply temperature (normally 50° to 60°F). Cooler outside air is then drawn into the system and mixed with return air to cool the spaces in the facility. The modifications needed to install a dry-bulb economizer cycle depend on the nature of the facility's existing air distribution system. If existing dampers do not fit well, they should be replaced with high-quality opposed-blade dampers with seals at both the edges and the ends of blades to minimize air leakage. Some manufacturers provide dampers designed for specific environments such as near the seashore, where there is much salt in the air.

Figure 14-4. Economizer Controls



If dry-bulb economizer cooling is used in the summer, the outside air dampers must be able to accommodate the full volume of air required by the supply fan. It may also be necessary to install return air and outdoor air dampers. In all cases, the indoor air pressure caused by the outdoor air must be relieved.

The savings provided by a dry-bulb economizer cycle can be substantial, depending on climate, type of facility, type of HVAC system, and related factors. In general, energy savings from an economizer will be in the 10 to 60 percent range.

An *enthalpy economizer cycle* is regulated by the total heat content (enthalpy) of the air. Outdoor air is used for cooling when its enthalpy is less than the enthalpy of the return air. Otherwise it is similar to a dry-bulb economizer cycle.

The choice between dry-bulb or enthalpy economizer cycles should be based on economics. If ones area of the country tends to be more humid (that is, more than 8,000 wet-bulb degree-hours per year), the additional expense of an enthalpy economizer is probably justified; if high humidity is rare, a dry-bulb economizer is the better choice.

Beyond saving energy, economizer cycle cooling provides more comfort because it uses fresh outdoor air. Because it allows the mechanical cooling system to operate less, an economizer cycle also extends the operating life of the cooling system and reduces cooling system maintenance requirements.

☞ *If the quality of the outdoor air in ones area is less than ideal, be certain to provide adequate filtration. If installing an economizer cycle will require changes to the outdoor air intake, be sure to check all ventilation, fire, and safety codes.*

Insulate Pipes and Ductwork

In general, pipes that carry heated or cooled liquids and ducts that carry air through unconditioned spaces should be insulated. Air or liquid in uninsulated ducts and pipes will become warmer or cooler, causing the systems that heat or cool the air or liquid to work harder and therefore waste energy.

Use the following guidance when determining the appropriate types of insulation to install on pipes and ducts:

- ***Large Pipes***—Curved or flat segments or, if easy removal for frequent servicing of the pipe is necessary, cylindrical half-, third-, or quarter-sections.
- ***Small Pipes***—Cylindrical half-sections or insulation furnished with factory-applied jackets that form a hinge-and-lap.
- ***Fittings (valves, tees, and elbows)***—Preformed fitting insulation, fabricated fitting insulation, individual pieces cut from sectional straight-pipe insulation, or insulating cements.
- ***Duct*** —Semirigid fibrous material (either glued in place or fixed with special clips or bands), flexible mats clipped or wired on, or sprayed-on foam or flexible blanket-type insulation composed of fibrous material.

Pipes carrying liquids at moderate temperatures (that is, between 55° and 100°F) do not need to be insulated.

Ducts that supply warm air in winter and cold air in summer require a vapor barrier to keep moisture from infiltrating the airstream. Ducts that carry warm air only do not require a vapor barrier.

Minimum thickness for both pipe and duct insulation should be in accordance with ASHRAE Standard 90.1P, as shown in Table 14-1.

Use Separate Make-Up Air for Exhaust Hoods

Exhaust hoods remove large quantities of conditioned air from a facility. This air must be replaced by outdoor ("make-up") air, which generally must be conditioned, causing the heating or cooling system to consume more energy.

Make-up air supplied to exhaust hoods, however, does not have to be conditioned to the same degree as make-up air delivered to facility occupants. In general, the temperature of exhaust-hood make-up supply air needs to be only 50° to 55°F (or even less), assuming it is introduced near to or around the perimeter of the hood, as in a double-walled exhaust hood. Accordingly, it may be cost-effective to install an exhaust-hood supply air system that is completely or partially separate from the rest of the HVAC system.

In kitchens, consider installing a timer to shut down or scale back operations during periods of nonuse. For critical operations such as chemical hoods and paint booth hoods, install drive controls to minimize exhaust or close the hoods when the station is not in use.

Replace Leaky Outdoor Dampers

The outside air dampers on many HVAC systems, particularly rooftop units, do not accurately control the amount of air let in or out. Even when these dampers are fully closed, the quantity of air leaking in may exceed minimum outdoor air requirements. As always, outdoor air that enters the system must be conditioned, which requires heating or cooling energy. One can save the energy wasted on unnecessary outdoor air by replacing leaky outdoor air dampers with high-quality opposed-blade dampers which have air seals at the blade edges and ends.

Redistribute Stratified Air During Winter

Because hot air rises, it becomes trapped (stratified) near the ceiling. Particularly in facilities with high ceilings, the floor area, where the people are, is relatively cold. Installing devices to bring the stratified hot air down to the floor will save energy because the heating system will not have to work as hard to maintain thermostat settings. It will also prevent loss of heat through the roof.

One can choose from a variety of ceiling-fans and destratifiers to redistribute stratified air. If a ceiling fan is properly equipped, reversing its direction will recirculate warm air back to the floor. Destratifiers are usually fans mounted in flexible or rigid tubes that either draw warm air downward through a duct for redistribution or blow floor-level cold air upwards to create a circulating pattern of air movement.

Do not use destratifiers during the cooling season, when stratification of heavy cool air at the occupied level is desirable, and be sure to revert ceiling fans back to normal cooling mode during the cooling season.

Add Zone-Demand Reset Controls

Adding zone-demand reset controls can substantially reduce the energy consumption of terminal reheat, dual-duct, and multizone HVAC systems. These controls work by continually resetting HVAC system output to meet actual facility requirements. When cooling is needed, an economizer calls for outdoor air if it is available, thus reducing the cooling load. When cooling is not required, the control shuts the intake or exhaust ventilation dampers. An automatic timer or manual switch is sometimes used to turn off the cooling system or lower the heating temperature setpoint to reduce energy use during unoccupied hours.

Terminal Reheat Systems

Either electronic or pneumatic zone-demand controls can be applied to terminal reheat systems (Figure 14-2). The control determines the zone that requires the least amount of reheating – and thus the most cooling – by comparing the temperature in each zone to a "full-cooling" reference point. It then shuts off reheat at that zone and increases the supply-air temperature just enough to meet the requirements of that zone. Thus no cooling energy is wasted. A high limit

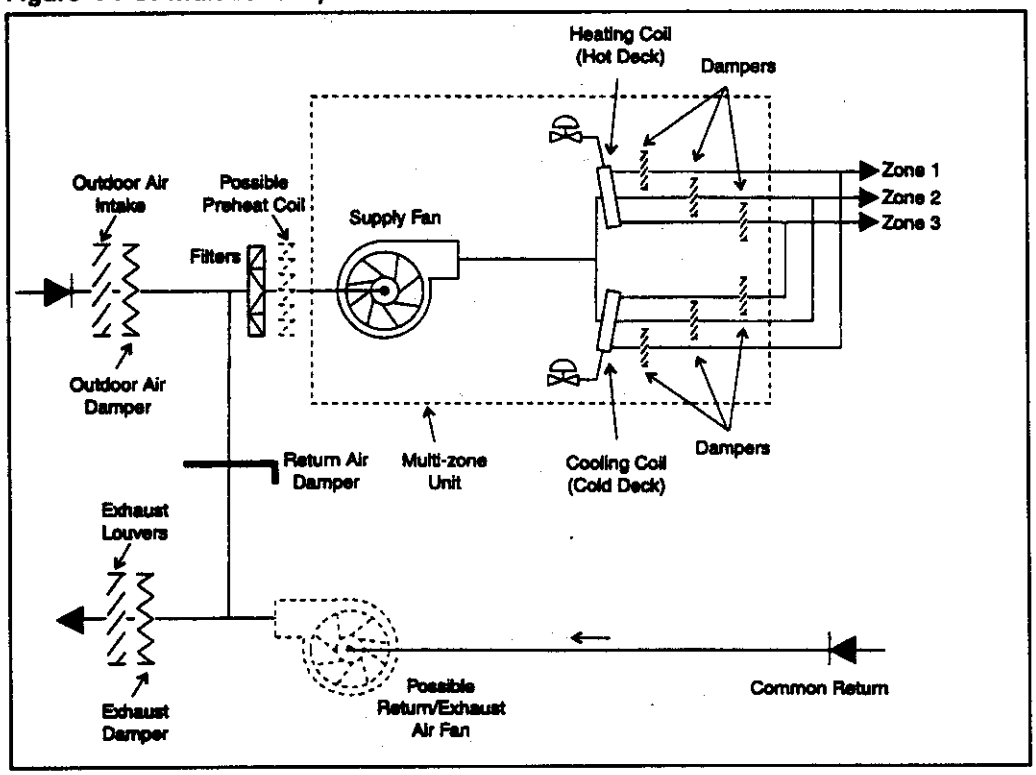
on the amount of resetting prevents high humidity in all zones.

Less demanding zones continue to use just enough reheat to satisfy their individual zone controls. In this case, some reheating will occur well into the summer because of system diversity; all zones do not peak simultaneously. Nonetheless, by cooling only enough to meet the most demanding zone, reheating is minimized.

Dual-Duct Systems

In dual-duct systems, both cold-deck and hot-deck temperatures are controlled to meet the most demanding requirements for cool air and warm air. The control progressively increases the cold deck air temperature until the most demanding zone control signal is met. Likewise, a "full-heating" reference is established to determine the

Figure 14-5. Multizone System



appropriate hot-deck temperature. In summer conditions, the hot-deck temperature is reset to a point low enough that the air in effect becomes unprocessed "return air." This type of deck-temperature resetting can often reduce a facility's total utility cost by 10 percent.

Table 5-1. Minimum Pipe Insulation (inches)[a]

Fluid Design Operating Temperature Range, °F	Insulation Conductivity Conductivity Range Btu-inch/ (H x FT^3 x °F)	Mean Rating Temperature °F	Nominal Pipe Diameter (inches) Runouts[b] up to 2	1 and Less	1¼ to 2	2½ to 4	5 and 6	8 and up
Heating Systems (steam, steam condensate, and hot water)								
Above 250	0.32-0.34	250	1.5	2.5	2.5	3.0	3.5	3.5
251-350	0.29-0.31	200	1.5	2.0	2.5	2.5	3.5	3.5
201-250	0.27-0.30	150	1.0	1.5	1.5	2.0	2.0	3.5
141-200	0.25-0.29	125	0.5	1.5	1.5	1.5	1.5	1.5
105-140	0.24-0.28	100	0.5	1.0	1.0	1.0	1.5	1.5
Domestic and Service Hot Water Systems[c]								
105 and greater	0.24-0.28	100	0.5	1.0	1.0	1.5	1.5	1.5
Cooling Systems (chilled water, brine, and refrigerant)[d]								
40-55	0.23-0.27	75	0.5	0.5	0.75	1.0	1.0	1.0
Below 40	0.23-0.27	75	1.0	1.0	1.5	1.5	1.5	1.5

[a]For minimum thickness of alternative insulation types see 9.4.8.2.
[b]Runouts to individual terminal units not exceeding 12 feet in length.
[c]Applies to recirculating sections of service or domestic hot water systems and first 8 feet from storage tank for non-recirculating systems.
[d]The required minimum thicknesses do not consider water vapor transmission and condensation. Additional insulation, vapor retarders, or both, may be required to limit water vapor transmission and condensation.

Multizone Systems

In multizone systems (see Figure 14-5), a central unit heats and cools several zones. A thermostat in each zone controls dampers at the unit, which mix the hot and cold air to meet that zone's load requirements. With zone-demand controls, each zone thermostat transmits a signal indicating the difference between the zone's actual temperature and its thermostat setting. The signal is transmitted to the individual damper control or zone actuator, which controls the zone dampers based on the temperature differential, and to an electronic device called a discriminator network, which compares incoming signals from all zones and resets the cold-deck temperature based on the requirements of the zone that needs the most cooling. The hot-deck temperature is reset in the same manner. The two zones that determine the hot-deck

and cold-deck temperature settings are called *critical zones*. This system saves energy because the critical zones control the amount of heating and cooling, as opposed to constant settings that, in most cases, exceed needs.

Add a Variable Volume Device to Terminal Reheat and Dual-Duct Systems

The airflow in terminal reheat and dual-duct systems is fixed; that is, a constant volume of air is always heated or cooled regardless of the actual volume of conditioned air needed to meet temperature requirements. This inefficiency can be almost entirely eliminated by adding a variable air volume device and a fan control within existing ducts, so that only the volume of air actually needed to heat or cool a zone is allowed to enter. As soon as enough conditioned air has been provided, the variable air volume system reduces the amount of air provided to the zone. The supply air fan senses the reduction and modulates fan inlet vane speed accordingly. The reduced volume of air drawn into the system and passed by the fan thereby reduces the energy needed to drive the fan.

The reduction in air volume allows virtual elimination of heating or reheating to interior spaces. When an interior space is receiving little or no air because of its proximity to other treated spaces, the need to heat or reheat that air is eliminated.

☞ *Installing a variable air volume system can be complex and expensive, depending on the type of system involved. Pay particular attention to ensure that the reduction in circulation does not cause higher-than-usual humidity or a buildup of odors or smoke.*

Use High-Efficiency Equipment

HVAC equipment at or near the end of its useful life should be replaced with equipment that operates efficiently at both design and part-load operating conditions.

A significant amount of research in the last 5 years on HVAC systems and equipment has produced improvements in areas such as high-frequency heat-transfer surfaces, scroll compressors, electronic expansion valves, variable speed drives, and refrigerant-charge management techniques. Many of these improvements are incorporated in the packaged heat pumps and air-conditioners that make up the unitary systems being used in more and more commercial facilities.

Recent efforts have also included improving the rotary compressors used in the chillers in many facilities. This device

has been enhanced significantly so that it operates more efficiently, with less noise and vibration. Other chiller improvements include more efficient rotor profiles, intermediate-pressure refrigerant stream injection for improved refrigerant cycle design, and use of multiple slide valves for varying the built-in volume ratio. These advances have given chillers greater flexibility and made part-load performance far more efficient, allowing significant enhancements in overall HVAC system design.

Electronic controls play a major role in all of these improvements. The cost of such controls is declining, while current and voltage switching capabilities (to 500 amperes and 1,000 volts, with turn-on times measured in hundreds of nanoseconds) are rapidly increasing. Not only are the electronic controls more economical, but they also are easier to install and maintain, run more efficiently, and allow more precise control of temperature and humidity. Electronic adjustable speed drive technology has already been incorporated in fans and advanced unitary heat pumps.

Other options for HVAC system upgrades include energy-efficient electric closed-loop water-source heat pumps, ground water heat pumps, earth-coupled heat pumps, heat-recovery heat pumps, electric chillers, and unitary and applied packaged air-conditioners.

Add a Deadband Control

HVAC systems are generally controlled by room air temperature, outside air temperature, and fixed equipment settings. However, using multiple factors to control equipment settings often leads to waste.

A deadband system bases its control of HVAC equipment primarily on a single factor: room temperature. A deadband thermostat provides no heating or cooling over a certain temperature range. For example, it can be set so that no conditioning is provided (the system is "dead") within a 9°F temperature band. Only ventilation is provided in this 9°F temperature band and cooling and heating coils are shut-off. When the space temperature drops below 67°F, heating is provided; when the temperature exceeds 76°F, cooling is provided. Thus, the 9°F deadband is from 67 to 76°F.

Deadband controls can reduce heating and cooling energy consumption; the amount depends on the type of HVAC system and the range of the deadband. In essence, the more direct the control and the larger the deadband, the lower the energy

consumption for heating and cooling. Because thermostat controls with wide deadbands can reduce energy consumed for heating and cooling, their use in commercial facilities is increasing.

14.5 INSTALL EVAPORATIVE COOLERS

Direct evaporative coolers are ideally suited for areas with hot, dry climates. Because they operate by evaporating water into an airstream, they work best when there is a difference between the outdoor wet-bulb and dry-bulb temperatures of at least 18°F.

Direct evaporative cooling units cool the airstream by direct contact with water, through either an extended wetted pad (the most common method) or a series of sprays. Wetted-pad cooling units use fans to pull air through evaporative pads and to the conditioned space. The pads are continually wetted by a circulating pump that lifts sump water into the system. The water filters through the pads and back into the sump.

The effectiveness of a direct evaporative cooling unit depends on the difference between the outdoor dry-bulb and wet-bulb temperature (called the wet-bulb depression). Higher wet-bulb depressions lead to better performance because they allow a larger difference between the dry-bulb temperature of supply air and the temperature of the air leaving the cooler. During low wet-bulb depressions – when the airstream is close to saturation – there is less potential for increasing the latent heat content of the airstream. In these cases, the system's supply water can be chilled by mechanical refrigeration to provide lower leaving air temperatures and lower humidity.

Packaged wetted-pad air coolers are available in sizes from 2,000 to 40,000 cubic feet per minute. They use approximately 1.3 gallons of water per hour per 1,000 cubic feet per minute for each 10°F reduction in dry-bulb temperature. Because the fans and pumps are always on during cooling, the amount of energy consumed does not depend on the cooling load. However, when cleaned and maintained properly (including water treatment or bleedoff to prevent scaling and algae buildup on heat transfer surfaces), direct evaporative coolers operate at overall efficiencies of approximately 80 percent.

Provide Controls to Improve System Operating Efficiency

Equipping each separate HVAC system or zone with a thermostat and providing automatic controls that operate systems in both unoccupied and occupied modes can improve

operating efficiency significantly. In an unoccupied mode, ventilation and exhaust systems should be shut off if possible, and comfort heating and cooling systems should be shut off except to maintain setback conditions (that is, the minimum and maximum levels required to prevent damage to the facility or its contents and provide for a reasonable morning pick-up period). In an occupied mode, controls should provide for a gradually changing control point as system demands change from cooling to heating.

Controls should also be able to prevent the simultaneous operation of heating and cooling systems in the same space.

☞ *In some areas, this may not be possible because of ventilation or air circulation requirements. In such cases, reduce air quantities as much as possible before reheating, recooling, or mixing hot and cold airstreams. Then, reset the supply-air temperature to extend economizer operations and reduce reheating, recooling, or mixing losses.*

If a system is designed to humidify or dehumidify the air in certain zones, each affected zone should be equipped with a humidistat to prevent new energy from being used to produce space relative humidity above 30 percent or below 60 percent.

Unoccupied Zone Shutdown Controls

Consider installing controls that can shut down airflow to spaces such as conference rooms or audiovisual areas that are usually unoccupied. One such technique for unoccupied zone shutdown relies on zone dampers. Depending on the cost and type of energy used for heating and other factors, this can save as much as $30 per 1,000 cubic feet of air per minute.

☞ *Because shutting down HVAC equipment in one zone can affect other zones, a consulting HVAC engineer should identify the best approach. The consultant can also help weigh the cost of installation and the extent of energy savings.*

Fan Volume Controls

Some of the benefits of converting to variable air volume can also be obtained by adding fan volume controls. Fan volume controls save energy by reducing fan volume and thus electrical costs when zones are shut down. They can also be applied to variable air volume systems, increasing their savings even more.

☞ *Although installing fan volume controls is easier than converting to a variable air volume system, professional guidance is still recommended.*

Isolate Offline Boilers

Light heating loads in a multiple-boiler installation are often met by having one boiler on line, while the remaining boilers idle on standby, consuming energy needlessly. In many cases, this loss is increased even more by a continuous flow of air induced through the idling boilers and up the stack.

Unless a boiler is about to be used to meet an expected increase in load, it should be secured and isolated from the heating system (by closing valves) and from the stack (by closing dampers. To isolate a large boiler, fit it with a bypass valve or a regulating orifice. This allows the minimum flow required to keep it warm and avoid thermal stress when it is brought on line again.

☞ *When the boiler's water side is isolated, it is important to prevent airflow through the stack, as a backflow of cold air could freeze the boiler.*

Install Low-Excess-Air Burners in Oil-Fired Systems

Replace steam-atomizing burners at or near the end of their useful lives with low-excess-air burners. Conventional burners require large quantities of excess air to ensure complete combustion. This results in substantial heat loss through the stack. Low-excess-air burners, which use venturi throats to provide turbulent airflow into the combustors, save energy by using less air and improving combustion efficiency.

Replace Existing Boilers With Modular (Multiple) Boilers

Most boilers achieve maximum efficiency only when they operate at their rated output. However, this full capacity is seldom required, because a typical heating load is usually 60 percent or less than the full load. As a result, large-capacity boilers operate intermittently during most of the heating season, resulting in low seasonal efficiencies.

A modular or multiple-boiler system consisting of two or more boilers increases overall seasonal efficiency when each boiler is fired near capacity as much as possible. As heating load increases, the boilers are brought on line in sequence until the load is satisfied. In a typical installation, replacing one large-capacity boiler with multiple boilers may improve seasonal

efficiency by 5 to 10 percent. Consider such a replacement when the existing boiler system is due for replacement.

Add Automatic Blowdown Controls

Boiler blowdown – done either intermittently as a manual operation or continuously by installed equipment – is necessary because it reduces concentrations of dissolved and suspended solids in the boiler water and also removes boiler sludge. How often it is actually required depends on the amount of solids in the boiler makeup water and the type of water treatment used. Continuous blowdown results in a steady energy drain because makeup water must be heated. This continuous use of energy may not be necessary.

Blowdown energy losses can be minimized by installing automatic blowdown controls that monitor the conductivity of the pH of the boiler water and "blow down" the boiler only when it is needed to maintain acceptable water quality. Automatic controls also reduce the amount of chemicals required to treat makeup water, as the reduction in blowdown also reduces the need for makeup water. Piping the blowdown water through a heat exchanger or a flash tank with a heat exchanger can produce additional savings. In this way, heat from the boiler-blowdown flashtank can be used to preheat feed water.

Install Flue Gas Analyzers for Boilers

Insufficient combustion air causes incomplete combustion, which wastes fuel and generates poisonous carbon monoxide gas. Excessive combustion air must be heated, which increases flue gas losses, which in turn reduce efficiency by depositing soot on heat transfer surfaces.

Optimal combustion efficiency, which varies constantly with load and stack draft, can be maintained only by continuously analyzing flue gas. Consider installing an automatic flue gas analyzer to provide information for manual adjustment of the fuel-to-air ratio. The three types of systems available are oxygen trim, carbon monoxide trim, and carbon dioxide trim. Oxygen systems are the lowest cost, but cannot differentiate between flue-gas oxygen and oxygen in outside air drawn into the flue through leaks. Carbon monoxide systems offer more potential for savings by providing a true measure of boiler efficiency, but are higher in cost than oxygen systems. Carbon dioxide systems have costs similar to carbon monoxide systems and are most effective when only one type of fuel is used.

Modify Radiator System Controls

Most steam-heated cast-iron radiators use inefficient manually operated valves that make it difficult to regulate energy use in accord with outside conditions; that is, it is difficult to lower water temperatures as outdoor air temperature increases. One way to overcome this inefficiency and regulate radiator temperatures is to install modulating radiator valves. Each of these self-contained units measures room temperature needs and modulates the steam or hot-water supply accordingly. The valves in many cases can eliminate overheating and underheating entirely, resulting in fuel savings of as much as 27 percent. Installation is simple and the cost is relatively low. The controls also smooth heating and cooling cycles and reduce the noise caused by pipe expansion and contraction.

An alternative is to control steam to the entire system (or zone) on a full-off or full-on timed-cycle basis, with cycle length determined by outdoor air temperature. The lower the temperature, the longer the on cycle. The controllers, which are commercially available, usually include an outside temperature sensing device, a heat sensor to attach to a remote steam branch, a manual compensator for windy days, and an optical night setback control. In this system, the on cycle may occur 5 minutes every half-hour on a mild day and 20 minutes every half hour on a cold day.

☞ *This method requires an independent piping system for heat, separated from any process loads. A control shutoff valve must be available. Frequently, an existing pressure-reducing valve can be modified and used for cyclical control.*

Upgrade Chillers

One should consider investing in an upgraded chiller for two reasons:

First, the energy efficiency upgrades one has been implementing have probably reduced the facility's cooling load significantly. A new, smaller, more energy-efficient chiller can increase the energy and cost savings already realized.

Second, as of January 1, 1996, the type of refrigerant currently used in most chillers will no longer be produced. This phaseout is required by the Clean Air Act Amendments of 1991 that address CFCs and HCFCs. All electric cooling equipment uses either chlorofluorocarbons (CFCs) or hydrochlorofluorocarbons (HCFCs) as working fluids. For example, most electric chillers

with centrifugal compressors use CFC-11, CFC-12 or HCFC-22 as working fluids; unitary air-conditioners and heat pumps primarily use HCFC-22. Many years of research and scientific study have provided conclusive evidence that CFCs and HCFCs contribute to the chemical deterioration of the Earth's ozone layer. To slow this deterioration, the United States and the international community are pursuing ways to regulate the production and use of CFCs and HCFCs. In an international agreement known as the Montreal Protocol, signed in 1987, the United States joined many other nations in agreeing to freeze and eventually eliminate production of many CFCs. The Clean Air Act Amendments enforce that action in the United States.

In response, HVAC equipment manufacturers are investigating several possible alternative refrigerants and new technology options. Alternative refrigerants replacement in existing systems in most cases results in some loss in efficiency and requires some equipment redesign.

While simply containing or recycling the existing refrigerant may seem like a viable alternative, consider the following:

- The phaseout that begins in 1996 may eventually cause serious shortages of refrigerants.
- The price of refrigerants will probably increase dramatically beginning in 1996.

Therefore, now is the time to consider the following options for upgrading ones chiller:

- Retrofit the existing chiller so that it can perform more efficiently at the newly reduced cooling loads and also use new refrigerants compatible with the refrigerants being phased out.
- Replace the chiller with a new, smaller, more energy-efficient model that uses the new refrigerants.

With either option, equipping the chiller with a variable speed drive that adjusts the chiller's flow to match the HVAC system's cooling load requirements will provide even more energy and cost savings, even at part-load conditions.

If the chiller is less than 10 years old, retrofitting that chiller so that it operates more efficiently at the newly reduced loads and uses new refrigerants may be 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 replacing refrigerant, use HCFC-123 in place of R-11 and HFC-134A in place of R-12. To make the facility's chiller compatible with one of these new refrigerants, one 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 other energy efficiency upgrades.

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. A life cycle cost analysis can be performed to verify the cost effectiveness of replacing the chiller.

Depending on the energy efficiency upgrades implemented, cooling load requirements in the facility may be reduced by at least 10 percent and possibly by as much as 40 percent. Thus one has the opportunity to downsize the new chiller accordingly. While the new chiller must be sized for peak loads, it must also operate efficiently at part-load conditions because the chiller operates at this level 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.

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 facility'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 one decide whether to retrofit or replace ones 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, as established by ASHRAE 1.8 (1986), is 23 years for absorption and centrifugal chillers and 20 years for reciprocating chillers.

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 maintenance 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 retrofitting or replacing, 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 manufacturers' guidelines on handling and care of the alternate refrigerant.

One may want to discuss the facility's requirements with a consulting mechanical engineer who can verify the cooling load reductions and provide insight on the various alternatives. One may also want to have the engineer look at the 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. One 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.

Isolate Off-Line Chillers

In a multiple-chiller installation, light cooling loads are often handled by circulating chilled water through all chillers, even though only one chiller needs to be operating, or on-line. This wastes pump energy because the rate of water flow through

the system is unnecessarily high. In addition, the temperature of on-line chiller water increases as it mixes with the warmer water that flows through the off-line chillers (the bypass effect). Accordingly, the on-line chiller must produce chilled water at a lower temperature to offset the temperature increase, using even more energy. This in turn causes the on-line chiller to operate at a lower evaporator temperature, reducing the cooling unit's coefficient of performance. Pump and fan energy is also wasted as water circulates through idle cooling towers.

Isolating valves can separate off-line chillers from the system and thereby reduce the chilled water flow rate. In addition, unnecessary chilled-water pumps can be deactivated to lighten the electrical load. If multiple chilled-water pumps are not installed, consider installing additional pumps or a multispeed drive on the existing pump. This will reduce energy consumption further by lowering auxiliary loads and prevent excessively high flows through the on-line chiller.

Also consider shutting down unneeded cooling towers and reducing condenser water flow correspondingly. If existing modules are all oversized for light loads, install new, smaller refrigerating and cooling tower units if it is cost-effective.

Use a Water-Side Economizer

A water-side economizer allows cool condenser water to be used for space cooling without operating chillers when ambient temperatures are below 55°F (dry-bulb). With a water-side economizer, properly strained and chemically treated cooling-tower condenser water is circulated through the chilled-water piping system and coils. At 55°F (dry bulb) and 48°F (wet bulb), this water can meet approximately half of the full-load cooling requirements for 50°F cooling-tower leaving water.

A water-side economizer is effective and therefore should be installed only when (1) chilled water below an ambient temperature level of 55°F (dry bulb) is required for a substantial number of operating hours per year, (2) air-conditioning units or other terminal devices are unable to use a direct outside air supply, and (3) cooling loads below 55°F ambient are no more than 35 to 50 percent of design full-load conditions.

Where necessary, install heat exchangers to isolate the system water from the cooling tower water. Consider installing a small sidestream filter to filter out impurities on the cooling tower side, and also variable speed drives or reversing fans on cooling

tower fans – both of which extend the "free" cooling period of hydronic free cooling systems. However, use caution, because maximum efficiency for free cooling is achieved when external dry bulb temperature conditions are best.

☞ *Adding controls to the tower fan also adds controls to the condenser water temperature; therefore, incorporate the water side economizer and condenser water temperature together through towerfan control (see "Increase Chilled-Water Temperature/Decrease Condenser Water Temperature and Modify Controls" below).*

Increase Chilled-Water Temperature/Decrease Condenser Water Temperature and Modify Controls

When all applicable EEOs have been applied to reduce load and thermal losses in the air distribution system, the quantity of cooling required from primary equipment will be reduced as well. This reduced cooling load allows changes in cooling equipment operating modes and conditions that will enable this equipment to run more efficiently at the part-load conditions that now prevail. Operating modes can be changed in two ways: raising chilled-water (evaporator) temperatures and lowering condenser water temperatures. Each of these methods will increase the efficiency of the refrigeration equipment.

To increase evaporator temperature, install controls that do the following:

- Raise the chilled-water temperature to "follow the load." (Install a limit switch in each modulating or diversion valve to measure whether the valve is fully open or partially open. Arrange the control circuits so that when all coil control valves are either closed or partially open (indicating light load conditions), the chilled-water supply's temperature setpoint is raised until one or more coil control valves return to the fully open position.)
- Raise supply-air temperature to follow the load.
- Allow relative humidity to rise in the conditioned air space (to 60 percent or more).
- Decrease the superheat on the DX coil (consult the manufacturer).
- If applicable, be sure that one chiller is operating at full load before starting a second chiller.

To decrease condenser water temperature, do the following:

- Use low-temperature wellwater (if available) for condenser water, instead of cooling-tower water. The energy required to pump wellwater will be about the same as that used for condenser water pumps and cooling tower fans, but the energy savings in compressor horsepower will be worthwhile.
- Where existing cooling systems operate at constant condenser-water temperatures and cooling-tower fans are cycled on and off, modify controls so that cooling tower fans operate continuously whenever a system is on line. Allow the condenser water temperature to drop until it reaches a predetermined lower limit. At that point the cooling tower fans can be cycled on and off.
- Install automatic tube cleaners to maintain low fouling factors while reducing condensing temperatures. One such device comprises a cylindrical brush in each tube. The brush is periodically forced from one end of the condenser tube bundle to the other by reversing the direction of the waterflow. This type of system can be very effective in keeping condenser tubes clean and, depending on the existing level of condenser tube fouling, can yield substantial energy savings.

Reduce Fan Energy Consumption

The following three steps, taken sequentially, can reduce fan energy consumption substantially:

- Reduce resistance to air movement throughout the HVAC system
- Reduce the quantity of air supplied to or returned from conditioned spaces
- Limit the periods during which fans operate.

Reduce Resistance to Air Movement

EEOs that reduce heating and cooling loads reduce the volume of air handled by HVAC systems. This reduction in volume in turn reduces the resistance to airflow in that section of the system, because resistance depends in large part on the quantity of air circulated. Resistance to airflow can be reduced even more by cleaning, repairing, or otherwise modifying system elements that affect resistance, including intake louvers and air outlet duct caps and elbows, heating and cooling coils, filters, ductwork, balancing dampers, exhaust hoods, registers, grills, diffusers, and the fan scroll and housing. These additional

steps are particularly effective if the HVAC system was oversized and original loads have been reduced.

Reduced airflow resistance allows more air to be distributed more efficiently. Thus, the appropriate air volumes can be maintained with slower fan speeds, substantially reducing fan power requirements.

Reduce the Quantity of Air

The operating characteristics of fans are determined by the following measures:

- Fan capacity (in cubic feet per minute)
- Static pressure (in inches of water column)
- Fan speed (in revolutions per minute)
- Horsepower (hp) required to drive the fan

To measure the amount of air delivered by a fan:

- Determine the fan's speed using a tachometer.
- Measure static pressure at the suction and discharge sides of the fan.
- Measure the horsepower of the fan motor using a clamp-on ammeter.

Compare the amount of air delivered by the fan (in cubic feet per minute) to the manufacturer's performance curves. If the amount of air being delivered is more or less than the manufacturer's design value, adjust the fan speed accordingly. Belt-driven units can be adjusted by replacing a drive pulley or a driven pulley with the next larger or smaller size. Some motor pulleys have adjustable sheaves, which makes changing fan speeds much easier.

Use the original fan manufacturer's guidance to determine the most efficient and stable operating speed for the fan, considering both the fan's performance and the HVAC system's requirements.

Once fans have been adjusted, the entire air distribution system should be balanced to ensure that conditioned air is delivered as needed, without over- or under-heating or cooling.

Reduce Energy Consumed by Pumps

The basic laws affecting pumps that circulate hot water, chilled water, and condenser water are similar to those governing fans. Therefore, reducing the flow rate or the system's resistance to

flow decreases the energy required to circulate water. However, unlike air distribution systems, pumping systems cannot be balanced because water moves through closed circuits, with the flow rate varied by throttling, mixing, or bypass valves. Additionally, because most pumps are direct-driven by constant-speed motors, reducing flow rate or resistance also reduces the ability to adjust pumps. Nonetheless, pumping systems still present significant potential for energy savings because of their extensive operating hours and the oversizing designed into most pumps to provide unnecessarily generous safety margins.

Replace Oversized Motors

Because initial load estimates for a facility's mechanical equipment usually are conservative (that is, they assume that the equipment will operate for many more hours than what will actually be needed under real-world conditions) most motors are oversized for the equipment load they will actually be required to meet. The degree of oversizing increases as the facility's loads are reduced through EEOs. When the ratio of a motor's load to its horsepower rating is small, power factor and load factor do not correspond and the motor operates inefficiently.

To determine the power and load factor situation in a facility, conduct a comprehensive study that includes these steps:

- Compile the following information:
  - The equipment served by the motor.
  - Motor nameplate information, including brand, type, frame, horsepower, speed (or speeds), voltage phases and frequency, mounting, and full-load rating.
  - Full-load running current of each phase leg. Record the date of each reading, which is taken with an ammeter.
  - Pulley size and type (for example, V-belt, chain).
- Determine the percentage of full-load rating represented by the motor's current load by dividing the full-load current by the full-load rating from the nameplate.

Exchange underloaded motors (those that are not loaded to at least 60 percent of their potential) with others sized to achieve as close to full loading as possible. Underloaded motors are inefficient and reduce the power factor of the entire electrical system. The motor's service factor (available from the manufacturer) establishes the highest possible overload that does not exceed the motor's rating. Use this information when exchanging and interchanging motors.

☞ *For cycling equipment, select smaller motors, rated slightly below maximum load requirements; allow some overloading to occur.*

Small split-phase or shaded-pole motors, such as those used in perimeter fan coil units, have low power factors and are inefficient. Turn off these motors during mild winter nights and allow the fan coil to operate by natural convection.

When installing new motors, consider high-efficiency motors. Match the phase and frequency with electrical distribution system characteristics. If available motors do not match system voltage exactly, use the following guidelines:

- For motors loaded to 75 percent or less of their capacity, select motors rated at slightly more than the system voltage.
- For motors loaded to more than 75 percent of their capacity, select motors rated slightly under the system voltage.

CHAPTER 15. ENERGY EFFICIENCY OPPORTUNITIES: LIGHTING

15.1 KEY CONCEPTS

- Lighting energy efficiency opportunities (EEOs) fall under the following general categories: reducing lighting use, reducing lighting levels, and using more efficient equipment.
- Reducing lighting levels can reduce energy costs; however, the new levels must be completely compatible with the productivity and other requirements of facility occupants.
- Major changes to a lighting system can have a significant impact on heating and cooling systems, most of which are designed to consider the amount of heat given off by the lighting system as originally designed.
- Eliminating veiling reflections can double the effectiveness of existing lighting, generally at far less cost than simply providing more illumination.
- Making sure that luminaires are fully lamped and regularly cleaned may be more effective than retrofitting luminaires with reflectors.
- Daylighting is usually most cost-effective in warmer climates or where electric rates are high.

15.2 OVERVIEW

The lighting systems in many facilities were designed with only initial cost in mind, without knowledge about how the space would ultimately be used and subdivided, and without the benefit of recent developments such as compact, high-efficiency fluorescent lamps and research in such areas as veiling reflection. As a result, there is a good chance that modifying the lighting system in a facility can substantially reduce energy consumption while still providing occupants with the quality and quantity of illumination needed to perform their various tasks.

This section describes a number of lighting upgrades that can be implemented in most commercial buildings. These upgrades, which range from simply reducing lighting levels

and using more efficient lamps and ballasts to installing motion detectors and improved controls, affect energy consumption and occupant productivity. In addition, most have very attractive payback periods and internal rates of return.

Lighting's effect on productivity is particularly important, and should be considered at every point in an upgrade program. Numerous case histories and research studies clearly indicate that energy-efficiency improvements in lighting also result in improved productivity. In one case study assembled by the National Lighting Bureau, for example, improved lighting reduced operating costs by approximately 15 percent and increased productivity by 7 percent. Although the 7 percent productivity boost is probably worth 50 times more than the energy dollar savings, there is really no way to estimate productivity increases from lighting system modifications before they are implemented. Therefore, decisions on lighting options generally must be based on energy cost savings, which can be calculated precisely. (An exception is when general benefits only are desired. For example, it is reasonable to assume that better security lighting at night will reduce vandalism, or that increasing illumination levels in an office or factory production area that is substantially under-illuminated will increase productivity. Nonetheless, there is still no way of precisely identifying the value of the benefits *before* the modifications are made.)

Before making any change to the lighting system, one must recognize that it is just that—a system. Its many elements are interrelated not only with one another but also with other systems in the facility. Major changes to a lighting system can have a significant impact on heating and cooling systems, most of which were designed to consider the amount of heat given off by the lighting system as originally designed. Therefore, the lighting system should be modified only after the entire facility system has been analyzed and all options have been evaluated. While energy efficiency is important, it must be achieved in a manner consistent with other requirements, such as productivity and visual comfort; aesthetics; and federal, state, and local codes and ordinances. For these reasons, it is a good idea to obtain competent technical assistance before making any significant lighting modifications and to implement modifications only after considering the building's illumination needs, the current lighting system, and the many different lighting options available. Generally, it is best

to get help from an experienced electrical contractor, a professional electrical engineer, or a lighting consultant.

The following sections describe many of the actions that should or can be taken as part of an effective lighting energy management program. Also be aware of the importance of maintaining the building's lighting systems. Preventive maintenance actions for lighting are discussed in Chapter 12.

15.3 NO-COST / LOW-COST OPPORTUNITIES

Low-cost and no-cost energy efficiency opportunities for lighting include reducing lighting use, reducing lighting levels, and using more efficient lamps.

Develop a Lighting Schedule

If maintenance and cleanup crews generally work after hours, examine their use of lighting. In many cases, they will turn on all, lighting on a floor, even though only a portion of it is needed. Working with their supervisors, determine how maintenance and cleanup crews can perform their jobs in a more orderly fashion, using the least amount of lighting. Develop a schedule for their use and monitor their performance to ensure the schedule is followed.

Schedules for outdoor lighting can also be beneficial. Turning lights on before they are needed and keeping them on when they are not needed wastes energy. Automatic lighting controls are especially appropriate for outdoor lighting. A timer is a relatively inexpensive, cost-effective way to ensure that lights are turned off and on according to schedule.

Reduce Lighting Levels

Reducing lighting levels can reduce energy costs; however, *the new levels must be completely compatible with the productivity and other requirements of facility occupants.* Such compatibility can be determined only through a lighting survey.

Conduct a Lighting Survey

A lighting survey is conducted using a portable light meter. The light meter should be accurate to about ±15 percent over a range of 30 to 500 footcandles and ±20 percent from 15 to 30 footcandles. It should also be corrected for

color and cosine. Generally, measurements refer to the average maintained horizontal footcandles at the task or in a horizontal plane 30 inches above the first floor.

Measurements should be made at any representative point between and under fixtures; an average of several readings may be necessary. Daylight should be excluded during illumination-level readings for a true determination of illumination level without the benefit of daylight.

Compare findings with the current recommendations of the Illuminating Engineering Society (IES). If the readings are consistent with IES recommendations, do not adjust the lighting level. If the readings indicate the illumination level exceeds what is needed, lighting levels could be reduced without causing any difficulty.

However, it is extremely important to note that *light meter readings alone may not give a true indication of important lighting factors because a standard light meter does not register a veiling reflection.* When light from a source strikes the work surface in such a way that it bounces up into the viewer's eyes, it creates what is called a *veiling reflection*. A veiling reflection reduces the contrast between different elements of the work surface, for example, the letters on this page and the paper on which they are printed. Reduced contrast increases the time it takes to see and increases the likelihood of error, the same effect caused by less-than-adequate lighting levels. Thus, while the light meter indicates that 100 footcandles are being provided, the effectiveness of that level may be reduced to just 60 or 70 footcandles because of veiling reflections. If the tasks involved are highly sensitive to productivity factors, as usually is the case for industrial operations, key punching, and so forth, more in-depth analysis of both lighting quantity and quality factors should be performed to ensure that reduced illumination will still support maximum productivity.

One of the most effective ways to reduce lighting levels is to install lower wattage, high-efficiency lamps. Another alternative is to use one larger lamp instead of two smaller ones; for example, one 75-watt incandescent lamp instead of two 60-watt lamps.

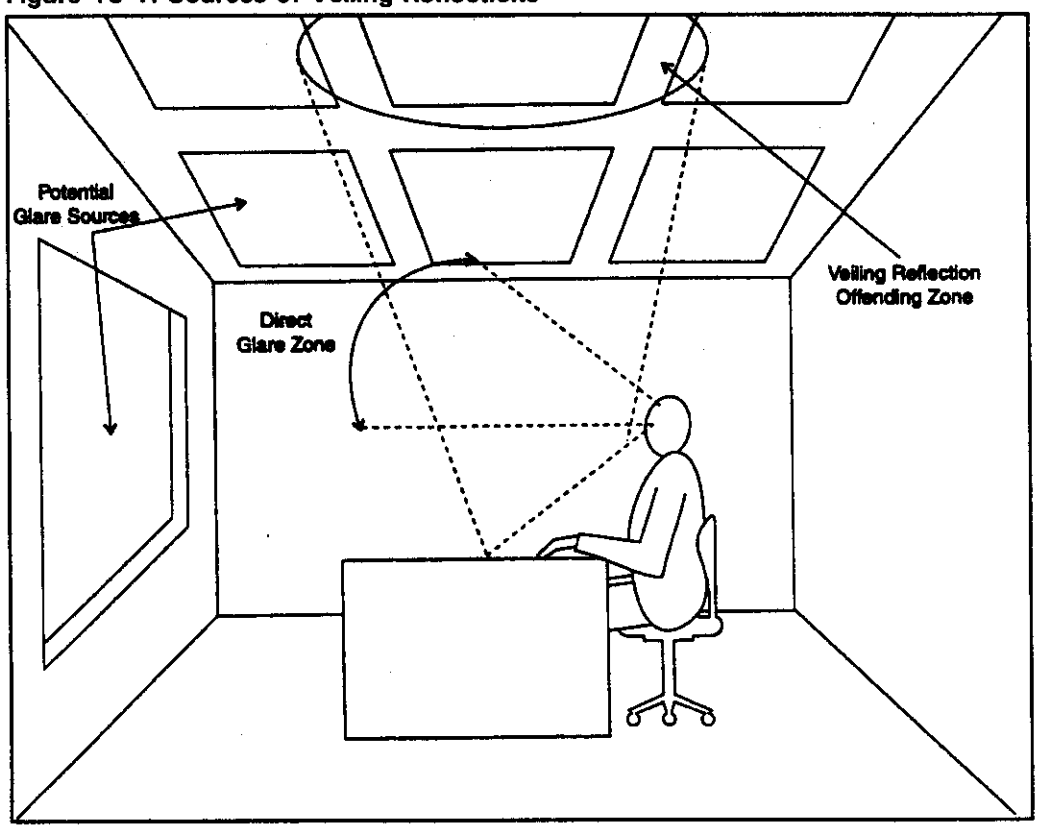
When removing fluorescent lamps from a lighting fixture, all lamps controlled by a single ballast should be removed to prevent premature failure of the ballast or the remaining lamps. Except in the case of instant-start lamps or lighting fixtures with circuit-interrupting lamp holders, unused

ballasts should be disconnected to prevent them from consuming energy.

Reduce Veiling Reflections

Veiling reflections are an important concern when considering interior lighting systems used primarily for office space. As indicated in Figure 15-1, a veiling reflection occurs when light bounces off an object being viewed into the observer's eyes. Although the observer may not be aware of what is happening, the reflected light diminishes the contrast rendition of the object being viewed. For

Figure 15-1. Sources of Veiling Reflections

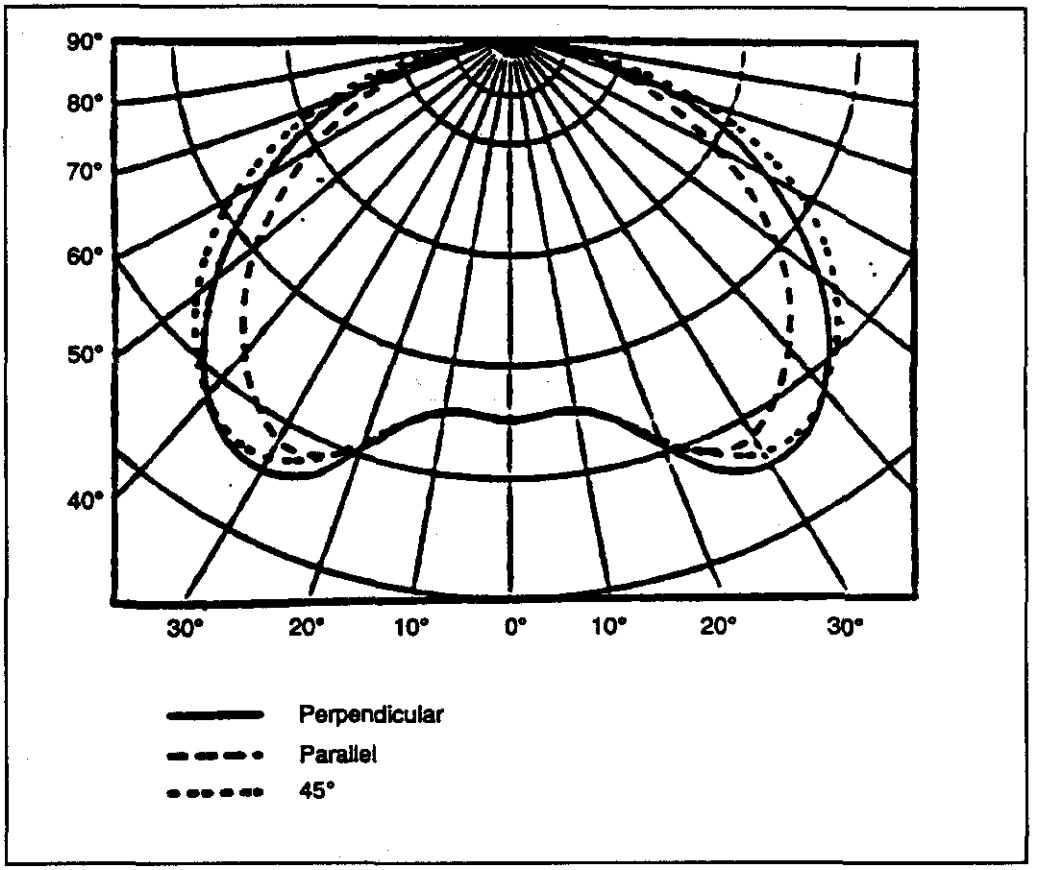


example, if the object is a piece of white paper with black printing on it, the black print appears lighter, and the white paper becomes gray. From the viewer's standpoint, it is as though a thin, gauzy veil was placed between the eyes and whatever is being viewed; hence the term "veiling reflection."

Veiling reflections make it more difficult to see, which increases the time required to perform a visual task and also the likelihood of errors. Simply providing more illumination

improves contrast, but usually also increases expense. Therefore, generally speaking, it is far less costly to improve the quality of lighting by eliminating the veiling reflection. This can be done by (1) reorienting luminaires and workstations; (2) moving luminaires; (3) using special luminaires that provide sideways distribution of light, or (4) using special lenses, such as those that provide batwing distribution (Figure 15-2) or that polarize light.

Figure 15-2. Flux Distribution of a Batwing Lens



In some cases, eliminating veiling reflections, primarily by properly distributing light, can double the effectiveness of existing lighting. Lighting levels thus can be reduced accordingly, saving half of the energy consumed by the lighting system before it was upgraded.

Use Switchplate Reminders

Preprinted paste-on stickers on lighting switchplates, reminding people to turn off lights when they leave a room, are an inexpensive way to reduce unnecessary lighting use. There is a popular belief that turning fluorescent lamps off

and on frequently is inefficient and reduces the usable life of the lamp. This belief is outdated. Turning today's new, long-life lamps off and on costs only 2 or 3 minutes of life (out of 3 to 7 years) and does no damage to either ballasts or lamps.

If lighting-switch stickers are not effective enough, consider signs on the door so people cannot help but notice the request to "Please Turn Off the Lights."

15.4 MODERATE-COST AND CAPITAL-INTENSIVE OPPORTUNITIES

This section describes a variety of moderate-cost and capital-intensive energy efficiency opportunities for lighting.

Use More Efficient Lamps

Lamp efficiency is measured in terms of units of output per unit of input, just as automobile efficiency is measured. With automobiles, output units are miles; the unit of input is a gallon of gasoline. With lamps, output units are lumens; the unit of input is a watt. The lumens per-watt efficiency ratings of different categories of lamps vary greatly, as indicated in Table 15-1. A wide range of variance also occurs between specific types of lamps within the same category.

Savings from new, high-efficiency lamps can be substantial (see Table 15-2). For example, if using 150-watt R40 lamps in stack baffled downlights, one can easily convert to 75-watt ER30 lamps with ellipsoidal reflectors. Ellipsoidal reflectors used in this manner deliver the same amount of light for exactly half the cost.

Converting from one lamp category to another, as from incandescent to fluorescent, generally involves considerable initial expense. (There are some exceptions, such as existing mercury vapor luminaires that can accept specific types of metal halide and high-pressure sodium lamps.) However, conversion in the long run provides far more illumination for the same amount of money.

Typical input power savings, relative light output, and annual energy savings provided by relamping and replacement of indoor incandescent, fluorescent, and high-intensity discharge lighting systems are shown in Tables 15-3 through 15-6. These tables do not include the potential additional savings that can be provided by other upgrades, such as new reflectors, switches, and controls.

☞ *Carefully consider the actual lighting needs before making any lighting changes. If the additional illumination is not needed, the change is not practical.*

Table 15-1. General Lighting Lamp/Ballast Characteristics

Type of Lamp	Wattage Range	Initial Lumens Per Watt Including Ballast Losses	Average Rated Life (hours)
Low-Pressure Sodium	18-180	62-150	12,000-18,000
High-Pressure Sodium	35-1,000	51-150	7,500-24,000+
Metal Halide	70-2,000	69-120	5,000-20,000
Mercury Vapor - Standard	40-1,000	24-63	12,000-24,000+
Mercury Vapor - Self-Ballasted	160-1,250	14-25	12,000-20,000
Fluorescent	4-215	14-95	6,000-20,000+
Incandescent	15-1,500	8-24	750-3,500

Note: Data are based on the more commonly used lamps and are provided for comparison purposes only. Actual results to be derived depend on factor unique to the specific products and installation involved. Consult manufacturers for guidance. Lumens (of light output) per watt (of power input) is a common measure of lamp efficiency (efficacy). Initial lumens-per-watt data are based upon the light output of lamps when new. The light output of most lamps declines with use. The actual efficiency to be derived from a lamp depends on factors unique to an installation. The actual efficiency of a lighting systems depends on far more than the efficiency of lamps or lamps/ballasts alone. More than efficiency should be considered when evaluating a lighting system.

Replace Ballasts

If lamp ballasts are near the end of their useful lives, the cost of converting to new high-efficiency ballasts will be minimal – the difference in cost between the two types of ballast. In general, if ballasts need to be replaced, one should consider changing to a more efficient type of lamp at the same time. Also consider the possibility of new control systems, some of which require specific types of ballasts.

If ballasts are fairly new, the cost of converting to high-efficiency electromagnetic ballasts will in effect be greater, but still may be justified. For example, high-efficiency ballasts for fluorescent lights can reduce power consumption by 7 percent, while improving light output. Electronic or high-frequency ballasts also are available for use with standard or reduced-wattage, high-efficiency fluorescent lamps. These are approximately

Table 15-2. Energy Savings Lamp Interchangeability Chart [a]

Standard Lamp	Replacement Lamp	Wattage Savings[b]	Comparative Light Output of Replacemnt Lamp[c]	Value of Energy Savings Over Life of Replacement Lamp at $0.7./kWh	Other benefits[d]
60W Incandescent	Self-Ballasted Fluorescent	42	+	$22.05	X
75W Incandescent	Self-Ballasted Fluorescent	57	+	$29.93	
100W Incandescent	Self-Ballasted Fluorescent	56	=	$29.40	X
75W PAR-38 Spot or Flood Incandescent	65W PAR-38 Spot or Flood Incandescent	10	=	$1.40	
150W R-40 Flood Incandescent Downlight	75W ER-30 Incandescent Downlight	75	=	$10.50	
	120W ER-40 Incandescent Downlight	30	+ +	$4.20	X
150W PAR-38 Spot or Flood Incandescent	120W PAR-38 Spot or Flood Incandescent	30	=	$4.20	
300W R-40 Flood Incandescent Downlight	120W ER-40 Incandescent Downlight	180	–	$25.00	
500W Incandescent	450W Self-Ballasted Mercury Vapor[e]	50	–	$56.00	
1,000W Incandescent	750W Self-Ballasted Mercury Vapor[e]	250	–	$280.00	
F-40 Fluorescent	F-40 Reduced-Wattage, High-Efficiency Fluorescent	7	=	$9.80	
	F-40 Reduced-Wattage, High-Efficiency Color-Improved Fluorescent	7	–	$9.80	
	F-40 High-Brightness Fluorescent	0	+	$0.00	X
F-96 Fluorescent	F-96 Reduced-Wattage, High-Efficiency Fluorescent	16.5	–	$20.80	
F-96 HO Fluorescent	F-96 HO Reduced-Wattage, High-Efficiency Fluorescent	16.5	–	$20.80	
F-96 1,500 MA Fluorescent	F-96 1,500 MA Reduced-Wattage, High-Efficiency Fluorescent	30	–	$23.83	
175W Mercury Vapor	150W Retrofit High Pressure Sodium	40	+ +	$33.60	X
	175W Retrofit Metal Halide	0	+ +	$0.00	X
250W Mercury Vapor	215W Retrofit High-Pressure Sodium	65	+ +	$54.60	X
400W Mercury Vapor	325 W Retrofit Metal Halide	70	+ +	$98.00	X
	400W Retrofit Metal Halide	0	+ +	$0.0	X
	300W Retrofit High-Pressure Sodium	60	+ +	$67.20	X
1,000W Mercury Vapor	880W Retrofit High-Pressure Sodium	160	+ +	$59.50	X
1,000W Mercury Vapor	950W Retrofit Metal Halide	50	+ +	$42.50	X

[a]All numbers shown are approximations and in certain cases assumptions are made about the types of fixtures and other conditions involved. Consult manufacturers for accurate data relative to direct replacements possible for a given installation as well as any ballast operating temperature or other restrictions which may apply.
[b]Wattage savings include ballast losses, where applicable. Actual ballast losses to be experienced depend on the specific type of ballast involved and operating conditions which affect its performance. In those cases where wattage savings exceed the difference in lamp wattage (if any), operation of the replacement lamp also has the effect of reducing ballast losses.
[c]Symbols used indicate the following: + + substantially more; + more; = about the same; – less; – substantially less. Consult manufacturers for accurate information relative to conditions unique to the lamps and installations involved.
[d]Other benefits typically provided by retrofit lamps include reduced maintenance costs due to longer lamp life, improved productivity, safety/security, quality control, etc., due to higher light output, ability to reduce number of lamps installed systemwide due to higher output of retrofit lamps, and improved color rendition.
[e]For high voltage only.

Source: National Lighting Bureau

Table 15-3. Retrofit Options for Incandescent Fixture[a]

Existing Lamp	Retrofit/ Replacement Option	Input Power Savings (watts)	Relative Light Output (%)	Value of Annual Energy Savings ($)[b]
	Lamp Retrofit			
60W Std. Lamp	52W Energy-Saving	8	85	2.00
	13W Compact Fluorescent	44	92	14.00
	18W Compact Fluorescent	42	124	13.00
75W Std. Lamp	18W Compact Fluorescent	57	100	18.00
150W Std. Lamp	135W Energy-Saving	15	91	5.00
	90W Halogen	60	61	19.00
500W	450W Self-Ballasted Mercury Vapor	50	84	16.00
1000W	750W Self-Ballasted Mercury Vapor	250	59	80.00
	System Replacement			
500W	174W Metal Halide	290	121	93.00
1000W	250W High-Pressure Sodium	695	119	222.00

[a]The data presented in this table are extrapolated from several sources and therefore must be considered approximate. In choosing between different systems or similar systems offered by different manufacturers, data relating to the specific installation should be obtained.
[b]Assuming 4,000 hours of operation of $0.08/kWh.

15 percent more efficient than the high-efficiency electromagnetic ballasts and may last as long. In some instances they are more versatile because they are compatible with dimming controls.

In some cases, fewer electronic ballasts may be required. For example, four- and three-lamp fluorescent luminaires that operate with two electromagnetic ballasts usually can operate with just one electronic ballast specially designed for four- or three-lamp operation. With this option, one does not need to rely on split-ballasting and will still be able to use dimmers.

Table 15-4. Retrofit Options for Recessed Baffled Incandescent Downlight[a]

Existing Lamp	Retrofit Option	Input Power Savings (watts)	Relative Light Output (%)	Value of Annual Energy Savings ($)[b]
	Lamp Retrofit			
75W R30	18W Compact Fluorescent	57	96	18.00
150W R40	120W Energy-Saving	30	Same	10.00
	75ER30	75	Same	24.00
	90W Halogen	60	Same	19.00
300W R	120E R40	180	Same	58.00
75W PAR	65W Energy-Saving PAR	10	Same	3.00
	45W Halogen PAR	30	Same	10.00
150W PAR	120W Energy-Saving PAR	30	Same	10.00
	90W Halogen PAR	60	Same	19.00
	60W HIR	90	Same	28.00

[a]The data presented in this table are extrapolated from several sources and therefore must be considered approximate. In choosing between different systems or similar systems offered by different manufacturers, data relating to the specific installation should be obtained.
[b]Assuming 4,000 hours of operation of $0.08/kWh.

Controllable electronic ballasts, which are relatively new, can be dimmed by specific controls as part of an overall lighting system. They likely will become the preferred control and dimming system for fluorescent lamps in the future.

☞ *There are significant differences among electronic ballasts. Contact the manufacturer for information about factors such as the potential for electromagnetic interference, power factors, line current harmonics, and controllability.*

Evaluate Retrofit Reflectors

Highly polished retrofit reflectors are now being marketed for application in existing fluorescent luminaires. These reflectors are typically promoted for use with four-lamp fixtures. Manufacturers suggest that retrofit reflectors enable elimination of two of the four lamps with no significant loss of light. However, such claims may be based

Table 15-5. High-Bay Industrial Lighting Fixture[a]

Existing Lamp	Retrofit/ Replacement Option	Input Power Savings (watts)	Relative Light Output (%)	Value of Annual Energy Savings ($)[b]
	Lamp and Ballast Retrofit			
175 W Mercury Vapor	70W HPS	105	79	34.00
	100W HPS	70	112	22.00
	100W MH	71	106	23.00
	100W HPS	155	87	50.00
250W Mercury Vapor	150W HPS	97	147	31.00
	150W MH	100	104	32.00
	175W MH	70	106	22.00
400W Mercury Vapor	150W HPS	266	82	85.00
	250W HPS	150	141	48.00
	250W MH	159	97	51.00
	325W Energy-Saving Metal Halide	70	100	22.00
1000W Mercury Vapor	250W HPS	775	62	248.00
	400W HPS	610	79	195.00
	950W Energy-Saving Metal Halide	50	200	16.00

[a]The data presented in this table are extrapolated from several sources and therefore must be considered approximate. In choosing between different systems or similar systems offered by different manufacturers, data relating to the specific installation should be obtained.
[b]Assuming 4,000 hours of operation of $0.08/kWh.

on "before" conditions, where luminaires and lamps have not been cleaned regularly. Published data suggest that a four-lamp luminaire relamped to two-lamp operation and fitted with a retrofit reflector commonly produces 40 percent less light than a fully lamped, recently cleaned four-lamp luminaire.

It also is important to note that retrofit reflectors can result in inferior lighting by providing less illuminance and by creating "hot spots" beneath the fixture, dark areas between luminaires, and darkened, "gloomy" walls.

Table 15-6, Four-Lamp Fluorescent 2' x 4' Luminaire with Flat Prismatic Lens[a,b]

Existing Lamp	Retrofit/Replacement Option[c]	Input Power Savings (watts)	Relative Light Output (%)	Value of Annual Energy Savings ($)[d]
	Lamp Retrofit			
4 40WT 12 2Mag Hi-Eff Bal	4 34WT12 2 Mag Hi-Eff Bal	22	88	7.00
	4 32WT12 2 Mag Hi-Eff Bal	30	88	10.00
	Lamp and Ballast Replacement			
4 40WT12 2Mag Hi-Eff Bal	4 40WT12 2 Cath Cutout Bal	22	86	7.00
	4 34WT12 2 Cath Cutout Bal	41	79	13.00
	4 32WT8 2 Mag Bal	28	95	9.00
	4 40WT12 2 Elec Bal	22-34	101-98	7.00-11.00
	4 34WT12 2 Elec Bal	38-51	91-79	12.00-16.00
	4 40WT10 2 Elec Bal	16-17	110	5.00-6.00
	4 32WT8 2 Elec Bal	45-49	97-101	14.00-16.00
	4 32WT8 1 Elec Bal	45-49	97-101	14.00-16.00
	System Replacement			
4 40WT12 2Mag Hi-Eff Bal	3 40WT12 1 Elec Bal	50-53	76-72	16.00-17.00
	3 34WT12 1 Elec Bal	65-73	67-61	21.00-23.00
	3 40WT10 1 Elec Bal	53	84	17.00
	3 32WT8 1 Elec Bal	63-76	73-65	20.00-24.00

[a]The data presented in this table are extrapolated from several sources and therefore must be considered approximate. In choosing between different systems or similar systems offered by different manufacturers, data relating to the specific installation should be obtained.
[b]Electronic ballast data are given in ranges to accommodate the industry variation in design. In general, the higher input power savings match the lower relative light output listings.
[c]Conversion requires recentering of sockets.
[d]Assuming 4,000 hours of operation of $0.08/kWh.

Reflectors also may increase maintenance costs, because highly polished surfaces require more frequent and rigorous cleaning to maintain their effectiveness and also make luminaire maintenance such as ballast replacement more difficult.

Further, installation of a retrofit reflector could void the Underwriters' Laboratories (UL) or other listing of a luminaire, which would result in a code violation. It could also void the remaining portion of the fixture manufacturer's warranty.

Cost factors also must be assessed. Optimal reflector performance requires custom design and fitting. Overall, the expense required may be close to that associated with other, potentially more effective modifications, such as lamp and ballast replacement or new luminaires.

Replace Inefficient Lenses

Replace all degraded, yellowed, or otherwise inefficient lenses with efficient lenses that pass more light into the space, eliminate glare, and diffuse light more uniformly.

Consider Daylighting

Daylighting – that is, using natural light for illumination – can be used in many facilities to supplement existing lighting systems. However, because the amount of available daylight depends on variables such as weather, time of year, and time of day, daylighting cannot replace a lighting system.

Daylighting systems usually have a control system, including a dimmer and a photocell; interior or exterior shading mechanisms; and thermal barriers for unoccupied periods (to ensure that heat buildup does not increase the building's cooling load).

Studies have shown that daylighting has a positive influence on workers' moods. It can also provide a higher quality, more attractive ambience, especially in areas that are primarily used from 8 a.m. to 6 p.m. However, while daylighting can reduce lighting energy costs, it could actually add to the energy bill by increasing heating loads in the summer (requiring more cooling energy) and increasing heat loss in the winter (requiring more heating energy). Daylighting is usually most cost-effective in warmer climates or where electric rates are high.

Daylighting (perimeter dimming) also reduces internal heat gain and chiller loads. Thus, energy savings during the cooling season are from reduced light use and reduced chiller operation. In winter, when it is usually cold and dark, lights tend to brighten the space and reduce the heating load. Depending on location and electric rates, it may be best to increase the square footage of glazing, because the heat lost from reduced lighting use is more than made up in reduced lighting-energy and initial construction costs. The minimum life-cycle cost can be achieved based on the orientation of the facility and its curtain glazing, which again depends on the building's location.

☞ *Conduct a feasibility study to determine if daylighting is appropriate for the facility. A computer program can be used to determine if the negative impact of solar gains in the cooling season are worth the positive benefits of "free" lighting and heat gains in the heating season.*

The following new daylighting technologies, if not available already, should be on the market in the near future.

- ***Spectrally reflected glazings*** capture visible light while blocking its infrared component (that is, they permit light without heat). For example, a layer of spectrally selective film suspended between two pieces of ordinary green glass will admit more than 50 percent of the visible light while blocking 95 percent of the infrared heat.

- ***Holographic glazings*** offer a new and fundamentally different approach to collecting and diffusing daylight. The glazings have a transparent, micron-thin holographic pattern (with silver halide emulsion, photopolymers, and embossed thermoplastic) that literally tracks the sun to focus daylight on a selected fixed surface or surfaces (for example, the ceiling or walls), where it can be redistributed as desired.

- ***Top-reflective venetian blinds*** bounce light up to the ceiling, where it reflects back down to the interior surfaces. These blinds are different from conventional blinds in that individual panels have reflective films attached. The blinds are typically assembled concave-side up.

- ***Electrochromic glass coating*** uses an electric current to vary the amount of daylight and heat transmission through the window.

Electric lighting controls are essential components of any daylighting scheme because they reduce the lighting power level when there is sufficient daylight. It is important to integrate manual override mechanisms with the automated controls, particularly to accommodate individual lighting preferences. Proper maintenance of the lighting control system is critical.

The interior floor plan configuration and design of the space where daylighting is to be employed are also important. To use daylight to its greatest advantage at the perimeter space in a typical window configuration, for instance, place opaque partitions no further from the window than approximately 2½ times the height of the window itself. Excessive light, veiling reflections on work surfaces, and increased solar gain must be accounted for when designing a daylighting scheme. For daylighting to be effective, windows must be kept clean and glare must be minimized.

Modify Switching

Large groups of luminaires are often controlled by a single master breaker located at the main electrical panel. This arrangement generates substantial waste, because 50 or more luminaires may be activated even though only 4 or 5 are needed. To reduce waste, consider installing new switches so that relatively few luminaires are controlled by a local switch near the luminaires being controlled. In this way, users can be far more selective, especially during normally unoccupied hours. All luminaires can be connected to a single timer or similar control that deactivates all lighting – with the exception of safety and security lighting – at a predetermined time. Local switches can then override the master control for those working after hours.

The applicability of local switching can be determined only after analysis of the results of a comprehensive survey of how the lighting system is used during both occupied and unoccupied hours. In all cases, new switching should be flexible, so that enough lighting can be provided for all possible requirements in a particular area.

Arrange the switching so it provides even illumination for the area without sacrificing the good design practices recommended by the Illuminating Engineering Society. Some of these methods of control are as follows:

- Control rows of fluorescent fixtures or point-source fixtures with close spacing by switching adjacent rows.

- Control rows of fluorescent fixtures or point-source fixtures by switching alternate fixtures within each row.

- With two-lamp fluorescent fixtures in a continuous row, wire the ballast so lamps can operate as a single row on one side of all fixtures within the row.

- In four-lamp fluorescent fixtures, control a pair of lamps so that one two-lamp ballast supplies the two inner lamps and the other two-lamp ballast supplies the two outer lamps to give a symmetrical appearance when operated separately.

- Wire fixtures with other combinations or types of lamps to provide some uniformity of appearance.

- Control the following separately: nonuniform or accent lighting, the various system-lighting architectural elements, pictures, displays, machines, and other special "seeing" tasks.

- Control selected lighting equipment for security purposes so it operates continuously on a separate circuit.

Review the control system to ensure it meets local building codes. As necessary, consult a competent electrical contractor, lighting engineer, or lighting designer.

Modify Controls

Many types of control devices may be applicable to the indoor and outdoor lighting systems. These include timers, dimmer switches, photocell controls, occupancy sensors, and centralized programmable controls. Essentially, all of these work by either shutting off lights entirely when or where they are not needed or adjusting lighting levels so that no more light than necessary is provided.

Timers. Timers switch lights on and off automatically in relation to the time of day. Some have an "astronomic dial" that automatically accounts for changing hours of darkness throughout the year. For example, office lights can be turned on automatically at 8 a.m. and turned off at whatever time is selected. Because timers are automatic, they are recommended for unsupervised offices or industrial installations with a daily routine. However, they may be relatively more expensive to install than wall switches or

dimmers because they require a sophisticated clock and more specialized labor.

Dimmer Switch Controls. New solid-state silicon controlled rectifier dimmer switches allow lighting levels to be adjusted to suit the needs of specific tasks at specific times. Thus only the energy needed is used. These dimmer switches act like an extremely fast switch, turning power on and off during each electrical cycle. A wide variety is available to control incandescent, fluorescent, and some high-intensity discharge lights.

☞ *Older style rheostat dimmers provide no power reduction. Consider replacing these types of dimmers.*

Photocell Controls. Photocell controls turn lights off or on when ambient light levels reach a predetermined level. They are frequently used to control outdoor roadway lighting, parking lot lights, and indoor lighting where there is a large window area used to obtain ambient lighting. Photoelectric switches provide considerable energy savings because they automatically turn the lights off when they are not needed. They can also be used in conjunction with timers to control turn-on times.

☞ *Be cautious when evaluating the use of natural daylighting to meet interior illumination needs. Solar light also means solar heat gains.*

Occupancy Sensors. Occupancy sensor controls activate or deactivate lighting based on the presence of people. Four types are used: *ultrasonic controls*, which sense motion; *passive infrared controls*, which detect infrared energy (heat); *active infrared controls*, which transmit and receive beams and detect changes in reflected light; and *acoustic controls*, which detect sounds within a certain frequency. Occupancy sensors can be integrated with local HVAC units, dimmers, and security systems.

Centralized Programmable Controls. Centralized programmable controls offer the most comprehensive automatic control available. They are used to control lighting (and other systems) throughout the building. They can be operated from one central computer or through distributed processing, and they can integrate facility systems and control loads automatically based on occupancy, time of day, and other variables. Most are also equipped with manual overrides so that individuals can activate or deactivate lighting.

Consider Nonuniform Lighting

Many offices and industrial spaces have uniform lighting systems with identical luminaires arranged in a uniform grid pattern on the ceiling. This design usually was mandated because the designer had no idea of how the workstations would eventually be arranged. Accordingly, the lighting level selected for the space was the IES recommendation for what the designer assumed would be the most visually difficult, recurring task in the space. As such, IES recommendations were misused, because they apply to tasks, not spaces. However, no alternative was available. Even if luminaire location and type were specified on the basis of a known layout, chances are that the design still would end up counterproductive, because workstation layouts frequently change.

Today, however, there are alternatives. Many lighting designers now use flexible branch wiring systems with preassembled cable sets that can be plugged and unplugged with ease. A luminaire mounted in a suspended ceiling can easily be reconnected in a new location. As a result, only the amount of lighting actually needed is provided. The resulting nonuniform pattern tends to create visual interest, which can easily be enhanced through decorative lighting techniques. Flexible branch wiring should be considered whenever a major renovation or remodeling is planned.

CHAPTER 16. ENERGY EFFICIENCY OPPORTUNITIES: SERVICE HOT WATER

16.1 KEY CONCEPTS

- No-cost and low-cost opportunities include reducing hot water consumption, and reducing temperature settings.
- A service hot water temperature of 105°F will accommodate most needs.
- Service hot water storage tanks and external heaters should be covered with insulation that has a minimum conductivity of 0.3.
- Heat pump water heaters are ideal for locations that require hot water and year-round cooling.

16.2 OVERVIEW

A service hot water system consists of the components that generate, store, distribute, and dispense hot water. Each of these components, the way they are used, and the overall design of the entire system affects the amount of energy consumed. Service hot water accounts for 4 percent of all energy consumed in many large commercial buildings. The consumption may exceed in buildings with restaurants, cafeterias, or laundromats, but may not be applicable to most FAA facilities.

Some of the major energy efficiency opportunities for service hot water systems in federal/commercial buildings are described below. Preventive maintenance actions for service hot water systems are discussed in Chapter 12.

16.3 NO-COST / LOW-COST OPPORTUNITIES

No-cost and low-cost energy efficiency opportunities for service hot water systems include reducing hot water consumption and reducing hot water temperature settings.

Reduce Hot Water Consumption

Install flow-reduction devices to reduce hot water consumption. These devices include flow restrictors installed in the water line, aerators that reduce water flow

and mix the water with air, and faucets that automatically shut off.

Reduce Temperature Settings

The temperature settings of most service hot water systems range from 120° to 150°F. Activities like dishwashing and sterilization are not applicable to FAA facilities, which may require delivery temperature may range up to 180°F. In many cases, the highest temperature required for one use is supplied to all taps on a service hot water system.

Reducing the temperature of service hot water saves energy because a lower temperature reduces system losses. For example, when the temperature is reduced from 180° to 125°F, heat losses in uninsulated piping in a 68°F room are cut in half. In addition, a significant temperature reduction can extend the life of a glass-lined storage tank.

One of the easiest ways to reduce service hot water energy consumption is to set the temperature to the lowest point that will accommodate the majority of uses (normal temperature requirements are shown in Table 16-1). A temperature lowered to 105°F will probably accommodate most needs. Where higher temperatures are required, a small booster heater can be installed near the point of use. The booster then heats the 105°F water to the temperature needed. An economic analysis probably will show that the savings obtained by reducing the central system temperature will quickly pay back the cost of installing and operating the booster heaters.

Table 16-1, Representative Hot Water Utilization Temperatures

Use	Temperature °F
Lavatory	
Hand Washing	105
Shaving	115
Showers and Tubs	110
Therapeutic Baths	95
Commercial and Institutional Dishwashing	
Wash	140
Sanitizing Rinse	180
Commercial and Institutional Laundry	180
Residential Dishwashing and Laundry	140
Surgical Scrubbing	110

If a space-heating boiler is used to provide hot water, lower the thermostat setting to 105°F. This temperature can be used year-round. If the service hot water system is the only summer load on the space-heating boiler, consider installing a separate water heater for summer use. The savings achieved by avoiding summertime losses usually produce a rapid payback for the separate system.

16.4 MODERATE-COST AND CAPITAL-INTENSIVE OPPORTUNITIES

Moderate-cost and capital-intensive opportunities range from actions as simple as adding insulation to pipes and storage tanks to complex upgrades such as solar water heaters. The service hot water energy efficiency opportunities described in this section fall into three general areas: preventing heat losses; recapturing lost heat and using it to heat service hot water; and installing local hot-water heaters to meet localized high-water-temperature demands.

Table 16-2. Minimum Pipe Insulation (inches)[a]

Characteristic	Requirement for Domestic And Service Hot Water Systems
Fluid Design Operating Temperature Range, °F	105-140
Insulation Conductivity	
Conductivity Range (B x inches/°F x hour x sf)	0.24-0.28
Mean Rating Temperature (°F)	100
Nominal Pipe Diameter (inches)	
Runouts[b] up to 2	0.5
1 and less	1.0
1 to 2	1.0
2 to 4	1.5
5 and 6	1.5
8 and up	1.5

[a]For minimum thicknesses of alternative insulation types, see Section 9.4.8.2 of the ASHRAE/IES Standard.
[b]Runouts to individual terminal units not exceeding 12 feet in length.
[c]Applies to recirculating sections of service or domestic hot water systems and first 8 feet from storage tank for nonrecirculating systems.

Insulate Service Hot Water System Piping

To reduce distribution losses, insulate hot-water piping according to the guidelines shown in Table 16-2. Small pipes should be insulated with cylindrical half-sections of

flexible cell material. Large pipes can be insulated with flexible material.

Insulate Storage Tanks and Heaters

Heat loss from storage tanks and heaters must be offset by providing more heat to maintain a ready supply of hot water. Unless special controls or operating practices have been introduced, this heat loss occurs 24 hours a day, 7 days a week. To minimize this loss, be sure that all storage tanks and external heaters are covered with insulation that has a minimum conductivity of 0.3. Add new or additional insulation as required and replace or repair all missing or torn insulation. Check local building codes to determine which insulation materials are acceptable.

Table 16-3. Ratios of Insulation Thickness and Tank Size to Hourly Heat Loss

Insulation K = 0.3	Tank Size In Gallons	Btuh Lost at Water Temperature of		
		100°F	140°F	180°F
Bare	50	1,301	3,024	5,100
	100	2,190	5,089	8,584
	250	3,840	8,923	15,051
	500	6,292	14,620	24,660
1"	50	206	441	678
	100	346	743	1,142
	250	607	1,303	2,002
	500	994	2,135	3,280
2"	50	109	236	362
	100	184	397	609
	250	323	696	1,069
	500	528	1,140	1,751
3"	50	74	160	245
	100	125	270	412
	250	219	473	722
	500	359	775	1,184

One can determine the savings provided by the insulation by comparing tank heat losses before and after insulation. Table 16-3 shows energy losses for different tank sizes and water temperatures if the tank is located in a 65°F space, with insulation thicknesses as indicated.

Install Local Service Water Heaters

In many facilities, the service hot water thermostat is set to a relatively high setting, such as 140°F or greater, to satisfy the highest temperature demand. This causes double waste. First, much of the heating energy used is not needed for most applications. Second, because most applications require a lower temperature, more cold water must be used to offset the high-temperature hot water. This wastes water and increases water and sewer charges. In addition, if a circulating pump system is used, that electric energy is wasted.

Installing the following types of local hot-water heaters will help reduce these losses and save money:

- Booster heaters at points of high-temperature water use eliminate the need to heat all water to the highest temperature required. For example, special service areas may require 180°F water. Most other uses, however, need only 115°F water. It may be possible to install booster heaters in these special service areas and lower the temperature of the central water heater to 115°F.

- Separate, smaller hot-water systems may be appropriate for specific applications.

- Point-of-use or instant-on water heaters may be appropriate for little-used systems, such as private washrooms. Circulating pumps can be downsized, and energy losses from circulating unused hot water are reduced. In addition, construction costs can be significantly lower, because an instant-on heater requires only one line.

Either of these approaches requires a feasibility study to ensure its cost-effectiveness.

Preheat Feedwater With Reclaimed Waste Heat

Waste heat from other facility equipment processes (such as chiller condensers, boiler flues, and engine exhausts) can be reclaimed and used to preheat feedwater. Because the hot-water load profile may not match the profile of energy available from waste heat sources, a storage tank may be required.

Recover Waste Heat for Service Hot Water Heating

Refrigeration systems, steam systems, diesel or gas engines, incinerators, and other facility system often produce waste heat. This waste heat can be recovered and used to heat service hot water.

Figure 16-1. Waste Heat Recovery Using a Hot Condensate Heat Exchanger

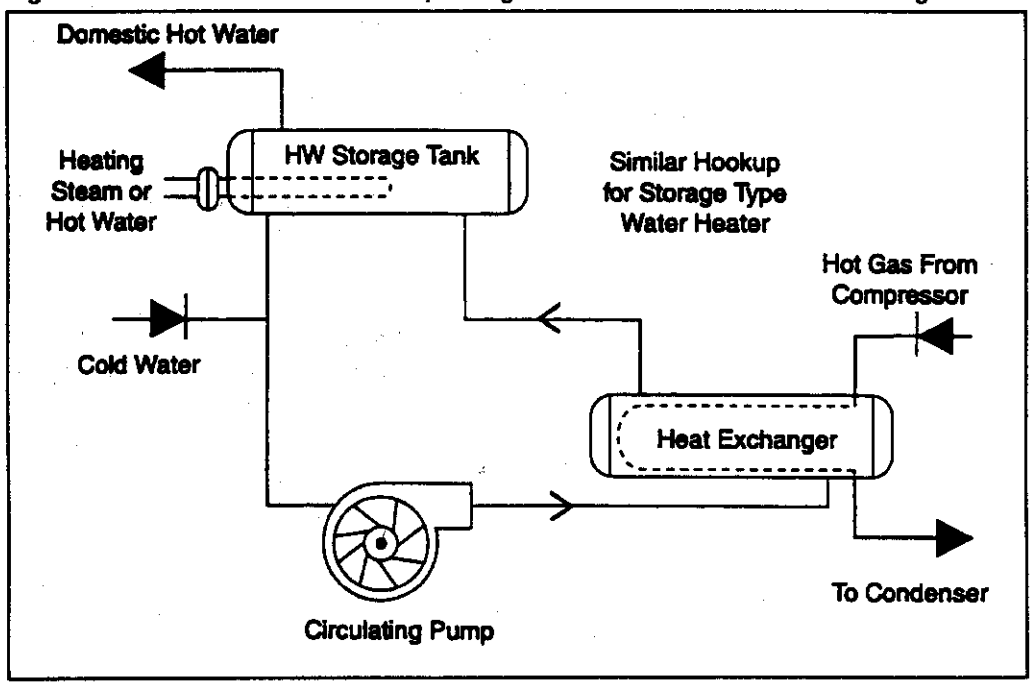


Figure 16-1 shows how waste heat is recovered from the condensate return of a steam system. A heat exchanger is placed in the system's cycle between the condensate return and the condensate receiver to recover some of the heat from flash steam as it is reduced to atmospheric pressure in the condensate receiver. The recovered heat is then used to preheat water. Heat exchangers can be installed similarly to recover heat from engines, boiler breechings, and air-conditioning systems. Heat can also be recovered from large incinerators that burn 1 or more tons of solid waste per day, and through solar energy systems. If the recovered heat cannot be used immediately, it can be stored until it is needed, or it can be heated and stored during non-peak hours to take advantage of lower utility rates.

Add Demand Controls to Electric Storage Water Heaters

Demand-controlled storage water heaters operate on the principle that a building's peak electrical demand exists for only a short period. During that period, heated water can be supplied from storage rather than by continuing to use electricity for on-demand heating. Avoiding use of electricity during peak demand periods allows water to be heated at the time when it costs the least (that is, during non-peak periods) in many utility rate schedules. Demand controls read the building's electrical load and compare it with peak demand data. When the load is below peak demand, the device allows the water heater to operate. Some controllers can program deferred loads in steps as capacity becomes available. This priority sequencing may involve each of several banks of elements in a water heater or multiple water heaters.

Use Heat Pump Water Heaters

Heat pump water heaters can perform the dual functions of water heating and space cooling and dehumidification. They are ideally suited for areas with year-round cooling requirements and a need for hot water.

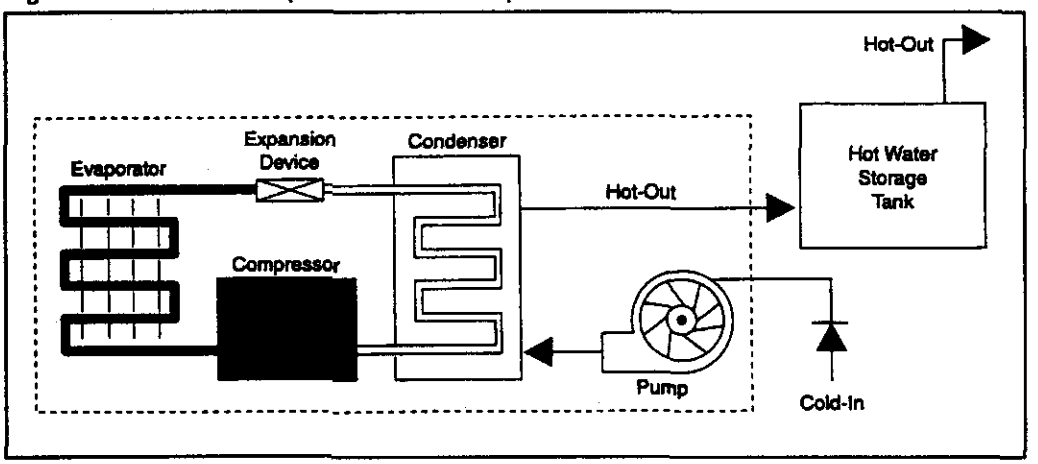
Heat pump water heaters are generally heat-only, air-to-water heat pumps that can heat water to about 140°F (Figure 16-2). They are very energy efficient, partly because they use heat available from the indoor environment and therefore require less heating energy. They are about three times more efficient than conventional electric water heaters, and four to six times more efficient than conventional gas water heaters. Performance coefficients are about 2 to 4 when heating water to 140°F and 4 to 6 when heating water to the 85° to 95°F range (for example, for pools).

Heat pump water heaters are available in sizes that can provide from 18 to 275 gallons of hot water per hour and from 2/3 to 10 tons of cooling. While operating costs are the same as or slightly less than those of gas water heaters in many areas, they are 25 to 50 percent lower than those of electric resistance water heaters. When the cooling byproduct is used, operating costs are reduced even further.

Heat pump water heaters can be integral or remote units. In integral units, the heat exchangers and compressor are permanently mounted on the hot-water tank. In remote units, the evaporator is located away from the tank and is connected by pipes; these units can be placed where the most heat is available or most cooling is required. Heat

pump water heaters should be kept in rooms with ambient temperatures between 45° and 95°F (frost could form at temperatures below 40°F). Water tanks can be fitted with supplemental resistance heating to help ensure that peak heating requirements are always met.

Figure 16-2. Heat Pump Water Heater Operation



Use Desuperheaters

A desuperheater includes a heat exchanger, a small water circulating pump, and controls. Its main component is an insulated, double-walled refrigerant-to-water heat exchanger, which is used to recover waste heat from the hot refrigerant vapor in the condenser of an air conditioner. The recovered heat is transferred to the service hot water supply.

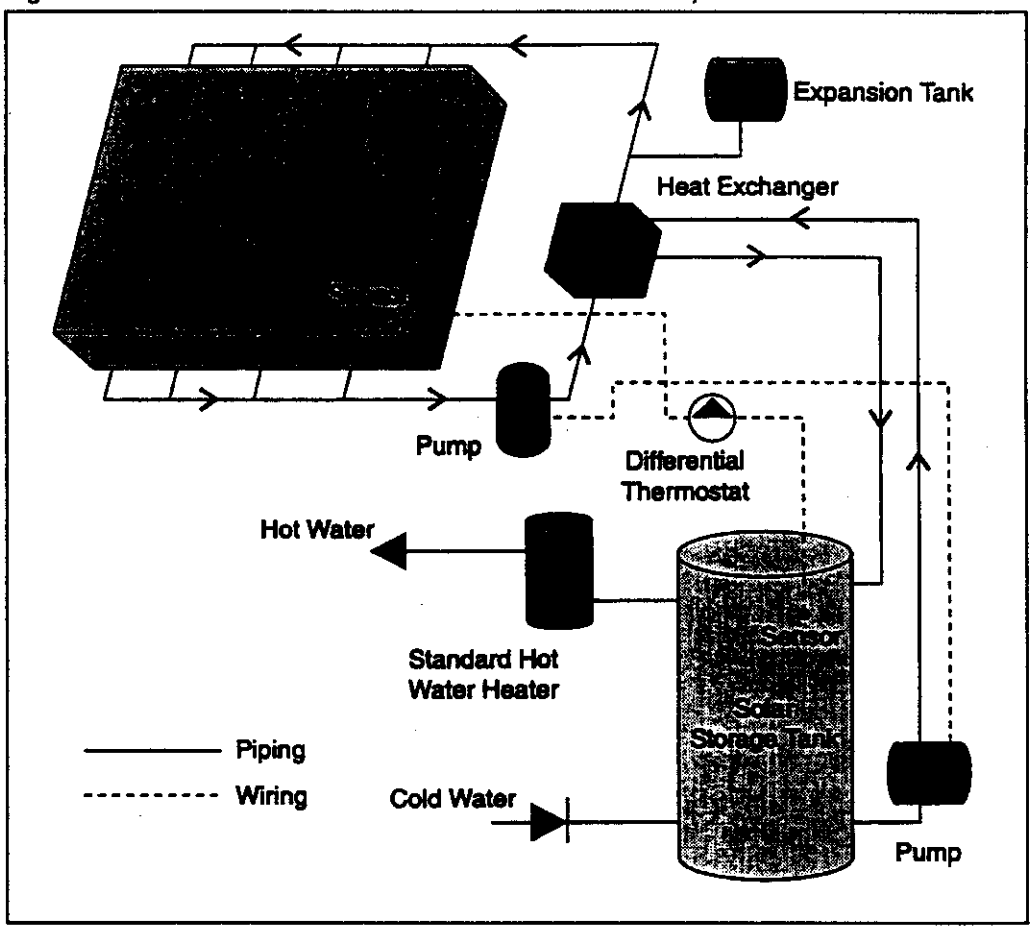
The heat exchanger is installed in the refrigerant line between the compressor (hot gas) and the condenser (cooler gas). The water loop runs from the lower part of the service hot water heater's tank, through the heat exchanger, and then back into the tank. Hot gas temperature depends on head pressure, but is usually between 200° and 280°F. A desuperheater produces about 3 gallons of heated water per hour per ton of air-conditioning capacity.

Heat Water With Solar Energy

Solar energy can supply the heat for service hot water (Figure 16-3), although the efficiency of a solar system depends on climate and location. In general, installing a typical solar water heating system is no different than installing a conventional water system, except for the solar collectors. The collectors should be placed as close to the

storage tanks as possible to reduce piping costs and heat loss, and in such a way that all fluid can be drained completely. For best annual performance, the collectors should be installed at a tilt angle, equal to the local latitude, above the horizontal. They should be oriented toward *true* south, *not* magnetic south.

Figure 16-3. Schematic of a Solar Service Hot Water System



Two types of solar water heaters are available: *direct* and *indirect*. In direct solar water heating systems, the potable water is directly heated in the collector. In indirect water heating systems, potable water is heated by a heat exchanger that uses water, nonfreezing fluids, or air transported by either natural or forced circulation. Natural circulation takes place via natural convection (or thermosiphoning), whereas forced convection requires pumps or fans. Forced circulation systems are controlled through differential thermostats.

CHAPTER 17. ENERGY EFFICIENCY OPPORTUNITIES IN ELECTRICAL SYSTEMS

17.1 KEY CONCEPTS

- Energy can be saved by finding ways of reducing the length of time that motors run; improving motor and motor-machine efficiency can also save energy.
- Consider replacing motors that are not loaded to at least 60 percent of their potential.
- Demand-side management is not the same as demand control; rather, demand control is a part of demand-side management.

17.2 OVERVIEW

Electric utilities employ a number of demand-side management techniques to minimize peak demand for electricity. This helps forestall the need for additional generating facilities. Utilities also have developed a variety of incentive programs to create customer acceptance of these demand-side management plans. One should be familiar with how the electric utility in their area manages demand and what the utility has to offer in the way of demand-side management incentives.

This chapter describes a number of ways to reduce electricity consumption, use electricity more efficiently, and adjust electricity consumption to avoid excess demand charges.

17.3 NO-COST / LOW-COST OPPORTUNITIES

Low-cost and no-cost opportunities include improving the efficiency of electric motors and making operational changes in electrical systems such as elevators, escalators, water coolers, and vending machines.

Improve the Performance of Electric Motors

Electric motors are typically used in facilities to drive fans, pumps, compressors, and elevators. One can save energy by finding ways to reduce the length of time that motors run – for example, by installing controls that automatically cycle the motors of various types of equipment – however, as much or more energy can be saved by improving motor and

motor-machine efficiency. Improving the efficiency of a motor has the additional benefit of saving energy while the motor is in use. Typical steps to improve motor efficiency include the following:

- Lubricate the motor and drives regularly to reduce friction.
- Replace worn motor bearings.
- Keep motors clean to facilitate cooling.
- Check the alignment between the motor and the equipment it drives to reduce wear and excessive torque.
- Tighten belts and pulleys at regular intervals to reduce losses due to slippage.

After these energy efficiency opportunities (EEOs) are implemented, they should be incorporated into the preventive maintenance program.

When replacing worn or defective motors, select the highest efficiency motor available, sized as close to the load as possible.

Cut Back Elevator and Escalator Operation

The amount of power required to operate an elevator is a function of the height of the building, the number of stops, passenger capacity and load factors, and the efficiency of the hoisting mechanism. For example, a 2,500 pound-capacity "local" elevator making 150 stops per car-mile consumes about 5 kilowatt-hours (kWh) per car-mile. An "express" elevator making 75 stops per car-mile consumes about 4 kWh per car-mile. A 4,500-pound-capacity elevator that stops at every floor in a 12-story building uses 13 kWh per car-mile. Energy consumption also is affected by type of hoisting motors and controls, type of service, and the amount of load offset by the counterweight.

To reduce energy consumption, select speeds that are as slow as possible while keeping maximum waiting time to no more than 2 minutes. Ask the elevator manufacturer or a consulting engineer to study the building's traffic patterns and to reschedule elevator service as necessary. When multiple elevators are installed, reduce the number in service during light traffic periods.

Assuming 35 percent equivalent full-load operation, escalator energy consumption varies from 1.3 kWh per hour

for a 32-inch-wide model operating at 90 feet per minute with a 14-foot vertical rise, to 3.0 kWh per hour for a 48-inch-wide model operating at 90 feet per minute with a 25-foot vertical rise. Escalators consume energy whether or not they are carrying passengers. Unlike elevators, they may be used when de-energized. Therefore, the number of escalators in service can easily be reduced, particularly during light traffic periods.

Shut Off Water Coolers and Vending Machines

Shutting off vending machines and water coolers when they are not needed, either by adding timers or running them on a centrally automated system, can save $10 to $25 per year per machine. Many of these machines are grouped and can be controlled by a single timer.

Installing timers is usually easy. For example, because a freestanding drinking fountain usually has a cord and plug beneath its shroud, a plug-in timer can be installed in minutes.

☞ *Do not install timers on machines that use refrigeration to prevent spoilage.*

Where central chillers provide cold water for fountains, consider retrofitting individual units or installing variable speed drives to reduce pumping energy, compressor operations, and losses through piping.

17.4 MODERATE-COST AND CAPITAL-INTENSIVE OPPORTUNITIES

Six moderate-cost or capital-intensive opportunities for reducing energy consumption and peak demand are described in this section: oversized-motor replacement, high-efficiency motors, variable speed motors, demand controllers, power-factor correction, and energy-efficient transformers.

Replace Oversized Motors

Because original load estimates for mechanical equipment are usually conservative, most motors are oversized for the equipment loads they serve. Decreased load factors of such oversized motors degrade power factors and reduce efficiency. Motor efficiencies drop off sharply below half-load.

Motors that are not loaded to at least 60 percent of their potential should be considered for replacement. To determine the load factor, divide the motor's part-load running current by the rated full-load current shown on the motor nameplate. Try to ensure that the characteristics of replacement motors match those of the electrical distribution system as closely as possible.

Use High-Efficiency Motors

High-efficiency motors reduce the losses in the conversion of electrical energy into mechanical energy. In general, the best applications for high-efficiency replacements are for motors that operate at least 8 hours a day.

Use Variable Speed Drives

Variable speed drives save energy by changing the motor speed to meet changing load requirements, which they sense automatically. There are two types of variable speed drives: mechanical and electronic. Electronic drives are more efficient but also more costly than mechanical drives. Centrifugal fans and pumps for water, sewage, refrigeration, and air are the best candidates for variable speed drives.

Install Demand Controllers

Commercial buildings are usually billed for both energy consumption and demand. Energy consumption is the total electric energy usage, read in kilowatt-hours. Demand charges are designed to assign customers a fair share of the utility's fixed investment in the production, transmission, and distribution equipment needed to meet the customer's maximum requirements. The utility bases demand charges on the rate at which electricity is consumed. The more electricity used at any given time, the larger the utility's investment in generation, transmission, and distribution systems and thus the higher the demand charge.

When a facility reduces its maximum demand through demand-side management, it helps the utility save energy and reduce its requirements for new generating capacity. Energy consumption savings from demand-side management are not great; however, it will provide significant savings in utility bills, in some cases thousands of dollars annually. In fact, even if no EEOs have been implemented to limit demand, chances are that demand-side management will have an immediate and positive impact.

Note that demand-side management is not the same as demand control; rather, demand control is a part of demand-side management (See Chapter 7 for details on demand-side management). Demand-side management involves the following steps:

- The first step in demand-side management is a survey that identifies when peak demands are recorded and the equipment that causes that demand. Through study of these and related data, it may be possible to simply reschedule certain operations to lower demand. For example, three pieces of equipment started simultaneously will incur far higher demand charges than the same equipment started at 5-minute intervals.

- The second element of demand-side management is *demand control*, in which a demand controller is used to take secondary loads off line. (Secondary loads include electric heating and cooling units, chillers, exhaust fans, air-handling unit fans, water heaters, and escalators.) The demand controller in effect prevents the demand limit from being exceeded.

In a typical application, a demand controller is connected to the utility's demand meter. Through any of several different logic systems, the controller determines electrical consumption during a demand interval and takes the secondary loads off line as necessary.

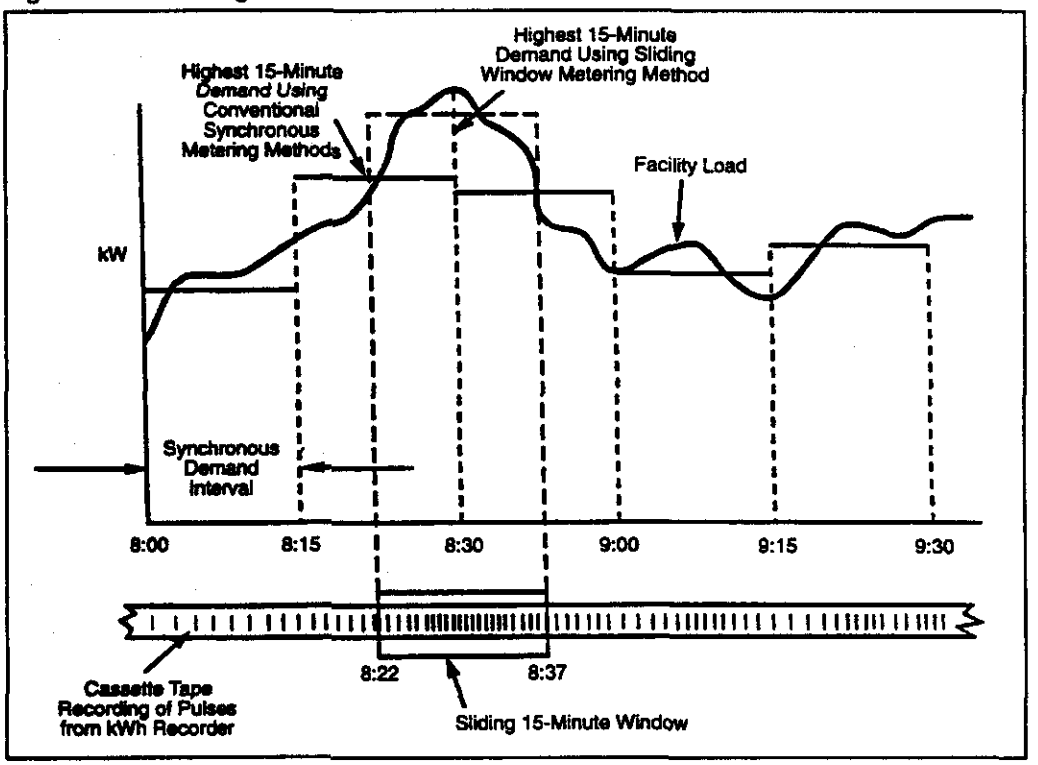
Because demand intervals are fixed throughout a utility system, widespread use of demand control equipment by utility customers creates an undesirable condition called the "roller-coaster effect": the utility experiences a system-wide high demand at the beginning of the demand interval. As demand controllers make their adjustments, demand drops off near the end of the interval.

To avoid the roller-coaster effect, many utilities no longer permit users to connect demand controllers to the utility meter to obtain the signal that marks the beginning of a demand interval. Some utilities are going a step further by doing away with fixed intervals altogether and using a "sliding-window approach" (Figure 17-1).

The sliding-window approach uses advanced demand metering equipment. A magnetic tape records consumption data. At the end of a billing interval, the tape is removed and scanned by a computer to find the 15 minutes (or other

period) during which maximum demand is recorded. With this approach, the demand interval can start at any time. It also results in higher demand than with the fixed interval method. With a fixed interval, the peak demand occurring at 8:22 and 8:37 is split between two intervals. When the sliding-window approach is used, the interval starts at 8:22.

Figure 17-1. Sliding Window Demand Record



Under the following conditions, it is best to tie demand control equipment directly into the utility's incoming lines, using current transformers:

- If a sliding-window approach is used.
- If the utility does not allow connection to its demand metering equipment.
- If the utility indicates that it may disallow connections to its demand meters in the future.

☞ *Some demand controllers cannot function under a sliding-window approach.*

Because the sliding-window approach can increase demand charges, effective demand control is becoming increasingly important. However, the sliding-window approach is just one of several approaches utilities are using, some

simultaneously, that also can increase the demand bill. For example, some utilities use "time-of-day metering," which may break a day into two, three, or as many as five different periods—for example, 6 a.m. to 6 p.m., 6 p.m. to midnight, and 12 midnight to 6 a.m. The demand rate, as well as the energy rate, differs for each period, but it is highest during periods of maximum system-wide use and lowest during periods of minimum system-wide use. However, through demand control and the rescheduling of certain operations, even time-of-day demand charges can be minimized.

A number of demand controllers are available. Each essentially keeps track of consumption at all times. When the controller's logic indicates that a preset demand limit will be exceeded during a demand interval, the controller's output – a signal – causes a secondary load to go off line. When the demand interval is over and the next interval begins, the load is restored.

Correct the Power Factor

A power factor is the ratio of actual power (expressed in kilowatts) to apparent power (expressed in kilovolt-amperes). A low power factor increases losses in electrical distribution and equipment such as wiring, motors, and transformers. It also reduces the load-handling capacity and voltage regulation of the building's electrical system. At a power factor of unity (that is, 100 percent), losses are at a minimum. When a power factor is below a designated level (for example, 85 percent), utilities often impose additional penalty charges. A lightly loaded motor is the best candidate for the savings that can be obtained by installing a device to correct its power factor.

Among the methods available for power-factor correction are the following:

- Capacitors are the least expensive way to reduce the reactive power of the system. Capacitors can be installed at any point in the electrical system, improve the power factor between the point of application and the power source, and can be added to each piece of offending equipment, ahead of groups of small motors, or at main services. For 1- to 60-kVA capacitance, one capacitor should be installed. For more than 60 kVA, banks of capacitors are required.

- Synchronous condensers and synchronous motors are also potential solutions; however, there are disadvantages associated with each: synchronous condensers are the most expensive solution, and small synchronous motors are not practical in most commercial buildings.

- A NASA-developed power-factor controller is available for improving energy efficiency in induction motors. The power-factor controller measures the difference in phase angle between voltage and current (that is, power factor) and optimizes the torque of the motor by reducing the voltage. It may reduce electricity consumption by 30 percent for lightly loaded, single-phase, low-efficiency motors. However, this controller is not economical for more heavily loaded motors, high-efficiency motors, or three-phase motors.

Install Energy-Efficient Transformers

Most dry-type transformers have efficiencies ranging from 93 to 98 percent, with losses deriving from the cores (magnetizing) and coils (resistance and impedance). Even when equipment served by the transformer is not operating, some energy is lost in the standby mode unless the primary power to the transformer is switched off.

The following measures will reduce the energy lost in the transformers:

- When replacing transformers, select the most energy-efficient transformers (that is, those with the lowest temperature rise ratings).

- If large liquid-filled transformers are required for new additions, select those with the highest efficiency.

- Disconnect from primary power the transformers that do not serve any active loads. (Do not disconnect transformers that power clocks, heating control circuits, fire alarms, and other critical equipment).

CHAPTER 18. HEAT-RECOVERY AND THERMAL STORAGE SYSTEMS

18.1 KEY CONCEPTS

- To effectively use a heat-recovery heat pump, the facility must generate sufficient heat to offset part or all of the space- and water-heating load.
- Runaround systems are seasonably reversible; they can provide preheating in the winter and precooling in the summer.
- The heat generated by compressors used for refrigeration units can be captured and used to provide space heating and humidity control.
- Electric heat storage systems shift daytime space-heating loads to non-peak periods.

18.2 OVERVIEW

Heat energy that otherwise would be rejected as waste can be reclaimed and used through a variety of heat-recovery systems. These systems can significantly reduce the primary energy consumption of HVAC systems. General applications of heat-recovery devices include tempering of ventilation air, space heating, and preheating of combustion air. Thermal storage systems can optimize heat recovery by making heating or cooling available when it is needed most.

18.3 HEAT RECOVERY SYSTEMS

Heat recovery systems include heat-recovery heat pumps, rotary heat exchangers, heat pipes, runaround systems, and refrigeration heat-recovery systems.

Heat-Recovery Heat Pumps

Heat-recovery heat pumps can meet the heating, cooling, and water-heating needs of many facilities. A basic requirement is that the facility generate sufficient heat to offset part or all of the space- and water-heating load. If the latter is not concurrent with the cooling load, thermal storage systems must be included.

Heat-recovery heat pumps generally fall into three general categories: *double-bundle heat-recovery chillers,*

water-to-water heat pumps, and *air-cooled heat-recovery heat pumps.*

The *double-bundle heat-recovery chiller* includes two separate (split) tube bundles in the same condenser shell or in separate condensers. One bundle is connected to the cooling tower loop, and the other is used for heating water.

A *water-to-water heat pump,* also known as an industrial heat pump, is a nonreversible heat pump that recovers heat from return warm water or the condenser cooling tower loop and circulates it to the chiller. A variant of this design employs a two-stage compressor in which part of the discharge gas from the first stage is raised in the second stage (or booster stage) to a higher pressure for heating.

An *air-cooled heat-recovery heat pump* is usually a direct-expansion, air-source heat pump that uses an air-cooled condenser for heat rejection and a water-cooled condenser for heat recovery.

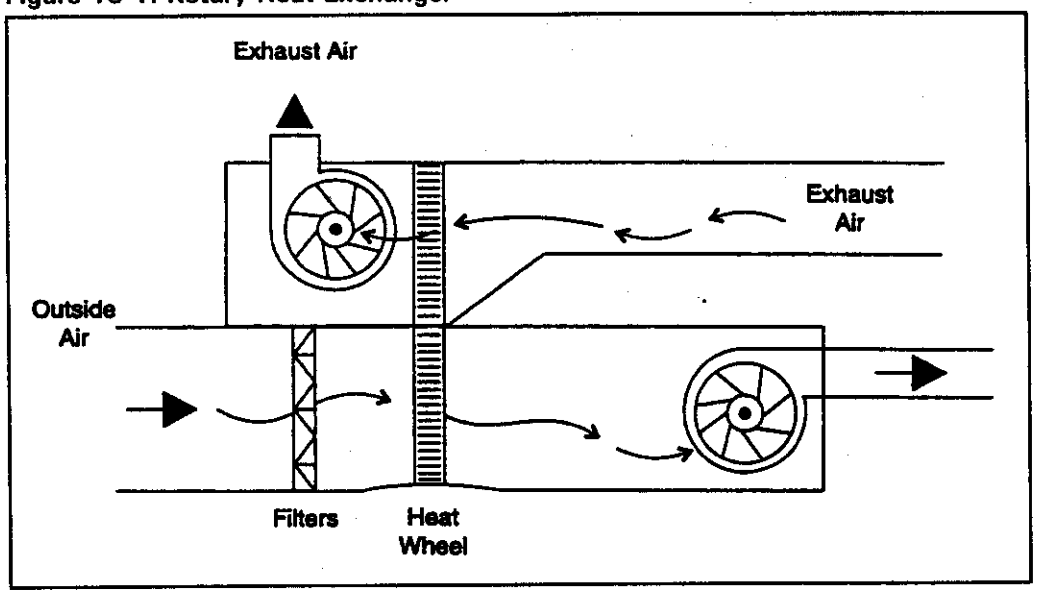
Rotary Heat Exchangers

Rotary heat exchangers (Figure 18-1) use a cylindrical drum or wheel as the heat-transfer medium. The wheel rotates slowly between the supply-air and exhaust-air streams, absorbing sensible (measurable) heat from the warmer airstream and rotating it to the other airstream, where the heat is picked up by the cooler air. When the wheel is treated with a desiccant (a drying agent) to provide a hygroscopic effect, it can also transfer latent heat in the form of water vapor from the humid airstream to the drier airstream. Nonhygroscopic wheels transfer water vapor only when the temperature of one airstream is below the dew-point temperature of the other and when there is direct condensation of water vapor. When temperatures are below 32°F, the supply air usually is preheated to prevent freezing.

A nonhygroscopic rotary exchanger can recover 70 to 80 percent of the sensible heat and 40 to 60 percent of the latent heat. When operated at approximately 8 to 10 revolutions per minute with a face velocity of 550 feet per minute, hygroscopic or enthalpy exchanger can recover 70 to 80 percent of the latent heat.

To apply a rotary heat exchanger, the supply and exhaust ductwork must be close together. If one of the airstreams is contaminated, purge sections must be added to the wheel,

Figure 18-1. Rotary Heat Exchanger



and special filtration may be needed in the supply air as well.

Heat Pipes

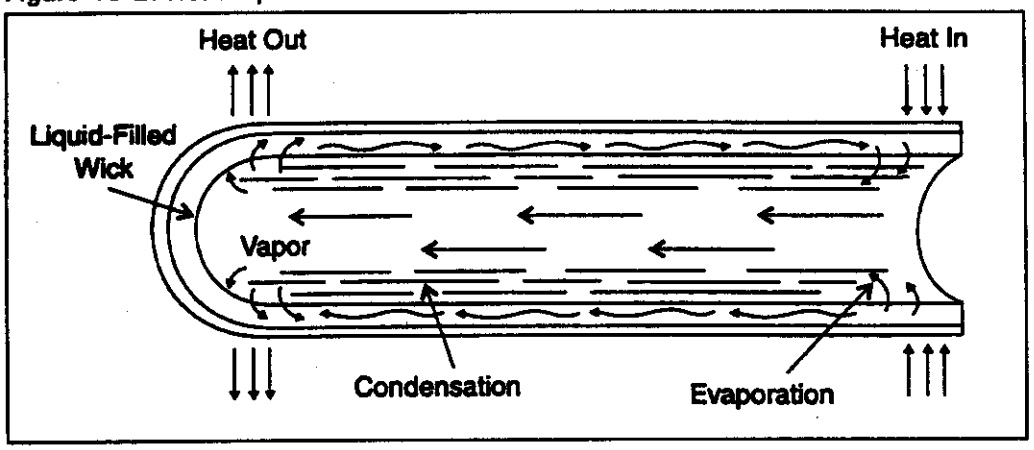
Heat pipes are passive heat exchangers consisting of closed fluid within a sealed tube (Figure 18-2). Cool air passing over one end of the tube is heated when the fluid enclosed in the tube condenses. The warmer airstream passing over the other end of the tube is cooled when the adjacent fluid contained in the tube evaporates. The action is reversible and operates whenever there is a temperature difference between the ends of the tube.

A heat pipe can be used for heat recovery only when the air intake and air exhaust ducts of a building's HVAC system are located close to each other. Heat is recovered by a group of heat pipes installed between the air intake and the air exhaust ducts.

Runaround Systems

Runaround systems (Figure 18-3), generally used to recover sensible heat, consist of finned-tube water coils located in the exhaust and supply airstreams and a pump to circulate water or a water-antifreeze solution between the coils. The system is seasonably reversible; that is, it can provide preheating in the winter and precooling in the summer.

Figure 18-2. Heat Pipe



The coils and the pump normally are selected to achieve sensible heat recovery efficiencies of 40 to 60 percent. Greater efficiencies can be achieved by adding more coils to the heat exchangers to increase their capacity. However, runaround systems require pumping energy, which will partially offset efficiency gains.

If latent recovery is necessary, water coils can be replaced with a cooling tower surface, and an additional solution pump can be used. This provides total heat (enthalpy) transfer as the solution absorbs heat and water vapor from the airstreams and also acts as an air washer or scrubber.

Refrigeration Heat-Recovery Systems

Refrigeration units and frozen-food cases usually have multiple compressor and condenser installations that generate large quantities of heat. This heat can be captured and used to provide space heating and humidity control.

Figure 18-3. Run-Around System

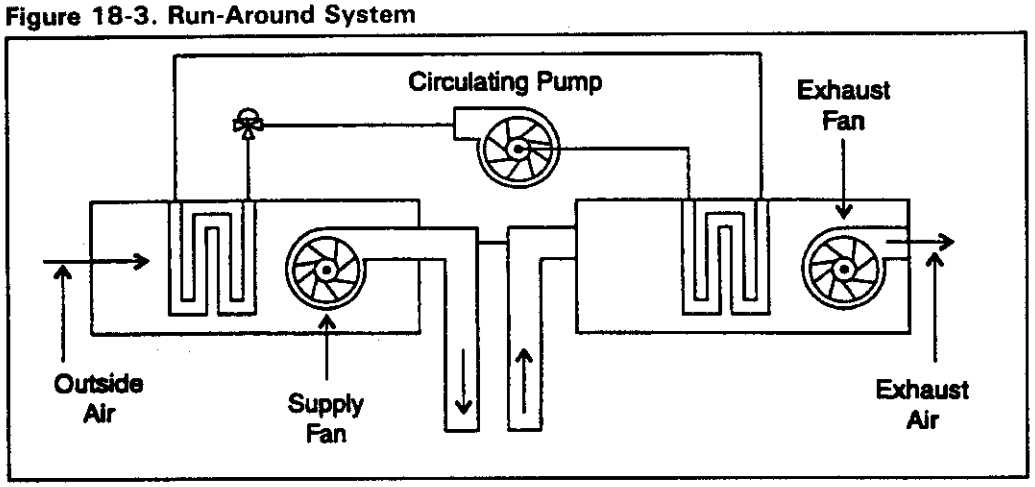
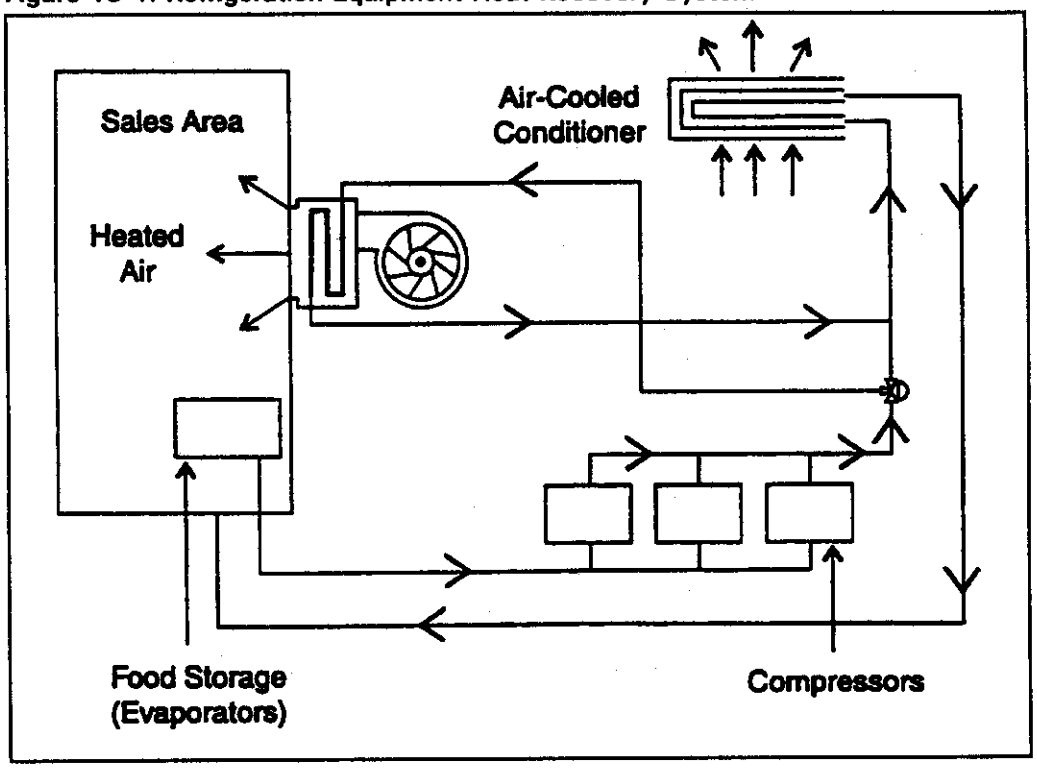


Figure 18-4. Refrigeration Equipment Heat Recovery System



A system for recovering heat energy from service refrigeration equipment is shown in Figure 18-4. Hot refrigerant gas from the individual compressors is fed into a common manifold. When heating is required, the manifold gas is piped to heat exchangers located in the air supply ducts. These exchangers can be arranged in two or more independent zones, depending on the building's needs. In warm weather, hot gas from the manifold is routed directly to an outside condenser, where its heat content dissipates into the atmosphere. Cooling is provided by condensing units that supply direct-expansion or chilled-water coils in ducts.

Another type of refrigeration heat-recovery system employs a closed hot-water loop to transfer energy from the refrigerant manifold to the duct coils or a closed-circuit cooling-tower. Air-to-water heat pumps and duct heaters, singly or in combination, supplement recovered heat in this system.

18.4 THERMAL STORAGE SYSTEMS

Thermal storage systems include partial and full cool storage and several types of electronic heat storage.

Cool Storage

With cool storage, chilled water or ice is produced during nonpeak hours, such as at night or on weekends, then stored for use at other designated times. A *full storage system* can meet all of a facility's cooling needs, particularly a facility with short peak cooling cycles. In *partial storage systems*, stored water or ice and a compressor share the task of meeting peak cooling requirements. Although these systems run more continuous hours than full storage systems, they cost less to install and require less storage capacity.

System controls are needed for efficient operation of a cool-storage system. For example, control systems can provide estimates of the next day's cooling load, which are needed to ensure that the refrigerating plant and storage subsystem do not make and store too much chilled water or ice. An adaptive controller for cool-storage systems can account for a variety of facility comfort needs and utility time-of-use rate structures. A typical facility in the Southwestern United States could reduce its annual cooling bill by 30 percent with such a control system.

Some of the advantages of cool-storage systems are as follows:

- Initial equipment costs for the energy distribution system are low, as are operating costs for fans and pumps.
- Storage tanks can provide backup for a fire-control system.
- HVAC equipment sizes can be reduced.
- Chiller condenser water from the ice-making process can be distributed to perimeter zones in winter to meet heat-loss requirements.
- Smaller air-handling equipment can be used for certain applications, and air temperature and relative humidity can be set lower.
- Stored energy from heat-recovery devices can be used to support facility heating needs.

- Exhaust air that has passed through heat exchangers can be used to reduce the temperature of incoming outdoor air.

Partial Storage Systems

There are two types of partial storage systems: *load-leveling* and *demand-limited.*

A *load-leveling* partial storage system supplies only part of the building's peak-period cooling needs from storage. Rather than completely shifting the building's peak electrical demand for cooling, it "levels" electricity demand for cooling over the design day. Storage capacity is sized such that the parallel operation of storage and refrigeration equipment meet design-day cooling needs. Load leveling also minimizes the size of storage and refrigeration equipment relative to other storage options, thereby minimizing initial costs. However, because a smaller share of the peak electricity demand for cooling is shifted to nonpeak hours, operating savings are correspondingly smaller.

Demand-limited storage reduces the building's maximum electricity demand to a predetermined level, normally the level of peak demand imposed by noncooling loads. Storage capacity is sized such that parallel operation of storage and refrigeration equipment does not cause the building's total electricity demand to exceed the maximum level.

Demand-limited systems generally require less storage capacity than full storage systems but more than load-leveling partial storage systems. Although they ensure maximum reduction of peak-period cooling demand, as do full-storage systems, their smaller storage capacity means that less energy is shifted to nonpeak hours. To effectively keep total electricity demand under the allowable maximum level, demand-limited partial storage requires the use of real-time controllers to monitor the building's noncooling loads and control the ratio of storage- and chiller-supplied cooling.

Cool storage systems can be used in many types of facilities, ranging from retail stores to highrise offices. However, their use is not very common because of their higher first cost as compared to conventional alternatives. Three types of cool storage systems are available: *ice storage, chilled-water storage,* and *eutectic salt storage.* Table 18-1 compares these systems.

Ice storage systems are either *static* or *dynamic*. The most common static system is the ice-on-coil (Figure 18-5), in which ice is formed on an evaporator surface. Another static system pumps a water-glycol solution from the evaporator to the storage tanks during the charging cycle, freezing water around mats of closely spaced plastic tubes, which act as heat exchangers.

Table 18-1. Comparison Between Types of Cool Storage Systems

	Ice Storage	Chilled Water	Eutectic Salt
Storage Capacity, ton-hours	80-1,200	Unlimited	80-1,200
COP	2.6-3.8	4.1-5.0	4.1-5.0
EER	9-13	4-17	14-17
Unit Life, years	15-20	15-20	15-20
Space Requirements	2-4ft^3/ton-hour storage plus 15-20 ft^2 for chillers and pumps	10-13ft^3/ton-hour storage plus 15-20 ft^2 for chillers and pumps	5.5ft^3/ton-hour storage plus 15-20 ft^2 for chillers and pumps

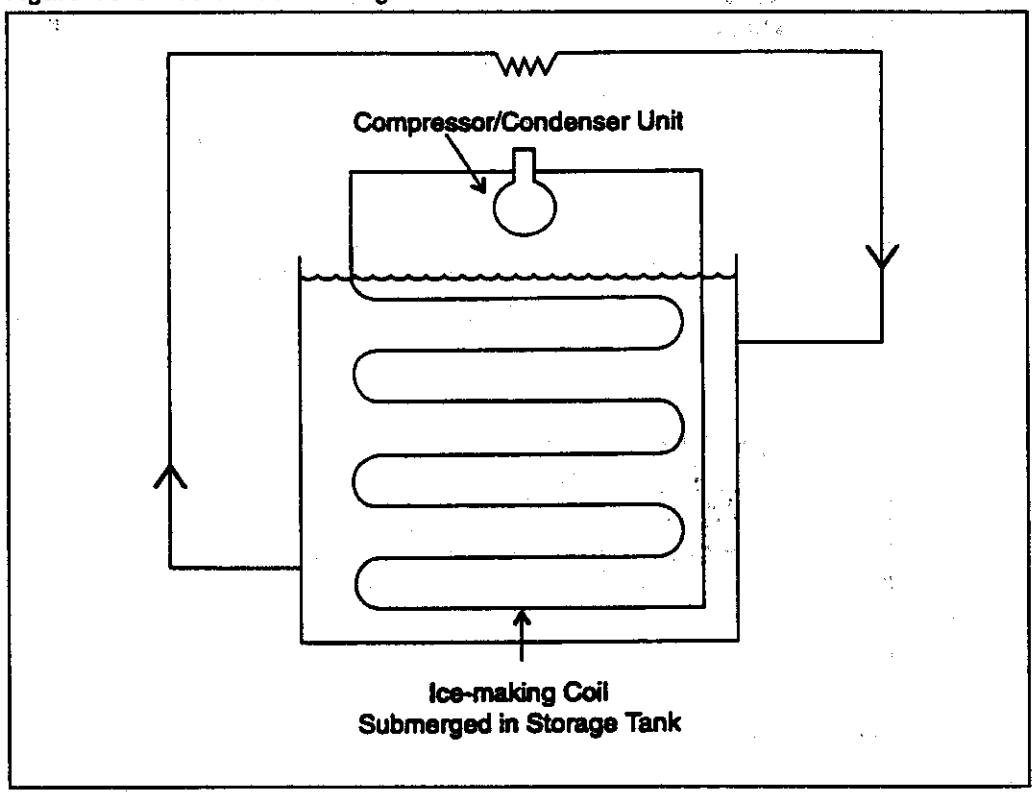
In dynamic ice storage systems, water from the storage tank is run over refrigerant plates or tubes suspended above the tank, causing ice sheets to form. Hot refrigerant is periodically passed through the plates for a few seconds, causing the ice sheet to break up and fall into the tank below.

Ice storage provides colder air (40 to 48°F) to conditioned spaces than chilled-water systems. Therefore, smaller pumps, piping, fans and ductwork can be used, thus saving the cost of larger components. Initial costs and operating costs are also lower than those of conventional air distribution systems, which disperse air at temperatures around 55°F. However, chilled-water systems generally run more efficiently than ice storage systems.

Several manufacturers offer modular ice storage systems that can be incorporated into existing HVAC system designs. An HVAC system that uses low ice-water temperature (33 to 35°F) to distribute low-temperature primary air (40 to 45°F) can take advantage of smaller fans, pumps, water piping, and ducts. This smaller equipment can reduce initial costs by as much as 19 percent. In some cases, smaller ducts allow lower floor-to-floor heights and thus lower structural costs per

floor. Studies involving systems installed in a variety of climates show that the increase in latent cooling load due to the low-humidity air provided by ice storage can be partially offset by lower fan energy, which also lowers operating costs. Moreover, the room dry-bulb temperature can be increased 3° to 4°F at lower relative humidities (for example, 30 to 35 percent) without affecting occupant comfort.

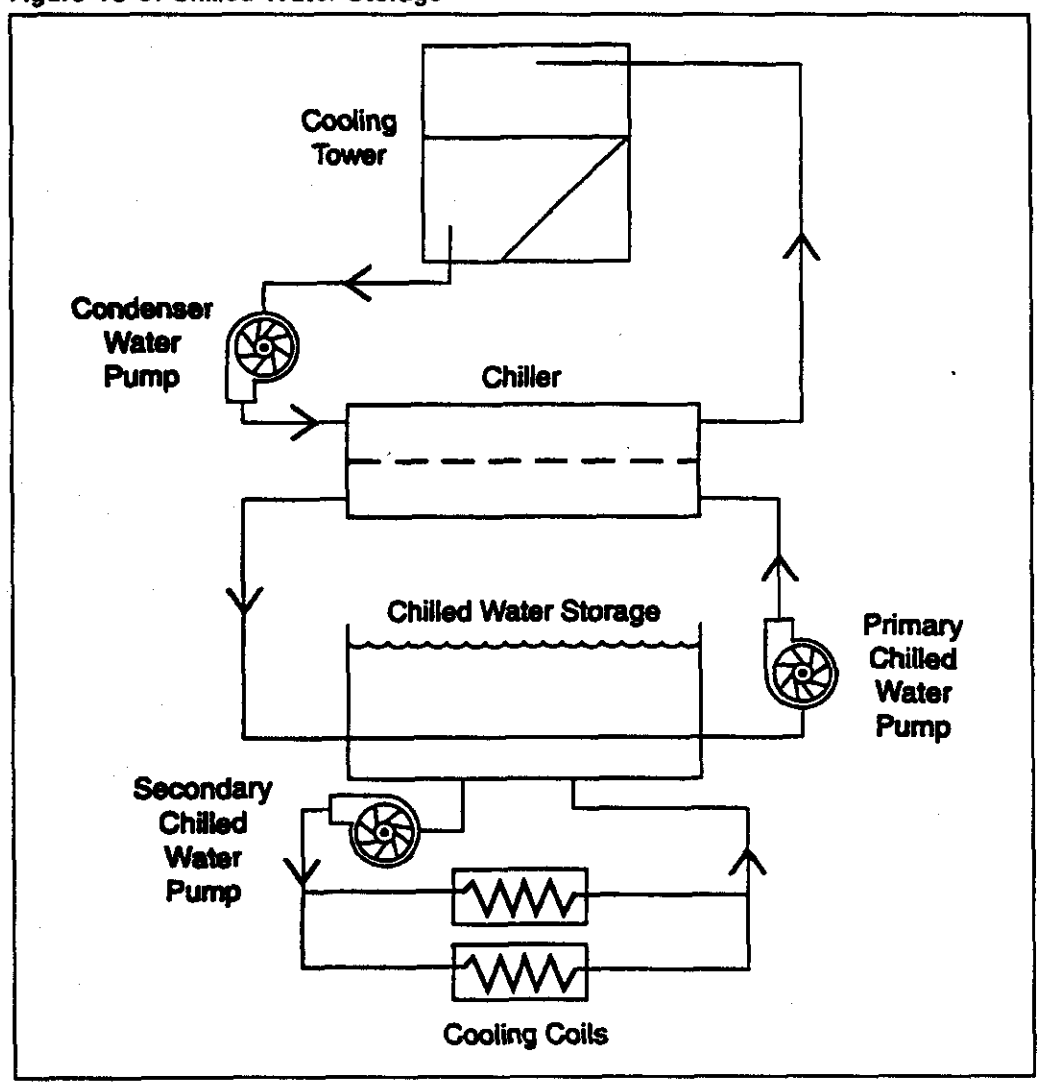
Figure 18-5. Ice-on-Coil Storage



Chilled-water storage systems (Figure 18-6) are identical to conventional chilled-water systems, except that they have a supplemental storage tank. These systems supply cold water by pumping water through cooling coils and discharging it to locations where it is needed. Supply water or returning water can be separated from the cold water by a thermocline (or rubber diaphragm) or by using different storage tanks.

A *eutectic salt storage system* uses a special solution of sodium sulfate, water, and nucleating and stabilizing agents in conjunction with conventional equipment to chill water. In

Figure 18-6. Chilled Water Storage



the cooling process, water flows between containers of eutectic salts, which lower its temperature.

Electric Heat Storage

Electric heat storage systems shift daytime space-heating loads to nonpeak periods. The four most common types of these systems in facilities are *ceramic brick storage, pressurized water storage, iron storage,* and *underfloor storage heaters.* These are described in the following sections.

Ceramic Brick Storage

Ceramic brick storage systems use forced air to distribute stored heat. These systems, which are available as central

and room units, contain a brick core heated by wire coils. Air passages through the core discharge the heat efficiently when it is needed. The core is insulated and fitted with ducts that allow the system to heat return air. To attain the correct air supply temperature, air drawn through the core is mixed with return air that has bypassed the core. Air movement is controlled by a fan near the supply opening.

A system of thermocouples, thermistors, and dampers controls the supply air temperature, level of charge, and charge-discharge cycles. An electronic charge controller regulates the amount of heat accumulated and stored during nonpeak periods, accounting for outdoor air temperatures and core temperature. A space thermostat controls the fan that circulates the heated air.

To provide the desired discharge temperature, the bypass damper, which is controlled by a mixed-air thermostat, adjusts the percentage of the circulated air forced through the core. Room thermostats and the mixed-air thermostat can be set back at night to allow for some space heating and recharging.

Pressurized Water Storage

Pressurized water storage devices consist of an insulated cylindrical steel tank with electrical resistance elements near the bottom and a water-to-water heat exchanger near the top. During nonpeak periods, the resistance elements are sequentially energized until the storage water reaches a maximum temperature of 280°F, corresponding to a gauge pressure of 35 pounds per square inch.

The heaters are controlled by a pressure sensor, which eliminates problems that could be caused by unequal temperature distributions. A thermal controller gives high-limit temperature control protection. Heat is withdrawn from storage by running water through the heat exchanger and a tempering device that keeps the output temperature at a predetermined level. The storage capacity of the device is the sensible heat of water between 280°F and a point 20°F above the desired output water temperature. The output water can be used for space heating or as service hot water. The water in the storage tank is permanently treated and sealed, requires no makeup water, and does not interact with the service water. The units are custom-made in sizes from 240 to 18,000 gallons, with input power from 20 to 5,200 kilowatts.

Iron Block Storage

Iron block storage can produce heat levels of up to 1,200°F by using a core of pig-iron blocks to store heat during nonpeak hours. Air is circulated through the blocks by a variable-speed fan. The fan extracts heat through an air-to-water heat exchanger in the base of the unit. A conventional hydronic heating system then circulates the water that has passed through the heat exchanger.

The temperature of the circulating water can be closely regulated by increasing the fan speed as demand increases or by cycling the fan at lower speeds. Fan speed can be controlled by room thermostats or determined by a high-limit water temperature discharge control and outside temperature sensor.

Underfloor Storage Heaters

Underfloor storage heaters consist of electric resistance cables buried in a bed of sand 1 to 3 feet below the floor of a building. They are suitable for single-story facilities, such as factories and warehouses. This type of storage acts as a flywheel; it is charged only during the nightly nonpeak period, but maintains a constant temperature (slightly higher than the desired space temperature) on the floor slab at all times. Because the heat from the mats spreads in all directions, they do not have to cover the entire slab area. For most facilities, a mat location of 18 inches below the floor elevation is optimum. The sand bed should be insulated along its perimeter with 2 inches of rigid, closed-cell foam insulation to a depth of 4 feet.

CHAPTER 19. ENERGY MANAGEMENT SYSTEMS

19.1 KEY CONCEPTS

- An energy management system provides various levels of control of energy-consuming devices, systems, or groups of systems.
- Local controllers provide independent, relatively low-cost control of specific systems or equipment.
- Remote controllers interface with single or multiple devices or systems.
- Centralized control systems make control decisions based on operating data, programs, and data stored in memory.
- Demand controllers adjust electrical loads to prevent a predetermined electrical demand from being exceeded.
- The energy management systems can be programmed to provide daily printouts of regular maintenance procedures that need to be performed.
- Diagnosis of reported problems with mechanical and electrical systems can be performed at the central console.
- Although cost-effectiveness is the main selection criteria, it is also very important that the energy management system be adaptable and have adequate technical support to keep it up and running.
- If control system and interface diagrams are not detailed and explicit, inaccurate bids and added costs may result.

19.2 OVERVIEW

An energy management system is an automated device or a group of automated devices connected by either a central controller or distributed controllers. It is linked to and provides various levels of control of any number of energy-consuming devices, systems, or groups of systems in a building or a group of buildings. The more sophisticated energy management systems can monitor a building's total environment, adjust all systems accordingly to conditions,

Table 19-1. Summary of Application Programs for Typical Building Mechanical and Electrical Systems

		Start/Stop Schedule	Duty Cycle	Demand Limit	Vent Recirculation	OA Enthalpy*	OA Economizer*	Night Setback	Start/Stop Optimization	Reheat Coil Schedule	Hot/Cold Deck Reset	HW OA Reset	Boiler Optimization	Chiller Optimization	Condensate Water Reset	Cold Water Reset
1	Single Zone AHU	■	■	■	■	■	■	■	■							
2	Terminal Reheat AHU	■	■	■	■	■	■	■	■	■						
3	Variable Air Volume AHU	■			■	■	■	■	■							
4	Multi-zone AHU	■	■	■	■	■	■	■	■		■					
5	Single-zone DX-A/C	■	■	■	■	■	■	■	■							
6	Multi-zone DX-A/C	■	■	■	■	■	■	■	■		■					
7	Two Pipe Fan Coil Unit	■	■	■				■	■							
8	Four Pipe Fan Coil Unit	■	■	■				■	■							
9	Heating Ventilating Unit	■	■	■	■			■	■							
10	System Unit Heat							■								
11	Electric Unit Heat	■	■	■				■	■							
12	Hot Water Unit Heater							■								
13	Steam Radiation							■	■							
14	Electric Radiation	■	■	■				■	■							
15	Hot Water Radiation							■	■			■				
16	Steam Boiler												■			
17	Hot Water Boiler												■			
18	Direct-fired Furnace	■	■	■	■			■	■							
19	Direct-fired Boiler	■	■	■	■			■	■							
20	Steam HW Converter											■				
21	HTHW Steam Converter											■				
22	HTHW HW Converter											■				
23	Water Cooled DX Compressor	■	■	■					■						■	
24	Air Cooled DX Compressor	■	■	■					■							
25	Air Cooled Chiller	■	■	■					■					■		■
26	Water Cooled Chiller	■	■	■					■					■	■	■
27	Lighting Control	■		■												
28	Domestic HW Electric	■	■	■					■							
29	Domestic HW Gas or Oil	■							■							

*Select Economizer or Enthalpy

adapt to changing energy usage patterns, and report on the performance of equipment, even providing warnings when abnormal conditions are encountered.

Energy management systems can greatly improve the efficiency of HVAC and other energized systems because they perform a variety of control functions, each of which has an impact on energy consumption (Table 19-1 shows some typical applications). This section describes the various types of energy management systems that are available, the types of functions that energy management systems can perform, and some factors to consider in selecting an energy management system.

19.3 TYPES OF ENERGY MANAGEMENT SYSTEMS

Energy management systems fall into three broad categories determined by the type of control provided: local controllers, remote controllers (limited function and multifunction), and centralized controllers.

Local Controllers

Local controllers provide independent, relatively low-cost control of specific systems and equipment. Each local controller is independent, controlling its specific operating system or equipment without acting in conjunction with any other controlling device. The initial cost of such devices is relatively low. Examples of local controllers include the following:

- Timers.
- Local annunciators and alarms.
- Local optimization devices that, for example, control dampers based on outside air temperature.

Local controllers are best used in the following circumstances:

- The control device is compatible with the system involved and will improve system operation and efficiency.
- Usage and climatic factors permit.
- The systems controlled are relatively simple.
- A single small facility with relatively few mechanical equipment rooms is involved, or each facility in a complex of facilities has relatively small, individualized systems.

- The capital budget is small (for example, $1,000 or less).
- Limited time is available for installation and immediate results are desired.
- Individual system or component optimization is more important than total system optimization.

Remote Controllers (Limited Function or Multifunction)

Remote controllers interface with a single device or system (limited function) or a number of devices or systems (multifunction). Many are programmable through use of microprocessors. Relatively low-cost, these devices can provide great energy savings, making this type of control one of the most beneficial available. Typical functions include the following:

- Remote start/stop (turning systems and devices on and off at specified times).
- Optimized start/stop (that is, based on outdoor and indoor temperature variances).
- Status monitoring (that is, is a system running or has it stopped?).
- Status alarms (that is, is the system operating outside of the normal range?).
- Demand control.
- Duty cycling.

Remote controllers are best used in the following circumstances:

- The capital budget is less than $10,000.
- The functions to be performed are limited.
- The number of points to be monitored and controlled is generally less than 100.

Differences among off-the-shelf systems are found in memory capacities, methods of programming, input/output ratings, expansion capabilities and increments, readout options, and methods used to accomplish end results.

Centralized Controllers

Centralized control systems employ one or more computers to make control decisions based on operating data and programs, as well as data contained in memory.

Typical functions of centralized control system include the following:

- Automatic start/stop.
- Closed-loop refrigeration and boiler system control.
- Status monitoring.
- Status alarms.
- Load shedding.
- Duty cycling.
- Data collection.
- Enthalpy control.
- Event initiation.
- Utility monitoring.
- Maintenance management.
- Monitoring and control of the building's life safety systems.
- Optimization of system operation to minimize energy consumption.

Centralized control systems are appropriate in the following circumstances:

- A capital budget of $20,000 or more is available.
- Optimization functions are needed.
- Control decisions are to be based on the number of parameters and conditions involved and on a specified series of events.
- Operating and maintenance personnel who understand the system either are on-hand or will be hired.
- User programming capability is available.
- The facility comprises a high-rise building or a complex of buildings with a central plant and several remote mechanical equipment rooms.
- There are 200 or more points to be monitored and controlled.

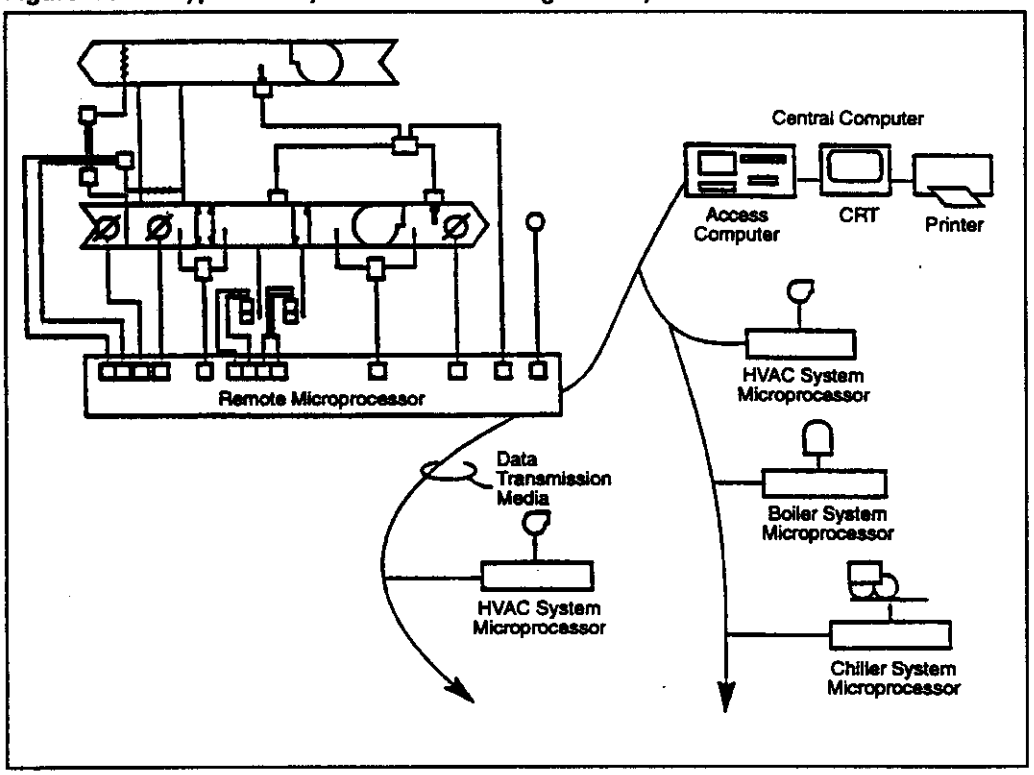
Centralized control systems can be divided into two general categories. A *packaged system* is complete in every respect and furnished by a manufacturer, who assumes sole responsibility. A *hybrid system* is composed of elements fabricated by several manufacturers. Depending on the nature of the purchase contract, one vendor may assume sole responsibility for the entire system.

A packaged system, by its nature, is somewhat limited. If it does not satisfy all needs by design, there is little recourse. A hybrid system can be designed to fit needs precisely, and

very often can accommodate the very latest state-of-the-art components.

Many large buildings and complexes are now using a "distributed processing" approach, meaning that functions normally performed solely by the system's central processing unit are, in part, distributed among other system elements (see Figure 19-1). In such a system, for example, field interface devices that serve various control and monitoring points in an area include microprocessors to handle various functions otherwise handled by the central processing unit.

Figure 19-1. Typical Fully Distributed Intelligence System



Functions that cannot be handled by the field interface devices are passed on through the system's hierarchy. Instead of going to the central processing unit, however, they are fed to an intermediary device called a central communications controller, in essence, a no-frills minicomputer. Only functions that cannot be handled by the central controller are passed on to the central processing unit.

The principal benefit of the distributed concept is the greatly enhanced system reliability that comes from increased

system redundancy. If one element of a system is down for any reason, another element in most cases can take over its functions. Distributed processing also makes it far easier and less expensive to accommodate expansion, either for addition of new points or new functions.

The latest advance in building controls is the so-called intelligent building, also known as the "smart" building. Most private branch exchanges (PBXs) now being used for telephone service rely on digital microcomputers to handle numerous complex telecommunications switching functions. The versatility of these computers has permitted the PBX to do additional tasks, such as voice mail, facsimile transmissions, video-conferencing, and long-distance voice and data transmission. These PBX systems are also capable of handling monitoring and control functions related to the building's heating, cooling, lighting, fire safety, and security systems.

19.4 ENERGY MANAGEMENT SYSTEM FUNCTIONS AND APPLICATIONS

The following discussion is about centralized controllers. However, the principles involved are applicable to all three types of energy management systems. The functions discussed are limited to those related to energy efficiency. However, most energy management systems can also perform functions associated with facility security, fire safety, and in some cases even accounting and inventory. The functions discussed apply to HVAC systems, but many of these can be applied to other systems (for example, remote start/stop for lighting systems).

Basic Functions

Basic functions are generally applicable to a broad range of systems and equipment. These functions include the following:

- ***Timed Operation***. Timed operation consists of starting and stopping a system according to a specified schedule (for example, one for weekdays, one for Saturdays, and one for Sundays and holidays).

- ***Duty Cycling***. Duty cycling consists of shutting down a system for predetermined short periods of time during normal operating hours, such as 15 minutes of each hour of operation. The off period normally is

increased during moderate seasons and reduced during peak seasons.

- ***Temperature-Compensated Duty Cycling***. With temperature-compensated duty cycling, a system is shut down for a specified length of time when a specified temperature is reached. The system starts back up when the temperature rises to another specified temperature.

- ***Demand Control***. Demand controllers adjust electrical loads to prevent a predetermined maximum electrical demand from being exceeded. These systems monitor demand continuously. If the demand limit is going to be exceeded, specified secondary loads are shut off until demand is reduced by a sufficient amount. The secondary systems are restarted as demand monitoring permits.

- ***Outside Air Temperature Cutoff***. With an outside air temperature cutoff, an outdoor temperature-sensing control shuts off specified heating systems when the outdoor temperature rises to within 5°F of the indoor design temperature, or to a minimum of 40°F.

- ***Warm-Up/Night Cycle***. The energy required to heat outside air used for ventilation may constitute a substantial percentage of the total heating and cooling requirements. The warm-up/night cycle function shuts outside air dampers when outside air would impose a thermal load during unoccupied hours.

- ***Space Temperature Night Setback***. Temperature set-points are lowered during unoccupied periods according to climatic conditions.

Optimizing Functions

Optimizing functions improve the operating efficiency of a given piece of equipment or system by monitoring performance and performing adjustments in real-time. Typical optimizing functions include, but are not limited to, the following:

- ***Economizer Cycle***. The economizer cycle uses outside air to cool the facility when the temperature (or total heat content) of the outside air is less than that of the return air from the space.

- ***Hot/Cold Deck Temperature Reset.*** Here the system selects the individual areas with the greatest heating and cooling requirements and adjusts hot and cold deck temperatures accordingly, minimizing the inefficiency of these systems by reducing the difference between hot and cold deck temperatures.

- ***Discharge Air Temperature Reset.*** The discharge air temperature reset function adjusts the cooling temperature upward until the zone with the greatest cooling demand no longer needs to reheat the air.

- ***Chilled Water Reset.*** Because chilled water temperatures are set for peak design times, most chilled water temperatures can be elevated during most operating hours, unless strict humidity control is required. The system can reset the chilled water temperature, allowing it to rise while still meeting the greatest cooling requirements. Specific control schemes depend on system configurations.

- ***Outside Air Schedule Reset.*** Water heating systems are designed to supply system heating requirements at outdoor design temperatures. Depending on the specific system design, the system can reduce the hot water supply temperature as heating requirements are reduced, usually in response to increased outdoor ambient temperatures. The temperature controller for the hot water supply is reset on a predetermined schedule as a function of outdoor temperature.

- ***Start/Stop Optimization.*** Mechanical systems that are shut down during unoccupied hours usually are restarted according to a fixed schedule, independent of weather or space conditions. Optimized start/stop is based on thermal inertia of a structure, the capacity of the system to either increase or reduce temperatures in the facility start-up and shut-down times, and weather conditions.

- ***Air Distribution Optimization.*** Here the system controls zone dampers to stop the flow of conditioned air to nonessential areas during unoccupied periods. Dampers are automatically positioned according to an optimum start/stop schedule. Supply fan dampers and associated exhaust fans are positioned by static pressure sensors.

- ***Chiller Plant Optimization***. In multiple chiller installations, chiller loads are balanced. For example, two chillers would be loaded equally, as opposed to having one loaded to 100 percent and another to 30 percent.

- ***Boiler Plant Optimization***. In one approach, electronic probes monitor the amount of oxygen that passes through the boiler plant stack. The system uses the data to determine heat losses associated with that stack. If the oxygen level is outside of specified limits the system regulates airflow through the boiler and stack at constant firing rates to bring the oxygen level to proper operating limits and maximum combustion efficiency. In another method of boiler plant optimization, the system decreases fuel flow to the boiler as it decreases the boiler load by mixing outlet water with inlet water, creating a mixture whose temperature is determined by the difference between the outside air temperature and the boiler water temperature.

- **Secondary Loop Chilled/Hot Water Optimization.** There usually are many secondary loops serving similar coils, each tied into the primary loop main distribution system. With optimization, coil capacity is adjusted to meet the load by modulating coil flow or by changing the temperature of water to the coil. Whenever the valve lowers coil output, it indicates that full capacity of the supply water is not needed. Accordingly, secondary loop optimization logic is based on the premise that if no coils need full supply water capacity, supply water temperature can be adjusted to save energy by raising chilled water temperature and lowering hot water temperature. This action also saves energy by reducing pipe heat gains and losses. Dehumidification must be considered when chilled water is affected.

Operational Functions

Operational functions are primarily those associated with monitoring and alarm. Examples are listed below.

- ***Chiller Profile Generation***. The energy management system develops a printed record of the operating status of the chiller equipment for a given set of conditions, such as load ambient conditions and time of day. The program accumulates chiller profile

historical data required to evaluate efficiency and cost of operation.

- ***Boiler Profile Generation***. The boiler profile records operating data of boiler plant equipment for a given set of conditions such as load, energy output, energy input, and ambient conditions to determine operating costs and accumulate historical data for the plant.

- ***Maintenance of Building Systems***. An energy management system can be programmed (depending on the specific type of system) to provide daily printouts of regular maintenance procedures that need to be performed, together with notification of unscheduled maintenance procedures that may be required. There are several ways in which the maintenance scheduling functions can be handled:
  - ***Calendar Time Scheduling***. With calendar time scheduling, for example, maintenance personnel could be given monthly reminders to change all air-handling-unit filters or to grease and lubricate certain equipment.
  - ***Machine Running Time Scheduling***. The system can be set to accumulate running-time data on certain equipment and, after a predetermined number of running hours for each item, print out maintenance instructions.
  - ***Efficiency Scheduling***. In certain cases the amount of time equipment runs will not be an accurate indicator of its operating efficiency or need for maintenance. Because the system can calculate equipment operating efficiency on the basis of raw data inputs, it can be programmed to provide maintenance instructions when efficiency deteriorates to a certain predetermined level.
  - ***Early Warning Monitor***. The system can be designed to provide early warning of impending equipment failure. For example, bearings of certain pieces of equipment can be monitored for vibration and/or temperature. Should the vibration or temperature level increase to a specified level, a panel light, readout, and the like would indicate an immediate, unscheduled maintenance problem.

- ***Maintenance Cost Management***. A maintenance cost management program stores maintenance costs and maintenance labor hours for individual units, fans, motors, pumps, and so forth.

- ***Trouble Diagnosis***. By monitoring certain parameters of mechanical and electrical systems, diagnosis of reported problems with mechanical and electrical systems can be performed at the central console. Some of the parameters that might be monitored include:

  - Hot and cold deck temperature, with high and low limits.
  - Leaving chilled water temperatures and hot water temperatures, with high and low limits.
  - Differential pressure switches indicating fan and pump operation and excessive pressure losses through filters or condenser tube bundles.
  - Space temperatures.
  - Space humidity.

- ***Safety Alarms***. Many items of mechanical equipment are provided with various types of alarms for both personnel and equipment protection. High and low water for boilers, gas pressure, and temperature and pressure on refrigeration machines are typical of the types of functions that can be monitored. Monitoring of such alarms provides the console operator with information regarding the failure of equipment or the development of potential problems with the system operation.

- ***Intercom***. The system can be used for communication between maintenance personnel and console operators.

19.5 HOW TO CHOOSE THE RIGHT ENERGY MANAGEMENT SYSTEM

Numerous factors must be considered in designing and specifying an energy management system. The following discussion highlights many of the specific factors involved.

Basic Selection Criteria

The basic criteria to consider in selecting a system are as follows:

- ***Cost-Effectiveness***. Cost-effectiveness is the main consideration used in determining which type of energy management system is best, and specifically, what type of system or architecture will yield the maximum return on investment. In general, cost-effectiveness is determined through use of life-cycle costing techniques (see Volume 1).

- ***Adaptability***. How well a given system can be adapted to an existing facility is extremely important. Physical requirements are the most important concerns. Will the system fit into the existing space? As much as 900 square feet could be required for the command center of an energy management system. The location of the center should be considered strategically in light of the functions to be performed there. If the space is not readily available, can it be made available? If something must be displaced, will new construction be necessary? These factors must be considered in the economic analysis.

  One must also consider existing local controls and communications protocols, or the possibility of installing local controls if a centralized controller will be added at a later date. Can the energy management system be interfaced with these local controls, or will the controls need to be replaced?

  Consider, too, the existing equipment. If costly mechanical equipment is scheduled for replacement, will the new equipment be compatible with the energy management system? Likewise, if the new equipment will be more efficient than that which it replaces, is the energy management system needed, or could local controls suffice?

- ***Maintenance***. The ability to keep the energy management system up and running is extremely important. The system provider should be able to support in-house maintenance through training programs and manuals. Equally important is the availability of professionally trained technicians employed, licensed, or authorized by the manufacturer.

  Whenever possible, check references to determine how satisfied other users of the proposed system are with the maintenance services provided. Check the completeness of preventive maintenance, the

responsiveness and capability of technicians, the annual cost of the maintenance (which usually is in the range of 8 to 12 percent of the installed cost), and the availability of a service maintenance agreement.

Recognize that, without proper maintenance, the system will not perform reliably. In fact, this has been a critical problem with many centralized energy management system installations. Maintainability should be considered in the system design. While a high level of sophistication may be desirable, increased sophistication often results in increased maintenance problems and costs. Tradeoffs may be necessary.

- ***Reliability***. Reliability encompasses two issues. The first is how well the system performs. The second issue is the way the system performs. Be certain that the system does not suffer from built-in problems such as interference with transmission lines, which could result in erroneous data.

- ***Expandability***. Allowance for future growth usually is advisable, especially from a cost standpoint. Additional points cost approximately three to four times more if added after initial installation, and an existing system may not even be able to handle additional points. Expansion may require the purchase of another computer, additional memory, or more and larger field interface devices. In addition to cost, it may necessitate reprogramming and could disrupt normal operational routines. These problems can be minimized by looking ahead at the time of initial design.

- ***Programmability***. It is recommended strongly that the system be user-programmable. In this way, programs can be easily modified or added in the field as needed. Manufacturer-provided program revisions usually are very expensive.

Specifications

Once a system has been decided upon, drawings and specifications – the contract documents – must be prepared. Drawings are extremely important. They must be reviewed carefully for completeness and accuracy and should clearly and precisely indicate the designer's intent. It

is also very important that the designer carefully coordinate the drawings with the specifications in terms of each component's functions with respect to other functions.

Many things should be included in a set of drawings. The following are a few of the most important factors common to all energy management system packages:

- Block diagram.
- Interconnecting trunk wiring data link diagram.
- Point schedule.
- Functional layout diagram.
- System schematics diagram.
- Field interface panels diagram.
- Existing control system and interface diagrams.

Existing control system and interface diagrams are extremely important because they delineate where all the existing components are located. If, for example, the system is to perform motor start/stop, the contractor must know where the motor starter is located, what kind of starter it is, and what modifications are required to include it as part of the system. Everything must be shown explicitly, detailing what can be used, what must be replaced, and what must be added. Detail is necessary for accurate bids and to avoid added costs caused by changed requirements or corrections resulting from lack of information.

Some of the major concerns that should be addressed in a specification are as follows:

- Degree of accuracy.
- Level of access.
- Use of existing controls.
- Electric power considerations.
- Factory debugging.
- Acceptance testing.
- Training.

An energy management system performs its function on systems. If it alters the operation of just one element of a system, the whole system is affected. Accordingly, before any decision is made about the functions to be performed, one must ascertain the types of functions that should be provided and the specific way these functions should be performed in light of the building system involved, the purposes for which it is used, and the effect – if any – that energy management system functions will have on system performance and output.

Timing of feasibility and design studies is important. An energy management system should be considered only after an initial energy management plan has been completed. If all energy efficiency opportunities are not considered – including those not affected by the energy management system – some major efficiency opportunities may be missed. In addition, modifying a system or replacing it may provide insights into what type of energy management system is appropriate.

CHAPTER 20. ALTERNATIVE, RENEWABLE, AND CLEAN ENERGY

20.1 KEY CONCEPTS

- Alternative, renewable, and clean energy is energy produced from nontraditional sources or recovered from conversion, including such forms as solar thermal, photovoltaic, geothermal, and wind.

- The Executive Order 12902 requires federal facilities to significantly increase the use of solar and other renewable energy sources. Additionally, the EO 12902 requires a reduction in the use of petroleum in their buildings and facilities by switching to a less-polluting and non-petroleum based energy source.

20.2 BACKGROUND

Definition

Generally, alternative, renewable, and clean forms of energy are produced by nontraditional sources and/or conversion processes. They have low emissions and minimal negative impact on the environment. Examples are solar thermal, photovoltaic, geothermal, wind, landfill methane, fuel cells, hydrogen combustion, and hydroelectric energy generation. This chapter provides a brief overview of the technologies which may be appropriate for FAA facilities (i.e., solar thermal, photovoltaic, and geothermal).

Energy Conversion Policies

The Executive Order 12902 requires federal facilities to significantly increase the use of solar and other renewable energy sources. The Department of Energy (DOE) is assigned to lead the effort to assist agencies in meeting this goal. Additionally, the EO 12902 requires federal agencies to reduce the use of petroleum in their buildings and facilities by switching to less-polluting and nonpetroleum-based energy source, such as natural gas or solar and other renewable energy sources.

The energy conversion requires replacing some current fuel sources with any form of alternative, renewable, and clean energy sources. FAA must actively seek out life cycle cost-effective applications for alternative, renewable, and clean energy sources.

The Clean Air Act (CAA) Amendment of 1990 renewed emphasis on the wider application of alternative, renewable, and clean energy technologies. The Amendment limits emissions of sulfur dioxide (SO_2) and establishes an SO_2 trading system for annual emission allowances. Any offender who does not have enough allowances to cover their emissions will be severely penalized and fined. It will become more difficult to meet these emission limits in future years because annual allowances are to reduce by an established amount each preceding year. FAA facilities can reduce and obtain additional SO_2 emissions allowances, if necessary, by investing in renewable technologies, which in turn will help to achieve compliance with the CAA and avoid the imposition of heavy fines.

20.3 SOLAR ENERGY

Solar energy is abundant and perpetually renewable, making it an ideal energy source in many ways. The amount of solar energy a site can receive is dependent upon location, time and environmental conditions. Solar radiation is the "resource" of solar energy. The maximum amount of solar radiation that a site can receive is approximately 2,550 $kwh/m^2/year$.

Solar energy can be converted to either thermal energy (solar-thermal) or electric energy (photovoltaic). Solar energy systems may be further classified by either active or passive systems. Active solar systems incorporate pumps to circulate liquids and/or motors to provide movement of fans or collectors. Conversely, passive systems do not utilize active components such as pumps and motors.

Solar energy has been proven to be life cycle cost-effective in many applications, but, as with most renewable energy systems, the "cheap" energy is offset by the initial capital investment costs. The use of private sector financing can help reduce the initial burden on a facility. Due to energy security and cost-effectiveness issues, relying on solar energy as the primary energy source for meeting all facility energy requirements is generally not practical. However, selective use of solar energy as a supplementary energy source offers a wide range of attractive applications. In addition, many other factors must be weighed before considering a solar energy system. The availability of engineers and technicians qualified to operate and maintain a solar energy system so that it is in harmony with a building's primary energy system is critical. Many solar

energy systems have been shut down in the past because of lack of operations and maintenance knowledge.

Before making a decision to use a solar energy application, energy managers should seek assistance in determining whether potential solar projects are technically and economically viable. The Department of Energy's (DOE) National Renewable Energy Laboratory (NREL) offers technical and operations assistance with solar energy systems, and provides assistance in determining project feasibility. NREL may have data on solar insolation at FAA facilities. Location is a critical factor in determining viability of solar energy applications. In certain locations in the United States, such as the Northwest, solar projects are usually not viable options. However, in the Southern states, solar applications can be very practical.

Solar Thermal Application

Solar thermal energy is the most widely used form of solar energy. There are many types of solar thermal system designs, ranging from a simple direct gain system to a solar absorption cooling system. All solar thermal systems absorb the sun's radiant heat energy and convert it to a usable thermal energy.

Passive solar thermal systems are virtually maintenance-free and can be easily integrated into building designs. All new building designs should incorporate some sort of passive solar thermal technology. Similarly, renovations to existing facilities should not be made without consideration of passive solar thermal technologies. Other appropriate solar thermal applications are process hot water/hot air applications and low/high pressure steam applications. In many cases, the use of solar energy for preheating process hot water or providing domestic hot water has been shown to be economically competitive with conventional practices.

Photovoltaic Application

Although photovoltaic (PV) energy systems are not as numerous as solar thermal systems, their application is rising due to the advances in solar cell design. The PV technology has improved steadily. New PV systems are more reliable at a lower cost than previous systems.

The output configurations for PV systems are virtually unlimited. Modules of solar cells can be connected in either parallel and/or series to provide different current and voltage

outputs. This modularity also factors heavily in system expansion and repair.

Because the application of PV technology is relatively new, its full potential is still being developed. Based on past performance, PV technology is well suited for use at remote locations where access to the power grid is not feasible. Some examples of effective use of PV technology are remote power supply for lighting, range instrumentation, navigational aids and communication repeater stations.

A good way to identify early potential PV projects is to consider remote or stand-alone applications that are currently being powered by portable gasoline or diesel units or by batteries. PV-generator hybrid systems can also be viable and they reduce energy vulnerability. When calculating life cycle costs, replacing or retrofitting an existing system with a PV system is extremely attractive because the conversion greatly reduces the need for maintenance and fuel delivery. In some cases, economic payback for remote site applications is less than 1 year.

20.4 GEOTHERMAL ENERGY

Geothermal energy is derived from the thermal energy of the earth. Geothermal is generally thought of as tapping the hot thermal energy in fluid-saturated rocks that are in close proximity to magma. These circumstances occur only in very few areas. Most geothermal producing sites in the United States are located on the West Cost and in Hawaii and Alaska. Such locations are often marked by geysers, hot springs and fumaroles. Furthermore, although various geographical signs suggest the potential for such productive geothermal resources, their definite existence can only be determined by drilling costly exploratory wells into the reservoir. It is highly unlikely that a facility resides on geothermal resources of this type.

Another and more abundant form of geothermal energy may be tapped by geothermal heat pumps. Geothermal (or ground-source) heat pumps are a hybrid system utilizing a conventional heat pump coupled with the earth. Due to the earth's relatively constant temperature, regardless of the climatic season, geothermal heat pumps are considered more efficient than conventional heat pumps. Furthermore, recent advances in geothermal heat pump design and facility techniques have made this a viable technology for many sites.

Geothermal Application

The exploration and development of magma-related geothermal resources require specialized expertise, and is highly risky and expensive. Geothermal production facilities of this type typically require extremely large up-front capital costs. Although the fuel is essentially free, maintenance is expensive because the "brine" (i.e., liquid pumped from underground reservoirs) is often corrosive. Furthermore, because of the nature of the geology and flow of mineral content in the fluid, the extraction and re-injection wells often have to be re-drilled at new locations. Most economical geothermal resources produce more electricity than may be needed by a single FAA facility. If there is a potential for tapping geothermal energy to generate electricity, the excess power can be sold to the local electric utility. It is, however, unlikely that such an opportunity exists for any FAA facility.

CHAPTER 21. WATER CONSERVATION AND MANAGEMENT

21.1 KEY CONCEPTS

- Water management is not only a wise stewardship of a precious resource, but also provides substantial cost savings.
- The true and total cost of water is not just the amount on the water bill, but also includes the energy cost associated with heating, cooling, treating and pumping it to where it is needed. The total cost also includes sewage costs.
- As a regulatory requirement, Federal facilities must assess their water use, examine available and appropriate water conservation products, and retrofit or replace existing equipment to make it more efficient.
- The water management plan should address both the supply side and the demand side. The plan should not just focus on facility occupants, but also involve water utilities.
- Water conservation measures should be implemented in phases, starting with obvious, low-cost options.

21.2 BACKGROUND

The Energy Policy Act passed by the Congress in 1992 requires each government agency to install in Federal facilities all energy and water conservation measures with payback periods of less than 10 years. Additionally, the Executive Order 12902, signed by President Clinton on March 8,1994, reiterates the Federal Government's commitment to energy and water management. The "Energy Efficiency and Water Conservation at Federal Facilities" Executive Order establishes specific deadlines for Federal water management efforts and outlines goals and reporting requirements (refer to a "Requirements under Executive Order 12902, 'Energy Efficiency and Water Conservation at Federal Facilities' ").

Federal energy managers must conduct a comprehensive facility audit of their facilities' water use, examine available

water management techniques applicable to the facilities, and then implement and monitor these measures. These measures must all be cost-effective, with a payback period of 10 years or less. In other words, the cost of the water management option – replacing an old toilet with a new, ultra-low-flow model, for example – must be repaid in water and wastewater treatment cost savings within 10 years.

21.3 BENEFITS OF WATER MANAGEMENT

Historically, clean water has been regarded as an inexhaustible and inexpensive resource. However, recent events, such as droughts in certain parts of the United States, outbreaks of illnesses caused by contaminated drinking-water supplies, and concerns over depleted aquifers and overdeveloped rivers, have led us to realize that it is better to use what we have more efficiently than to seek out new sources of supply or build more wastewater facilities. Wise use of this precious resource ensures that clean water supplies will be available for future generations.

In addressing water management, one indirectly addresses energy consumption as well: Using less water saves the electricity needed to heat, cool, treat, or move water, thereby cutting energy use. Less energy required means fewer harmful emissions from the burning of fossil fuels in power-plants, and thereby greater pollution prevention.

Water management can lead to a significant dollar savings. For example, just fixing a leaking faucet can save up to 36 gallons of water per day. Replacing that same faucet with an automatic-shutoff control that delivers a limited flow of water for a limited time can save about 5,000 gallons of water yearly, and reduce a water bill by roughly $50 per year. Savings multiply dramatically when they are expanded beyond a single facility.

21.4 FACTORS AFFECTING A FACILITY'S WATER CONSUMPTION

Facility Design

Water use is greatly affected by the type of facility, its characteristics, and the type of site on which it is located. The water demand of a warehouse, for example, is markedly different from that of an office building.

Facility design is a key determinant of both energy and water consumption. The facility's envelope or shell (walls, ceilings, and floors), heating, ventilating, and

air-conditioning systems, and lighting design determine indoor humidity and comfort, all of which may have a direct and indirect impact on water use. Likewise, the number and conservation potential of water fixtures (for example, toilets, urinals, faucets, and showers) have a direct effect on water use, as does the facility's amount of landscaped area.

Facility Size versus Use

The size of a facility, measured either in gross square footage or occupiable square footage, is not always a reliable predictor of water consumption. In many cases, occupancy and use are better predictors of water consumption. Warehouses and office buildings of the same square footage generally have different designs, occupancy, and functions, all of which lead to differences in water consumption. For example, an average warehouse may consume only one-third the water of the average office building, but contain nearly three times the floor space. This could be because a greater percentage of space in warehouses is used solely for storage – meaning that there is less space that needs to be conditioned and fewer people in the building to use water.

Climate and Geography

Climate and geography have major effects on water use. This may range from stimulating the need for air-conditioning in the summer and requiring heat in the winter, to determining how drought-resistant shrubs and turf may be used for landscaping the facility grounds. For new construction, to maximize water efficiency, facility architects should consider geography when planning a facility's design and landscaping. All other factors being equal, the warmer or more arid the climate and geography, the greater the water use.

21.5 PRINCIPLES OF WATER MANAGEMENT

Successful water management benefits from a holistic approach, one that not only considers the technical side, such as installing efficient fixtures and making operation and maintenance modifications, but also the human side, such as changing longstanding behaviors and expectations. It also requires that energy managers look at managing water use so that they comply with the law, make cost-effective decisions, and can document their environmental savings.

The following are the general guidelines to help in developing a comprehensive, effective water management program:

- Water management techniques fall into three general areas:
  - reducing losses (for example, fixing leaky faucets and pipes);
  - reducing the overall amount of water used (for example, using low-flush toilets and automatic shut-off faucets); and
  - reusing water that would otherwise be discarded (for example, treating water from sinks and toilets for use on landscaped areas).

- Conserving water within a facility also affects other building systems. For example, reducing the amount of hot water used in a dishwasher would also reduce the amount of electricity needed to heat that water.

- The overall cost reduction as a result of water conservation is not just reflected in the reduced water bill, but also in reduced cost to heat, cool, treat and pump it to where it is needed. Water conservation also reduces sewage costs.

- An effective plan is one that fully outlines not just how much water is used, but how it is used and by whom.

- The water conservation plan should address both the supply side and the demand side. In addition to focusing on facility occupants, an energy manager should also work with the local water utility.

- The water management plan, to a large degree, will only be as good as the data collected in order to develop it.

- Implementation of the water management plan should be done in phases, starting with obvious, low-cost options.

- State regulations are sometimes more stringent than Federal regulations in their requirements for water conservation.

- All water-conservation options should be evaluated based on life-cycle costing, not just by considering the initial investment.

- Management must be committed to water management if they want to convince federal employees that their actions make a positive difference.

21.6 DEVELOPING A WATER MANAGEMENT PLAN

Similar to the energy management plan discussed in chapter 11, developing a water management plan is logical and follows an established sequence of events. This plan depends on a clear and complete understanding of how a facility uses water, from the time it is piped into the facility to its ultimate disposal or reuse.

The steps involved in developing a successful water management plan are as follows:

Step 1	Create water conservation awareness in facility occupants.
Step 2	Gather information.
Step 3	Conduct a comprehensive facility survey.
Step 4	Explore and evaluate water management options.
Step 5	Conduct life-cycle cost analyses and explore financing options.
Step 6	Develop a water management plan and a work schedule.
Step 7	Implement and monitor the water management program.

Step 1: Create Water Conservation Awareness in Facility Occupants

Before developing the water management plan, energy manager should make facility occupants and visitors aware of water conservation needs and goals. Most water-efficient fixtures will only yield the savings expected when users are part of the solution. Begin by sending all occupants a letter urging support for the water management program and occupant participation. The letter should explain why changes are being made and what difference they will make, and finally, why water management is necessary. Signs should be posted near equipment and in restrooms, so visitors are aware of water-saving initiatives in place.

Because many water efficiency options produce savings only when used properly, you must teach occupants how to use them. If low-flow toilets requiring 3.5 gpf are flushed twice to remove waste, for example, operating them this way will use as much or more water than the original fixtures they replaced.

Bulletin boards, newsletters, and staff meetings may be used regularly to discuss the progress of the water management program. These sources for information and forums for discussion might also be used to create changes in overall occupant water use. Chapter 8 of the handbook discusses some more ideas to create awareness amongst the facility occupants. As part of the conservation program, some of the following suggestions may be incorporated:

- Set up a "hotline" to report leaks or other wastes of water to energy managers or maintenance personnel.
- Start a suggestions and incentives system to recognize water-saving ideas.
- Distribute flyers or pamphlets to promote the facility's water management plan or to educate occupants about good water use habits.
- Organize a slogan or poster competition.
- Start a water column in the agency's energy newsletter, featuring how much water has been saved through the water management program.
- Prepare a water conservation display covering different aspects of water use affected by the water management program (landscaping, low-flow plumbing products, water use habits, and the like) and place it in an appropriate location, such as the facility lobby or auditorium.

Step 2: Gather Information

Before starting the survey, as much existing information should be collected as possible. The people who are familiar with daily facility operations, especially operating and maintenance personnel, can be very helpful in this step. Some information will be readily available, while other data will take some time to collect. Specifically, gather the following information:

- Facility floorplan and plumbing drawings and schematics.
- Typical facility operating schedules, number of employees and visitors, and maintenance and janitorial work schedules.

- Lists of all water-using equipment with the manufacturers' rated flow-rates.
- Number of plumbing fixtures (toilets, urinals, and so forth).
- Outdoor water use applications, quantity, and schedule.
- Any prior water and energy surveys.
- Names of energy, water, and wastewater utilities.
- Water and sewer bills for the past 2 years.
- Anticipated water and sewer billing rates for the next 2 years, if available from the utility.
- Records that show actual water use for the last 2 years, from both source meters and submeters, and including any water meter calibration test results, so that adjustment of past meter readings can be made to reflect actual water use.

Step 3: Conduct a Comprehensive Facility Survey

After information collection outlined in Step 1, a water survey will be conducted. The exact extent of the survey will depend on the size of the facility, the complexity of its systems, and the survey budget. The more comprehensive the survey, the greater the value of the resulting water management options and cost savings.

The Survey Team

The first step is to assemble a team of professionals and identify their functions. The survey team may consist of a combination of the following:

- Representatives from the facility's management.
- The chief operating engineer.
- A representative from the maintenance department.
- Design or water management consultants.
- Qualified contractors who specialize in plumbing and mechanical, landscape, or other water management fields.

Depending on the policies of the local water utility, a representative may or may not wish to be involved in the on-site inspection portion of the survey. A utility survey should be conducted separately.

Conducting the Survey

Once the survey team is assembled, a detailed survey should be conducted to include the steps outlined below:

- *Walk through the facility*, and through direct observation and measurements, identify and list all equipment that uses water: faucets, toilets, showerheads, drinking fountains, kitchen equipment, water-using process equipment, cooling towers, heating boilers, and so forth. Note any discrepancies with information gathered during the previous step.

- *Compare floor-plans and plumbing drawings and schematics with actual conditions*. Plans are often outdated; plumbing fixtures noted in plans may have been removed or disabled, and new fixtures may have been added after the drafting of the original plans.

- *Record hours of operation* for plumbing fixtures, devices, and all water-using processes or pieces of equipment. Note if a particular fixture, device, or piece of equipment uses water for more than one operation. Ice makers, for example, use water both for making ice and for cooling. When possible, determine actual schedules of plumbing fixture use by talking to operating personnel familiar with the facility use.

- *Verify operating schedules and the number of facility occupants* during different times of the day. This step is particularly critical if the facility has a lot of visitors and foot traffic.

- *Determine the amount of water used* by each type of plumbing fixture or device within the facility. Log or record the consumption data for each device (most will have it printed or engraved on the equipment itself). If the equipment has been retrofitted or the amount is not visible, examine the fixture and measure or estimate the flowrate. When field-testing the flow of water through fixtures, it is usually sufficient to take sample readings at a few representative fixtures located throughout the facility. When measuring the flow rate by fixtures such as faucets that can operate at different settings, set the fixture at a typical temperature and adjust it to an average flowrate. Keep in mind that measured flows will vary on different floors because of static head losses at higher elevations.

- *Measure the quantity of water used by other water-consuming equipment.* Temporary water

meters may be installed to gauge water use by large water-using equipment. Compare the equipment water use measurements with the manufacturers' rated flow amounts; some equipment may be operating with higher water consumption rates than necessary. If there is a significant difference, consider having qualified personnel review equipment operation and make adjustments to lower water consumption.

- *Determine daily facility consumption rates* from water meter and submeter readings and other sources. This step will also help to prepare for monitoring water use reductions after beginning the water management program. After the survey is completed, continue to take meter readings on a monthly basis.

- *Identify the direction that water is flowing within a facility and its quality*. Knowing the quality of water as it travels through a facility is important because discharges from one use could possibly be used as the supply water for a second use. When examining water quality, if possible, consider its temperature; chemical makeup, including pH level, total dissolved solids, and conductivity; and the amount of solid waste it carries.

After finishing this step of the water survey, all uses of water in a facility should already be tracked. Ideally, the energy manager will be able to determine the amount of water consumed, lost to evaporation, and discharged for treatment. Also, remember that throughout the water survey, the energy manager should be observing and noting appropriate technologies to retrofit or replace existing products.

Utility Assistance

If possible, the local water utility should be involved in the survey. The water utility can be helpful in two ways. First, it can serve as a source of information, and, second, it can help to detect leaks or install or adjust meters and water-pressure-reduction valves.

- ***Leak Detection***: Leaks, low water pressure, and other problems may exist within the water distribution lines outside a given facility. During a utility water survey, the utility representative will visit the affected area

to detect where water losses may be occurring (for example, in water distribution lines, piping, and connections). Leaks are not uncommon in areas where utility water pressure and demand are high. Many surveys are also designed to detect unmetered water delivered through fire hydrants, water taken illegally from the distribution lines, inoperative system controls, and water used in flushing water mains and sewers. If any of these problems are found, the utility will usually fix them at its own expense.

- ***Meters***: Water submeters, which measure the amount of water used for specific processes in a facility, can be installed on a facility's water distribution lines to provide more accurate readings (information that is not provided by standard meters). That knowledge helps pinpoint areas of high water use (and thus, areas with great savings potential) and evaluate their consumption on a monthly basis. Just having a greater awareness of how water is specifically used in a facility has helped some facility managers change their water use patterns, resulting in a 13 to 45 percent savings.

Installing meters may alter the facility's water rate structure. The energy manager should ask the utility representative to review your current rate structure and other options that may exist. Traditionally, large water users have been charged either a flat or declining block rate. Under a flat rate, the price per unit of water remains at one cost regardless of the amount of water consumed, offering no incentive to cut water use. A declining block rate rewards waste by charging less for each unit as more water is used; fortunately, these rate structures are becoming less commonplace.

A more progressive rate structure that encourages water conservation is a *graduated rate*. With a graduated rate, the utility charges a certain amount for the first 150,000 gallons provided per month, a slightly higher rate for the next 150,000 gallons, and a graduated rate for each sequential 150,000 gallons. This type of rate schedule provides a stronger economic incentive for facility managers to use less water than when they are billed on a flat or declining block rate. Furthermore, some sewage or wastewater treatment facilities may offer similar rate

structures, further encouraging water conservation. Whichever the current rate structure, it is important to determine if there are options, and if any provide potential savings.

- ***Pressure Reduction Valves***: Lowering the water pressure level on a facility's distribution lines outside a building can often conserve water while still maintaining adequate pressure. Water utilities can install pressure-reducing valves (PRVs) that will regulate water pressure, typically maintained at between 50 and 60 pounds per square inch (psi) for maximum efficiency. Ask the local utility if the facility could benefit by installing PRVs.

Step 4: Explore and Evaluate Water Management Options

After compiling water-consumption and use data and obtaining a true idea of water costs, water management options should be identified. Determine which fixtures and equipment produce water savings while maintaining or improving the water functions and services the facility and its occupants require.

Most of the water management options fall into three main categories:

- Plumbing fixtures
- Heating, ventilating, and air-conditioning systems
- Landscape irrigation

Complete replacement is typically not an option for most facilities, and may not necessarily be the best solution. An older facility with inconsistent water pressure, for example, may not be suitable for a low-flow toilet replacement because the quantity of use or abuse (such as flushing excess paper down the toilet) will create related maintenance and performance problems, which could actually increase costs. Often, simple procedural changes in maintenance or operation can produce substantive water savings. A constantly running toilet, for example, can waste 6,000 gallons of water per day. Checking and replacing valves and ballcocks regularly can save this otherwise wasted water.

Federal legislation and state water conservation regulations should be considered as fixture and equipment options are considered. Some states that have experienced water shortages in the past, and those concerned about water use

and conservation in general, have passed regulations that exceed Federal legislation. Arizona, California, and Maryland have laws restricting water use in toilets, for example; California, New York, and Rhode Island have imposed special standards on low-flow showerheads and faucets.

Step 5: Conduct Life-Cycle Cost Analyses and Explore Financing Options

It is critical to choose appropriate and cost-effective water efficiency options for the facility to work in an environment where such options are usually expensive and budgets are limited. At the same time, initial cost should not be the only reason for deciding which option is best. For example, replacing an existing heavy-use toilet with a low-flow model will require a larger initial investment than simply installing a toilet dam. However, the dam will require regular surveillance and maintenance, and the labor costs may quickly offset the initial low cost of the dam.

Total Cost of Water

The total cost of water used by a facility goes beyond the facility's water and sewer bills. The total cost can be determined by adding all expenses for water use for a year and dividing the result by the quantity of water used during that year. To find the sum of all expenses for water use, be sure to include the following:

- The cost of the water purchased from water utilities. Water utility bills usually contain two components: a fixed charge and a charge based on the amount of water used. Do not include the fixed charge in the total, as this amount usually will not change with an increase or decrease in facility water efficiency.
- Energy cost of pumping water from wells.
- Cost of pretreating and on-site pumping.
- Cost of water heating and cooling.
- Chemical or other treatment costs, including treating cooling tower or boiler feed water.
- Sewer costs, which can be based on the amount of water, dissolved solids, suspended solids, and the need for chemical or biological oxygen.

When combining these costs, current prices can be used. However, if possible, use prices that will be in effect at the time any water efficiency and conservation changes are actually made. That way, differences in cost realized by changing facility water use can be assessed more accurately. After adding all costs, divide by the volume of

water purchased during that same time period to find total cost per unit of water used. Knowing the total cost per unit of water used is important because it will be used to determine savings realized by replacing or retrofitting with the options considered.

Economic Analysis and Financing

A life-cycle cost analysis evaluates the total initial and operating and maintenance costs of a water efficiency option over time, taking into account the "time value" of money. In other words, analysis considers the cost over the life of the system, rather than just the initial equipment cost. For any water conservation project, life-cycle costs must be analyzed to determine the payback period. All options with periods of 10 years or fewer must be considered.

FAA regions may have various financing and incentives programs available to implement water conservation options. Chapter 3 discusses economic analysis and financing methods for energy conservation projects, which can also be applied to the water conservation programs.

Step 6: Develop a Water Management Plan and a Work Schedule

Decisions to make changes or modifications to the facility should be made based on the previous examination of current water use, occupant needs, and the results of life-cycle costing analysis. Prioritizing the selected water management options in this way will maximize cost, water, and energy savings while maintaining or improving occupant comfort and increasing facility efficiency. Because individual facilities vary according to building type and use, occupant needs, and equipment, water, and sewage costs, no *one* plan is right for all facilities. After choosing water efficiency options, a comprehensive water management plan work schedule must be developed. Determine what funding is available for improvements, when the funding would be available, and the time required to complete the entire water management project. Examine large retrofit or replacement options or high-priority jobs to determine the time necessary to complete each. While some can be implemented in a few hours or days, others may require up to several months and the services of a professional contractor.

Step 7: Implement and Monitor the Water Management Program

Once work begins on retrofits or replacements, and as maintenance or operational changes are introduced, the program should be closely monitored to ensure that it runs smoothly. This part of the conservation plan should include at least the following items:

- Coordinate with contractors to verify that their work is progressing as promised.
- Follow-up regularly with operating and maintenance personnel to ensure that equipment is regularly checked and serviced.
- Listen to the facility's water users and keep communication lines open. Repairs or modifications should be made quickly if something is reported as not working properly.
- Check the water and sewer bills for a decrease in your consumption and billing. Energy managers should carefully monitor water use to see what types of savings are actually incurred.

21.7 IMPLEMENTING WATER MANAGEMENT OPTIONS

A wide variety of water management options are available to energy managers for virtually every use of water in a facility. Some options simply involve altering the water use habits of facility occupants. Other options, like changing the way fixtures and equipment are operated and maintained, can also achieve water savings. The most significant long-term savings, however, will probably require the retrofitting or replacement of fixtures and equipment.

In some instances, one option alone might achieve the desired savings (for example, retrofitting a showerhead by inserting a flow-restricting device). In others, a combination of options may be needed (for example, inserting flow restrictors and automatic sensors in bathroom faucets).

A comprehensive water management plan must thoroughly explore all water management options. This plan must recognize that a facility's water system, and changes to it, will have an impact on other systems in the facility, specifically the facility's use of electricity. For example, installing a flow restrictor on a faucet not only will reduce the amount of water consumed, but also will lower energy costs associated with heating this water for use, and for treating this water for disposal.

Some ways to reduce your current water consumption will be immediately apparent, such as fixing a leaky faucet. Others, such as determining how many and what type of toilets to install, will require both product research and on-site use observation.

It is important to evaluate each option not only on its ability to conserve water, but also on its practicality. For example, replacing a high-consumption fixture with a low-consumption fixture will enable you to realize the greatest amount of water savings over time. But, where limited budgets prevent the initial high price of replacement, other interim measures, such as retrofitting toilets with displacement devices, may help save significant volumes of water.

It is also important to remember that in order to comply with the Energy Policy Act, changes must be life-cycle cost effective, with a payback occurring in 10 years or less. Further, the Energy Policy Act also stipulates water consumption standards for products manufactured after January 1, 1994. These standards restrict showerheads and faucets to 2.5 gallons per minute (gpm), toilets to 1.6 gallons per flush (gpf), and urinals to 1 gpf.

SUMMARY OF LEGISLATION AND EXECUTIVE ORDERS FOSTERING FEDERAL ENERGY EFFICIENCY

The following material is from the U.S. Congress Office of Technology Assessment (OTA), Energy Efficiency in the Federal Government: Government by Good Example?, OTA-E-492, U.S. Government Printing Office, May 1991.

LEGISLATION FOR FEDERAL FACILITIES AND OPERATIONS

Congress has addressed the issue of improving energy efficiency in the facilities it owns and leases and in its operations several times since the mid-1970s. Each new piece of legislation has combined past experience with new approaches in an effort to promote further efficiency gains in Federal agencies.

Energy Policy and conservation Act (EPCA)

The EPCA of 1975 was the first major piece of legislation to address Federal energy management, directing the President to develop a comprehensive energy management plan, including procurement practices, and a 10-year building plan. The EPCA included few details, leaving those to the executive branch. The EPCA also amended the Motor Vehicle Information and Cost Savings Act to require that the Federal automotive fleet meet or exceed the corporate average fuel economy mileage standards.

Department of Energy Organization Act (DOEOA)

Section 656-of the DOEOA of 1977 established the Federal Interagency Energy Policy Committee (often called the "656 Committee"). The 656 Committee is a senior agency management group comprised of an assistant secretary or assistant administrator from each of the Departments of Defense, Commerce, House and Urban Development, Transportation, Agriculture, and Interior; from the U.S. Postal Service; and from the General Services Administration (GSA). The National Aeronautics and Space Administration and the Department of Veterans Affairs have also designated members for the committee. The committee is intended to strengthen energy conservation programs which emphasize productivity through the efficient use of energy and to concurrently encourage interagency cooperation in energy conservation. It meets periodically to discuss policy options and review agency progress toward Federal conservation goals. One of its purposes is to focus the attention of top Federal agency management on the tasks and missions related to national energy objectives rather than on the tasks of a particular agency.

National Energy Conservation Policy Act (NECPA)

In the NECPA of 1978, Congress took a more active role in defining detailed steps to be followed by the executive agencies. Several of the steps included in this legislation had been set forth by the President in Executive Order (EO) 12003 in 1977 (see below). For example, where the EPCA directed the President to develop an energy-related procurement policy, the NECPA specified the use of a life cycle costing

methodology" as the basis of policy. Similarly, where the EPCA directed the President to develop a 10-year building plan, the NECPA included details such as which buildings were subject to energy audits (all those exceeding 1000 square feet). Both of these NECPA provisions were part of EO 12003. Unlike EO 12003, the NECPA set no goal for percentage reduction in energy use, but instead specified the minimum rate at which Federal buildings had to be retrofit with all cost effective measures. All buildings were to have been retrofit by 1990. The main provisions of the NECPA were codified as the Federal Energy Initiative.

Comprehensive Omnibus Budget Reconciliation Act (COBRA)

The COBRA of 1985 amended the NECPA to provide Federal agencies an alternative sources of funding for energy efficiency investments during a time of great fiscal constraints. Under the COBRA, agencies were encouraged to seek private financing and implementation of energy efficiency projects through "shared energy savings" (SES) contracts (described below).

Federal Energy Management Improvement Act (FEMIA)

The FEMIA of 1988 amended the NECPA and modified and added several provisions to the Federal Energy Initiative. A central provision was the establishment of a goal to reduce energy consumption per square foot in Federal buildings by 10 percent between 1985 and 1995. Operations energy (i.e., energy used for transport or in energy-intensive activities such as nuclear reactors) was not included. FEMIA marked the first time that Congress specified the level of savings which should be achieved. Also, as an incentive to encourage use of SES contracts, Congress allowed agencies to retain a portion of cost savings for future energy conservation measures. Furthermore, the FEMIA created an Interagency Energy Management Task Force, and directed the Department of Energy (DOE) to carry out an energy survey in a representative sample of Federal buildings to: 1) determine the maximum potential cost-effective energy savings that may be achieved, and 2) make recommendations for cost-effective energy efficiency and renewable energy improvements.

Energy Policy Act of 1992 (EPAct)

Subtitle F of the EPAct, Federal Agency Energy Management establishes Federal agency goals and requirements and amends the NECPA to reflect and supplement goals and requirements set forth in E012759. The EPAct:

- Requires that all energy and water conservation measures with Life Cycle Cost (LCC) paybacks of less than 10 years be installed in all U.S. owned Federal Buildings by January 1, 2005.

- Contains provisions regarding energy management requirements, LCC methodology, budget treatment for energy conservation measures, incentives for Federal agencies, reporting requirements, new technology demonstrations, and agency surveys of energy saving potential.

- Authorizes GSA to receive rebates, other incentive payments, or goods and services from utilities and deposit funds into the Federal Buildings Fund for use in energy management improvement programs; and requires GSA to report annually to Congress on its activities related to Federal agency energy management.

- Amends sections of the NECPA relating to shared energy savings (SES), provides new language giving agencies authority to enter into energy performance contracts, and describes the methodology of contract implementation.

- In regard to intergovernmental energy management planning and coordination, requires GSA, along with the Interagency Energy Management Task Force, to hold five conference workshops in FY93 on energy management, conservation, efficiency, and planning strategy, and to hold biennial workshops in each of the ten standard Federal regions thereafter.

- Requires Federal agencies to establish and maintain programs to train energy managers and to increase the number of trained energy managers within each agency. The Act defines a "trained energy manager" as "a person who has completed a course of study in the areas of: (1) fundamentals of building energy systems, (2) building energy codes and applicable professional standards, (3) energy accounting and analysis, (4) LCC methodologies, (5) fuel supply end pricing, and (6) instrumentation for energy surveys and audits."

- Requires DOE to make available energy audit teams for Federal facilities and to establish programs to monitor the implementation of energy efficiency improvements based on energy audit team recommendations.

- Directs the OMB to issue guidelines for accurately assessing energy use in Federal buildings or facilities to be used in agency reports to DOE, and directs GSA to report annually on the estimated energy costs for leased space where the Government does not pay these costs directly.

- Directs agency Inspectors General to assess agency compliance with existing energy management requirements as well as the accuracy of energy-use and cost data reported by Federal agencies, and encourages periodic review.

- Directs GSA, DoD, and the Defense Logistics Agency to identify energy-efficient products on the Federal supply schedules that offer significant potential for LCC savings.

- Requires DOE to report to Congress on options for financing energy conservation measures, including an assessment of the investment required and the possible use of revolving funds.

- Directs agencies to establish criteria for improving energy efficiency in Federal facilities operated by contractors and to include such criteria in all cost-plus, award-fee contracts

- Confirms and expands upon the activities and goals of Section 11 of EO 12759 dealing with Federal fleets. Amends the Alternative Motor Fuels Act (AMFA) to include all types of alternative fuels and all types of light duty trucks, and changes the definition of fleet to "20 or more vehicles in metropolitan areas of more than 250,000 people." Requires consideration of pollution-reduction potential, requires alternative fuel use in dual-fuel use, requires 50 percent domestic fuels, requires heavy-duty use and disposal reports, and repeals termination of the AMFA. Requires the use of commercial refueling facilities if available, but authorizes funds for refueling facilities if necessary.

- Mandates fleet requirements for new acquisitions to the Federal fleet [i.e., FY93, 5,000 alternative-fuel vehicles (AFVs); FY94, 7,500 AFVs; FY95, 10,000 AFVs; FY96, 25 percent; FY97, 33 percent; FY98, 50 percent; and FY99, 70 percent]. Allows allocation of AFV incremental costs to be spread over all agency vehicles and authorizes funds as necessary for fiscal years 1993–1998.

- Requires DOE and GSA to establish an agency promotion, education, and coordination program; allows GSA to offer leased AFVs at lower costs as an incentive for three years; requires GSA to establish a recognition and incentive program for Federal employees; directs GSA to measure the use of alternative fuels in dual-fuel vehicles; and reduces data collection required to a representative sample.

EXECUTIVE ORDERS FOR FEDERAL ENERGY EFFICIENCY

Executive Order 11912

There have been several Executive orders related to Federal energy efficiency. The earliest was EO 11912 of 1976, which delegated authorities related to energy policy and conservation. Among other things, this order defined the roles of various Cabinet Departments with responsibility for Federal energy use:

- The Administrator of GSA was designated to take on the functions assigned to the President by the Motor Vehicle Information and Cost Savings Act, as amended, directing that rules be established to require the Federal fleet to achieve an average fuel economy of at least that applicable to vehicle manufacturers;
- The Administrator of the Federal Energy Administration (now the Secretary of Energy) was made responsible for coordination of a 10-year energy conservation plan for Federal buildings, energy conservation and rationing contingency plans, and preparation of annual reports to be submitted to Congress as required by the EPCA; and
- The Administrator of the Office of Federal Procurement Policy was required to provide policy guidance for application of energy conservation and efficiency standards in the Federal procurement process as mandated by the EPCA.

Executive Order 12003

Executive Order 12003, issued in 1977, amended EO 11912 and aggressively expanded the requirements of the Energy Policy and Conservation Act of 1975. For example, it specified a goal of a 20-percent reduction in energy use per square foot in existing Federal buildings, and required the Federal automobile fleet to exceed the minimum statutory requirement by 4 miles per gallon beginning in fiscal year 1980. As noted above, some of its provisions are also found in the NECPA. Key provisions of EO 12003 include the following:

- The Administrator of the Federal Energy Administration (now the Secretary of Energy) was directed to:
  - Develop, implement and oversee a 10-year energy conservation plan for Federal buildings over 5,000 square feet for the 1975—85 period which would achieve a 20 percent reduction in energy use in existing buildings and a 45 percent reduction in all new buildings;
  - Establish a life-cycle-cost methodology; and
  - Report to Congress annually on the progress of the plan.

- The Administer of GSA was directed to ensure that:
  - All passenger automobiles purchased by executive agencies exceed the manufacturers' corporate average fuel economy standard under the Motor Vehicle Cost and Information Act;
  - The Federal passenger automobile fleet exceeds minimum statutory requirements by 2 miles per gallon in fiscal year 1978, and by 4 miles per gallon beginning in 1980; and
  - The Federal light truck fleet also meets minimum standards, although not required under the Motor Vehicle Cost and Information Act.

Executive Order 12083

In 1978, EO 12083 created an Energy Coordinating Committee, composed of the Secretaries of the major Federal agencies. Its mission is to assure Federal coordination on energy-related matters, including both policy initiatives and resource allocation. In addition to the committee, an Executive Council was formed - consisting of the Secretary of Energy, Chairman of the Council of Economic Advisers, Assistant to the President for Domestic Affairs and Policy - to fulfill the functions of the committee during periods when the committee is not meeting.

Executive Order 12375

Executive Order 12375 of 1982 further amended EO 11912 to reduce the required Federal passenger automobile fleet efficiency established in EO 12003. Whereas EO 12003 required the Federal passenger fleet to exceed manufacturers' average fleet efficiency by 4 miles per gallon, EO 12375 required only that the Federal fleet meet the manufacturers' average efficiency and that light trucks meet standards set by the Secretary of Transportation. This Executive order contrasted sharply with EO 12003, which was far more ambitious and went beyond some minimum requirements set by Congress.

Executive Order 12759

On April 17,1991, EO 12759 was issued with provisions to:

- Extend the FEMIA Federal building reduction goal to 2000, requiring Btu per gross square foot to be reduced 20 percent from 1985 levels;
- Require agencies to prescribe policies for improving energy efficiency of industrial facilities by at least 20 percent in 2000 compared to 1985;
- Minimize petroleum use;
- Procure energy-efficient goods and products by Federal agencies based on life-cycle cost;
- Provide for Federal agency participation in demand-side management services offered by utilities;
- Provide new Federal vehicle fuel efficiency requirements and outreach programs; and
- Promote procurement of alternative fuel vehicles for the Federal fleet.

Executive Order 12845

Executive Order 12845, issued on April 21, 1993, establishes energy efficient acquisition standards for computer equipment. Microcomputers, including personal computers, monitors, and printers must meet the EPA "Energy Star" requirements for energy efficiency (i.e., a standby low power feature), so long as the additional costs of the equipment are offset by the potential energy savings. Exemptions to this requirement are permitted on a case-by-case basis (as approved by the Agency Head). Note: All exempted acquisitions must be reported annually to the General Services Administrative.

Executive Order 12902

EO 12902, Energy Efficiency and Water Conservation at Federal Facilities, aims at developing and implementing programs aimed reducing energy consumption in federal facilities by 30 percent by year 2005, while increasing energy efficiency for federal industrial facilities by 20 percent by year 2005. It mandates significant increase in the use of solar and other renewable energy sources. Federal facilities are to minimize use of petroleum products by switching to less polluting alternative energy sources. Every federal agency will designate one major building as a showcase for energy or water efficiency. The Order mandates design and construction of new facilities to minimize life-cycle costs through energy efficiency and water conservation.

[Federal Register: March 10, 1994]

Part XIII

The President

Executive Order 12902: Energy Efficiency and Water Conservation at Federal Facilities

Presidential Documents

Federal Register
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Title 3--

The President Executive Order 12902 of March 8, 1994

Energy Efficiency and Water Conservation at Federal Facilities

By the authority vested in me as President by the Constitution and the laws of the United States of America, including the Energy Policy and Conservation Act (Public Law 94-163, 89 Stat. 871, 42 U.S.C. 6201 et seq.) as amended by the Energy Policy Act of 1992 (Public Law 102-486, 106 Stat. 2776) and section 301 of title 3, United States Code, I hereby order as follows:

PART 1--DEFINITIONS

For the purposes of this order:

Section 101. The "Act" means the Federal energy management provisions of the Energy Policy and Conservation Act, as amended by the Energy Policy Act of 1992.

Sec. 102. The term "comprehensive facility audit" means a survey of a building or facility that provides sufficiently detailed information to allow an agency to enter into energy or water savings performance contracts or to invite inspection and bids by private upgrade specialists for direct agency-funded energy or water efficiency investments. It shall include information such as the following:

(a) the type, size, energy use, and performance of the major energy using systems and their interaction with the building envelope, the climate and weather influences, usage patterns, and related environmental concerns;

(b) appropriate energy and water conservation maintenance and operating procedures;

(c) recommendations for the acquisition and installation of energy conservation measures, including solar and other renewable energy and water conservation measures; and

(d) a strategy to implement the recommendations.

Sec. 103. The term "cost-effective" means providing a payback period of less than 10 years, as determined by using the methods and procedures developed pursuant to 42 U.S.C. 8254 and 10 CFR 436.

Sec. 104. The term "demand side management" refers to utility-sponsored programs that increase energy efficiency and water conservation or the management of demand. The term includes load management techniques.

Sec. 105. The term "energy savings performance contracts" means contracts that provide for the performance of services for the audit, design, acquisition, installation, testing, operation, and, where appropriate, maintenance and repair, of an identified energy or water conservation measure or series of measures at one or more locations.

Sec. 106. The term "agency" means an executive agency as defined in 5 U.S.C. 105. For the purpose of this order, military departments, as defined in 5 U.S.C. 102, are covered under the auspices of the Department of Defense.

Sec. 107. The term "Federal building" means any individual building, structure, or part thereof, including the associated energy or water-consuming support systems, which is constructed, renovated, or purchased in whole or in part for use by the Federal Government and which consumes energy or water. In any provision of this order, the term "Federal building" shall also include any building leased in whole or in part for use by the Federal Government

where the term of the lease exceeds 5 years and the lease does not prohibit implementation of the provision in question.

Sec. 108. The term "Federal facility" means any building or collection of buildings, grounds, or structure, as well as any fixture or part thereof, which is owned by the United States or any Federal agency or which is held by the United States or any Federal agency under a lease-acquisition agreement under which the United States or a Federal agency will receive fee simple title under the terms of such agreement without further negotiation. In any provision of this order, the term "Federal facility" shall also include any building leased in whole or in part for use by the Federal Government where the term of the lease exceeds 5 years and the lease does not prohibit implementation of the provision in question.

Sec. 109. The term "franchising" means that an agency would provide the services of its employees to other agencies on a reimbursable basis.

Sec. 110. The term "gainsharing" refers to incentive systems that allocate some portion of savings resulting from gains in productivity to the workers who produce those gains.

Sec. 111. The term "industrial facilities" means any fixed equipment, building, or complex for the production of goods that uses large amounts of capital equipment in connection with, or as part of, any process or system, and within which the majority of energy use is not devoted to the heating, cooling, lighting, ventilation, or to service the hot water energy load requirements of the building.

Sec. 112. The term "life cycle cost" refers to life cycle cost calculated pursuant to the methodology established by 10 CFR 436.11.

Sec. 113. The term "prioritization survey" means a rapid assessment that will be used by an agency to identify those facilities with the highest priority projects based on the degree of cost effectiveness and to schedule comprehensive facility audits prior to project implementation. The prioritization survey shall include information such as the following:

(a) the type, size, energy and water use levels of the major energy and water using systems in place at the facility; and

(b) the need, if any, for acquisition and installation of cost-effective energy and water conservation measures, including solar and other renewable energy resource measures.

Sec. 114. The term "shared energy savings contract" refers to a contract under which the contractor incurs the cost of implementing energy savings measures (including, but not limited to, performing the audit, designing the project, acquiring and installing equipment, training personnel, and operating and maintaining equipment) and in exchange for providing these services, the contractor gains a share of any energy cost savings directly resulting from implementation of such measures during the term of the contract.

Sec. 115. The term "solar and other renewable energy sources" includes, but is not limited to, agriculture and urban waste, geothermal energy, solar energy, and wind energy.

Sec. 116. The term "utility" means any person, State, or agency that is engaged in the business of producing or selling electricity or engaged in the local distribution of natural gas or water to any ultimate consumer.

PART 2--INTERAGENCY COORDINATION

Sec. 201. Interagency Coordination. The Department of Energy ("DOE") shall take the lead in implementing this order through the Federal Energy Management Program ("FEMP"). The Interagency Energy Policy Committee ("656 Committee") and the Interagency Energy Management Task Force ("Task Force") shall serve as forums to coordinate issues involved in implementing energy efficiency, water conservation, and solar and other renewable energy in the Federal sector.

PART 3--AGENCY GOALS AND REPORTING REQUIREMENTS FOR ENERGY AND WATER EFFICIENCY IN FEDERAL FACILITIES

Sec. 301. Energy Consumption Reduction Goals.

(a) Each agency shall develop and implement a program with the intent of reducing energy consumption by 30 percent by the year 2005, based on energy consumption per-gross- square-foot of its buildings in use, to the extent that these measures are cost-effective. The 30 percent reductions shall be

measured relative to the agency's 1985 energy use. Each agency's implementation program shall be designed to speed the introduction of cost-effective, energy-efficient technologies into Federal facilities, and to meet the goals and requirements of the Act and this order.

(b) Each agency shall develop and implement a program for its industrial facilities in the aggregate with the intent of increasing energy efficiency by at least 20 percent by the year 2005 as compared to the 1990 benchmark, to the extent these measures are cost-effective, and shall implement all cost-effective water conservation projects. DOE, in coordination with the 656 Committee, shall establish definitions and appropriate indicators of energy and water efficiency, and energy and water consumption and costs, in Federal industrial facilities for the purpose of establishing a base year of 1990.

Sec. 302. Energy and Water Surveys and Audits of Federal Facilities.

(a) Prioritization Survey. Each agency responsible for managing Federal facilities shall conduct a prioritization survey, within 18 months of the date of this order, on each of the facilities the agency manages. The surveys shall be used to establish priorities for conducting comprehensive facility audits.

(b) Comprehensive Facility Audits. Each agency shall develop and begin implementing a 10-year plan to conduct or obtain comprehensive facility audits, based on prioritization surveys performed under section 302(a) of this order.
(1) Implementation of the plan shall ensure that comprehensive facility audits of approximately 10 percent of the agency's facilities are completed each year. Agencies responsible for managing less than 100 Federal facilities shall plan and execute approximately 10 comprehensive facility audits per year until all facilities have been audited.
(2) Comprehensive audits of facilities performed within the last 3 years may be considered current for the purposes of implementation.
(3) "No-cost" audits, such as those outlined in section 501(c) of this order, shall be utilized to the extent practicable.

(c) Exempt Facilities. Because the mission within facilities exempt from the energy and water reduction requirements under the Act may not allow energy efficiency and water conservation in certain operations, actions shall be taken to reduce all other energy and water waste using the procedures described in the Act and this order. Each agency shall develop and implement a plan to improve energy and water efficiency in such exempt facilities. The prioritization surveys are intended to allow agencies to refine their designation of facilities as "exempt" or "industrial," so that only individual buildings in which industrial or energy-intensive operations are conducted remain designated as "exempt" or "industrial." Within 21 months of the date of this order, each agency shall report to FEMP and to the Office of Management and Budget ("OMB") the redesignations that the agency is making as a result of the prioritization surveys. Agencies may seek exemptions for their facilities pursuant to the Energy Policy and Conservation Act, as amended.
(d) Leased Facilities. Agencies shall conduct surveys and audits of leased facilities to the extent practicable and to the extent that the recommendations of such surveys and audits could be implemented under the terms of the lease.

Sec. 303. Implementation of Energy Efficiency and Water Conservation Projects.

(a) Implementation of New Audit Recommendations. Within 1 year of the date of this order, agencies shall identify, based on preliminary recommendations from the prioritization surveys required under section 302 of this order, high priority facilities to audit and shall complete the first 10 percent of the required comprehensive facility audits. Within 180 days of the completion of the comprehensive facility audit of each facility, agencies shall begin implementing cost-effective recommendations for installation of energy efficiency, water conservation, and renewable energy technologies for that facility.

(b) Implementation of Existing Audits. Within 180 days of the date of this order, agencies shall begin to implement cost-effective recommendations from comprehensive audits of facilities performed within the past 3 years, for installation of energy efficiency, water conservation, and renewable energy technologies.

Sec. 304. Solar and Other Renewable Energy. The goal of the Federal Government is to significantly increase the use of solar and other renewable energy sources. DOE shall develop a program for achieving this goal cost-effectively and, within 210 days of the

date of this order, submit the program to the 656 Committee for review. DOE shall lead the effort to assist agencies in meeting this goal.

Sec. 305. Minimization of Petroleum-Based Fuel Use in Federal Buildings and Facilities. All agencies shall develop and implement programs to reduce the use of petroleum in their buildings and facilities by switching to a less-polluting and nonpetroleum-based energy source, such as natural gas or solar and other renewable energy sources. Where alternative fuels are not practical or cost-effective, agencies shall strive to improve the efficiency with which they use the petroleum. Each agency shall survey its buildings and facilities that utilize petroleum-based fuel systems to determine where the potential for a dual-fuel capability exists and shall provide dual-fuel capability where cost-effective and practicable.

Sec. 306. New Space.

(a) New Federal Facility Construction. Each agency involved in the construction of a new facility that is to be either owned by or leased to the Federal Government shall:
(1) design and construct such facility to minimize the life cycle cost of the facility by utilizing energy efficiency, water conservation, or solar or other renewable energy technologies;
(2) ensure that the design and construction of facilities meet or exceed the energy performance standards applicable to Federal residential or commercial buildings as set forth in 10 CFR 435, local building standards, or a Btu-per-gross-square-foot ceiling as determined by the Task Force within 120 days of the date of this order, whichever will result in a lower life cycle cost over the life of the facility;
(3) establish and implement, within 270 days of the date of this order, a facility commissioning program that will ensure that the construction of such facilities meets the requirements outlined in this section before the facility is accepted into the Federal facility inventory; and
(4) utilize passive solar design and adopt active solar technologies where they are cost-effective.

(b) New Leases For Existing Facilities. To the extent practicable and permitted by law, agencies entering into leases, including the renegotiation or extension of existing leases, shall identify the energy and water consumption of those facilities and seek to incorporate provisions into each lease that minimize the cost of energy and water under a life cycle analysis, while maintaining or improving occupant health and safety. These requirements may include renovation of proposed space prior to or within the first year of each lease. Responsible agencies shall seek to negotiate the cost of the lease, taking into account the reduced energy and water costs during the term of the lease.
(c) Government-Owned Contractor-Operated Facilities. All Government-owned contractor-operated facilities shall comply with the goals and requirements of this order. Energy and water management goals shall be incorporated into their management contracts.

Sec. 307. Showcase Facilities.

(a) New Building Showcases. When an agency constructs at least five buildings in a year, it shall designate at least one building, at the earliest stage of development, to be a showcase highlighting advanced technologies and practices for energy efficiency, water conservation, or use of solar and other renewable energy.

(b) Demonstrations in Existing Facilities. Each agency shall designate one of its major buildings to become a showcase to highlight energy or water efficiency and also shall attempt to incorporate cogeneration, solar and other renewable energy technologies, and indoor air quality improvements. Selection of such buildings shall be based on considerations such as the level of nonfederal visitors, historic significance, and the likelihood that visitors will learn from displays and implement similar projects. Within 180 days of the date of this order, each agency shall develop and implement plans and work in cooperation with DOE and, where appropriate, in consultation with the General Services Administration ("GSA"), the Environmental Protection Agency ("EPA"), and other appropriate agencies, to determine the most effective and cost-effective strategies to implement these demonstrations.

Sec. 308. Annual Reporting Requirements.

(a) As required under the Act, the head of each agency shall report annually to the Secretary of Energy and OMB, in a format specified by the Secretary and OMB after consulting with the 656 Committee. The report shall describe the agency's progress in achieving the goals of this order.

(b) The Secretary of Energy shall report to the President and the Congress annually on the implementation of this order. The report should provide information on energy and water use and cost data and shall provide the greatest level of detail practicable for buildings and facilities by energy source.

Sec. 309. Report on Full Fuel Cycle Analysis. DOE shall prepare a report on the issues involved in instituting life cycle analysis for Federal energy and product purchases that address the full fuel cycle costs, including issues concerning energy exploration, development, processing, transportation, storage, distribution, consumption, and disposal, and related impacts on the environment. The report shall examine methods for conducting life cycle analysis and implementing such analysis in the Federal sector and shall make appropriate recommendations. The report shall be forwarded to the President for review.

Sec. 310. Agency Accountability. One year after the date of this order, and every 2 years thereafter, the President's Management Council shall report to the President about efforts and actions by agencies to meet the requirements of this order. In addition, each agency head shall designate a senior official, at the Assistant Secretary level or above, to be responsible for achieving the requirements of this order and shall appoint such official to the 656 Committee. The 656 Committee shall also work to ensure the implementation of this order. The agency senior official and the 656 Committee shall coordinate implementation with the Federal Environmental Executive and Agency Environmental Executives established under Executive Order No. 12873.

PART 4--USE OF INNOVATIVE FINANCING AND CONTRACTUAL MECHANISMS

Sec. 401. Financing Mechanisms. In addition to available appropriations, agencies shall utilize innovative financing and contractual mechanisms, including, but not limited to, utility demand side management programs, shared energy savings contracts, and energy savings performance contracts, to meet the goals and requirements of the Act and this order.

Sec. 402. Workshop for Agencies. Within a reasonable time of the date of this order, the Director of OMB, or his or her designee, and the Task Force shall host a workshop for agencies regarding financing and contracting for energy efficiency, water efficiency, and renewable technology projects. Based on the results of that meeting, the Administrator, Office of Procurement Policy ("OFPP"), shall assist the Administrator of General Services and the Secretary of Energy in eliminating unnecessary regulatory and procedural barriers that slow the utilization of such audit, financing, and contractual mechanisms or complicate their use. All actions that are cost-effective shall be implemented through the process required in section 403 of this order.

Sec. 403. Elimination of Barriers. Agency heads shall work with their procurement officials to identify and eliminate internal regulations, procedures, or other barriers to implementation of the Act and this order. DOE shall develop a model set of recommendations that will be forwarded to the Administrator of OFPP in order to assist agencies in eliminating the identified barriers.

PART 5--TECHNICAL ASSISTANCE, INCENTIVES, AND AWARENESS

Sec. 501. Technical Assistance.

(a) To assist Federal energy managers in implementing energy efficiency and water conservation projects, DOE shall, within 180 days of the date of this order, develop and make available through the Task Force:
(1) guidance explaining the relationship between water use and energy consumption and the energy savings achieved through water conservation measures;
(2) a model solicitation and implementation guide for innovative funding mechanisms referenced in section 401 of this order;
(3) a national list of companies providing water services in addition to the list of qualified energy service companies as required by the Act;
(4) the capabilities and technologies available through the national energy laboratories; and
(5) an annually-updated guidance manual for Federal energy managers that includes, at a minimum, new sample contracts or contract provisions, position descriptions, case studies, recent guidance, and success stories.

(b) The Secretary of Energy, in coordination with the Administrator of General Services, shall make available through the Task Force, within 180 days of

the date of this order:

(1) the national list of qualified water and energy efficiency contractors for inclusion on a Federal schedule; and
(2) a model provision on energy efficiency and water conservation, for inclusion in new leasing contracts.

(c) Within 180 days of the date of this order, the Administrator of General Services shall:
(1) contact each utility that has an area-wide contract with GSA to determine which of those utilities will perform "no-cost" audits for energy efficiency and water conservation and potential solar and other renewable energy sources that comply with Federal life cycle costing procedures set forth in Subpart A, 10 CFR 436;
(2) for each energy and water utility serving the Federal Government, determine which of those utilities offers demand-side management services and incentives and obtain a list and description of those services and incentives; and
(3) prepare a list of those utilities and make that list available to all Federal property management agencies through the Task Force.

(d) Within 18 months of the date of this order, the Administrator of General Services, in consultation with the Secretary of Energy, shall develop procurement techniques, methods, and contracts to speed the purchase and installation of energy, water, and renewable energy technologies in Federal facilities. Such techniques, methods, and contracts shall be designed to utilize both direct funding by the user agency, including energy savings performance contracting, and utility rebates. To the extent permitted by law, the Administrator of OFPP shall assist the Administrator of General Services and the Secretary of Energy by eliminating unnecessary regulatory and procedural barriers that would slow the implementation of such methods, techniques, or contracts or complicate their use.

(e) Agencies are encouraged to seek technical assistance from DOE to develop and implement solar and other renewable energy projects.

(f) DOE shall conduct appropriate training for Federal agencies to assist them in identifying and funding cost-effective projects. This training shall include providing software and other technical tools to audit facilities and identify opportunities. To the extent that resources are available, DOE shall work with utilities and the private sector to encourage their participation in Federal sector programs.
(g) DOE, in coordination with EPA, GSA, and the Department of Defense ("DOD"), shall develop technical assistance services for agencies to help identify energy efficiency, water conservation, indoor air quality, solar and other renewable energy projects, new building design, fuel switching, and life cycle cost analysis. These services shall include, at a minimum, a help line, computer bulletin board, information and education materials, and project tracking methods. Agencies shall identify technical assistance needed to meet the goals and requirements of the Act and this order and seek such assistance from DOE.

(h) The Secretary of Energy and the Administrator of General Services shall explore ways to stimulate energy efficiency, water conservation, and use of solar and other renewable energy sources and shall study options such as new building performance guidelines, life cycle value engineering, and designer/builder incentives such as award fees. The studies shall be completed within 270 days of the date of this order. The OFPP will issue guidance to agencies on life cycle value engineering within 6 months of the completion of the studies.

(i) The Secretary of Energy and the Administrator of General Services shall develop and distribute through the Task Force a model building commissioning program within 270 days of the date of this order.

(j) The lists, guidelines, and services in this section of the order shall be updated periodically.

Sec. 502. Retention of Savings and Rebates.

(a) Within a reasonable time after the date of this order, the Director of OMB, along with the Secretary of Energy, the Secretary of Defense, and the Administrator of General Services, to the extent practicable and permitted by law, shall develop guidelines and implement procedures to allow agencies, in fiscal year 1995 and beyond, to retain utility rebates and incentives received by the agency and savings from energy efficiency and water conservation efforts as provided in section 152 of the Energy Policy Act of 1992 and 10 U.S.C. 2865

and 2866.

Sec. 503. Performance Evaluations. To recognize the responsibilities of facility managers, designers, energy managers, their superiors, and, to the extent practicable and appropriate, others critical to the implementation of this order, heads of agencies shall include successful implementation of energy efficiency, water conservation, and solar and other renewable energy projects in their position descriptions and performance evaluations.

Sec. 504. Incentive Awards. Agencies are encouraged to review employee incentive programs to ensure that such programs appropriately reward exceptional performance in implementing the Act and this order. Such awards may include monetary incentives such as Quality Step Increases, leave time awards and productivity gainsharing, and nonmonetary and honor awards such as increased authority, additional resources, and a series of options from which employees or teams of employees can choose.

Sec. 505. Project Teams/Franchising.

(a) Agencies are encouraged to establish Energy Efficiency and Environmental Project Teams ("Project Teams") to implement energy efficiency, water conservation, and solar and other renewable energy projects within their respective agencies. DOE shall develop a program to train and support the Project Teams, which should have particular expertise in innovative financing, including shared energy savings and energy savings performance contracting. The purpose of the program is to enable project teams to implement projects quickly and effectively in their own agencies.

(b) Agencies are encouraged to franchise the services of their Project Teams. The ability to access the services of other agencies' teams will foster excellence in project implementation through competition among service providers, while providing an alternative method to meet or exceed the requirements of the Act and this order for agencies that are unable to devote sufficient personnel to implement projects.

Sec. 506. FEMP Account Managers. FEMP shall develop a customer service program and assign account managers to agencies or regions so that each project may have a designated account manager. When requested by an agency, the account manager shall start at the audit phase and follow a project through commissioning, evaluation, and reporting. The account manager shall provide technical assistance and shall have responsibility to see that all actions possible are taken to ensure success of the project.

Sec. 507. Procurement of Energy Efficient Products by Federal Agencies.

(a) "Best Practice" Technologies. Agencies shall purchase energy- efficient products in accordance with the guidelines issued by OMB, in consultation with the Defense Logistics Agency ("DLA"), DOE, and GSA, under section 161 of the Energy Policy Act of 1992. The guidelines shall include listings of energy-efficient products and practices used in the Federal Government. At a minimum, OMB shall update the listings annually. DLA, DOE, and GSA shall update the portions of the listings for which they have responsibility as new products become available and conditions change.
(1) Each agency shall purchase products listed as energy-efficient in the guidelines whenever practicable, and whenever they meet the agency's specific performance requirements and are cost-effective. Each agency shall institute mechanisms to set targets and measure progress.
(2) To further encourage a market for highly-energy-efficient products, each agency shall increase, to the extent practicable and cost-effective, purchases of products that are in the upper 25 percent of energy efficiency for all similar products, or products that are at least 10 percent more efficient than the minimum level that meets Federal standards. This requirement shall apply wherever such information is available, either through Federal or industry-approved testing and rating procedures.
(3) GSA and DLA, in consultation with DOE, other agencies, States, and industry and other nongovernment organizations, shall provide all agencies with information on specific products that meet the energy-efficiency criteria of this section. Product information should be made available in both printed and electronic formats.

(b) Federal Market Opportunities. DOE, after consultation with industry, utilities, and other interested parties, shall identify advanced energy-efficient and water-conserving technologies that are technically and commercially feasible but not yet available on the open market. These technologies may include, but are not limited to, the advanced appliance technologies referenced in

section 127 of the Energy Policy Act of 1992. DOE, in cooperation with OMB, GSA, DOD, the National Institute of Standards and Technology ("NIST"), and EPA, shall issue a "Federal Procurement Challenge" inviting each Federal agency to commit a specified fraction of their purchases within a given time period to advanced, high-efficiency models of products, provided that these anticipated future products can meet the agency's energy performance, functionality, and cost requirements.

(c) Accelerated Retirement of Inefficient Equipment. DOE, in consultation with GSA and other agencies, shall establish guidelines for the cost-effective early retirement of older, inefficient appliances and other energy and water-using equipment in Federal facilities. Such guidelines may take into account significant improvements in energy efficiency and water conservation, opportunities to down-size or otherwise optimize the replacement equipment as a result of associated improvements in building envelope, system, or industrial process efficiency and reductions in pollutant emissions, use of chlorofluorocarbons, and other environmental improvements.

(d) Review of Barriers. Each agency shall review and revise Federal or military specifications, product descriptions, and standards to eliminate barriers to, and encourage Federal procurement of, products that are energy-efficient or water conserving.

PART 6--WAIVERS

Sec. 601. Waivers. Each agency may determine whether certain requirements in this order are inconsistent with the mission of the agency and seek a waiver of the provision from the Secretary of Energy. Any waivers authorized by the Secretary of Energy shall be included in the annual report on Federal energy management required under the Act.

PART 7--REVOCATION, LIMITATION, AND IMPLEMENTATION

Sec. 701. Executive Order No. 12759, of April 17, 1991, is hereby revoked, except that sections 3, 9, and 10 of that order shall remain effective and shall not be revoked.

Sec. 702. This order is intended only to improve the internal management of the executive branch and is not intended to, and does not create, any right to administrative or judicial review, or any other right or benefit or trust responsibility, substantive or procedural, enforceable by a party against the United States, its agencies or instrumentalities, its officers or employees, or any other person.

Sec. 703. This order shall be effective immediately.

(Presidential Sig.)<Clinton1><><Clinton2>

THE WHITE HOUSE,

March 8, 1994.

[FR Doc. 94-5834
Filed 3-9-94; 11:02 am]
Billing code 3195-01-P

FEDERAL PROPERTY MANAGEMENT REGULATIONS [41 C.F.R. CH. 101 (1 JULY 1991 EDITION)]

The following is an excerpt from the Federal Property Management Regulations, 41 C.F.R. Ch. 101:

§101-20.107 ENERGY CONSERVATION

Agencies shall comply with the energy conservation guidelines set forth in 10 C.F.R. Part 436 (Federal Energy Management and Planning Programs) and shall observe the energy conservation policies cited herein.

(a) Agencies shall ensure that lights and equipment are turned off when not needed, that ventilation is not blocked or impeded, and that windows and other building accesses are closed during the heating and cooling seasons.

(b) Except where special circumstances exist, illumination levels shall be maintained as near as is practical to the following standards:

(1) 50 foot-candles at work station surfaces, measured at a height of 30 inches above floor level, during working hours (For visually difficult or critical tasks, additional lighting may be authorized by the GSA buildings manager or by agencies that have been given delegated authority to perform buildings management functions.);

(2) 30 foot-candles in work areas during working hours, measured at 30 inches above floor level;

(3) 10 foot-candles, but not less than 1 foot-candle, in non-work areas, sufficient to ensure safety in non-work areas during working hours. (Normally this will require levels of 5 foot-candles at elevator boarding areas, a minimum of 1 foot-candle at the middle of corridors and stairwells as measured at the walking surface, and 10 foot-candles in storage areas.); and

(4) Other lighting essential for safety and security purposes, including exit signs and exterior lights, shall be maintained.

(c)Within the limitations of the building systems, heating and cooling systems shall be operated in the most overall energy-efficient and economical manner.

(1) Thermostats shall be set to maintain temperatures between 66 and 70 degrees Fahrenheit during the heating season, and 76 and 80 degrees Fahrenheit during the cooling season. During nonworking hours, the heating temperature shall be set no higher than 55 degrees Fahrenheit and air-conditioning will not be provided. Temperatures in warehouses, loading docks, inspection facilities, and other similar spaces subject to external traffic shall be adjusted lower than 65 degrees Fahrenheit depending upon the type of occupancy and activity.

(2) The locations used for measurement of temperature to determine compliance will be representative of the spaces to be heated and cooled.

(3) Work stations which are the most adversely affected may be the basis for establishing the temperature levels throughout that portion of the building

(4) Reheating, humidification, and simultaneous heating and cooling shall not be permitted.

(5) During extreme weather conditions, building systems shall be operated as necessary to protect the physical condition of the building.

(d) The operation of portable heaters, fans, and other such devices in Government-controlled space is prohibited unless authorized by the GSA buildings manager or by agencies that have been given delegated authority to perform buildings management functions.

(e) Within limitations of the building system, ventilation will be provided in the most cost-effective manner. During working hours, 5 cubic feet per minute, per person, will be the minimum provided during the periods of heating or cooling. Additional outside air above this minimum level can be provided to allow "free" cooling.

(f) Energy standards for existing buildings will be no less stringent than those prescribed by the American Society of Heating, Refrigerating, and Air Conditioning Engineers and the illuminating Engineering Society of North America in ASHRAE/IES Standard 90A-1980, as amended by the Department of Energy (DOE). These energy standards are applicable where they can be achieved through life-cycle, cost-effective actions.

(g) Exceptions to the foregoing policies may be necessary for specialized requirements of agencies to accomplish their missions more effectively and efficiently. Such exceptions may be granted by the GSA buildings manager or by agencies that have been given delegated authority to perform buildings management functions.

(h) Contracting officers shall ensure that all new lease contracts are in conformance with the policies prescribed in this § 101-20.107. Existing lease contracts shall be administered in accordance with these policies to the maximum extent feasible.

(i) Each agency shall report to the Department of Energy (DOE) the energy consumption in buildings, facilities, vehicles, and equipment under its control within 45 calendar days after the end of each quarter as specified in the DOE Federal Energy Usage Report DOE F 6200.2 instructions. This report has been cleared in accordance with FPMR 101-11.11,[1] the Interagency Reports Management Program, and assigned interagency report control number 1492 DOE OU.

[52 FR 11263, Apr.8,1987: 52 FR 24158, July 29,1987]

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[1] Editorial Note: At 50 FR 26908, June 28, 1985, 41 CFR part 101-11 was recodified as 41 CFR parts 201-22 and 201-45. The reference to FPMR 101-11.11 should read FIRMR 201-45.6.

ENERGY POLICY ACT OF 1992
FEDERAL ENERGY MANAGEMENT PROVISIONS
SUBTITLE F – FEDERAL AGENCY ENERGY MANAGEMENT

SEC. 151. DEFINITIONS.

For purposes of this subtitle-

(1) the term "agency" means has the meaning given such term in section 551(1) of title 5, United States Code, except that such term does not include the United States Postal Service;

(2) the term "facility energy supervisor" means the employee with responsibility for the daily operations of a Federal facility, including the management, installation, operation, and maintenance of energy systems in Federal facilities which may include more than one building;

(3) the term "trained energy manager" means a person who has demonstrated proficiency, or who has completed a course of study in the areas of fundamentals of building energy systems, building energy codes and applicable professional standards, energy accounting and analysis, life-cycle cost methodology, fuel supply and pricing, and instrumentation for energy surveys and audits;

(4) the term "Task Force" means the Interagency Energy Management Task Force established under section 574 of the National Energy Conservation Policy Act (42 U.S.C. 8257); and

(5) the term "energy conservation measures" has the meaning given such term in section 551(4) of the National Energy Conservation Policy Act.

SEC. 152. FEDERAL ENERGY MANAGEMENT AMENDMENTS.

(Amends Sections 542 to 550, Part 3, of NECPA, 42 U.S.C. 8252 as follows)

SEC. 541. FINDINGS.
(No change)

SEC. 542. PURPOSE.

It is the purpose of this part to promote the conservation and the efficient use of energy and water, and the use of renewable energy sources, by the Federal Government.

SEC. 543. ENERGY MANAGEMENT REQUIREMENTS.

(a) Energy Performance Requirement for Federal Buildings.-(1) Subject to paragraph (2), each agency shall apply energy conservation measures to, and shall improve the design for the construction of, its Federal buildings so that the energy consumption per gross square foot of its Federal buildings in use during the fiscal year 1995 is at least 10 percent less than the energy consumption per gross square foot of its Federal buildings in use during the fiscal year 1985 and so that the energy consumption per gross square foot of its Federal buildings in use during the fiscal year 2000 is at least 20 percent less than the energy consumption per gross square foot of its Federal buildings in use during fiscal year 1985.

(2) An agency may exclude from the requirements of paragraph (1) any building, and the associated energy consumption and gross square footage, in which energy intensive activities are carried out. Each agency shall identify and list in each report made under Section 548(a) the buildings designated by it for such exclusion.

(b) Energy Management Requirement for Federal Agencies.-(1) Not later than January 1, 2005, each agency shall, to the maximum extent practicable, install in Federal buildings owned by the United States all energy and water conservation measures with payback periods of less than 10 years, as determined by using the methods and procedures developed pursuant to section 544.

(2) The Secretary may waive the requirements of this subsection for any agency for such periods as the Secretary may determine if the Secretary finds that the agency is taking all practicable steps to meet the requirements and that the requirements of this subsection will pose an unacceptable burden upon the agency. If the Secretary waives the requirements of this subsection, the Secretary shall notify the Congress promptly in writing with an explanation and a justification of the reasons for such waiver.

(3) This subsection shall not apply to an agency's facilities that generate or transmit electric energy or to the uranium enrichment facilities operated by the Department of Energy.

(4) An agency may participate in the Environmental Protection Agency's "Green Lights" program for purposes of receiving technical assistance in complying with the requirements of this section.

(c) Exclusions.-(1) An agency may exclude, from the energy consumption requirements for the year 2000 established under subsection (a) and the requirements of subsection (b)(1), any Federal building or collection of Federal buildings, and the associated energy consumption and gross square footage, if the head of such agency finds that compliance with such requirements would be impractical. A finding of impracticability shall be based on the energy intensiveness of activities carried out in such Federal buildings or collection of Federal buildings, the type and amount of energy consumed, the technical feasibility of making the desired changes, and, in the cases of the Departments of Defense and Energy, the unique character of certain facilities operated by such Departments.

(2) Each agency shall identify and list, in each report made under section 548(a), the Federal buildings designated by it for such exclusion. The Secretary shall review such findings for consistency with the impracticability standards set forth in paragraph (1), and may within 90 days after receipt of the findings, reverse a finding of impracticability. In the case of any such reversal, the agency shall comply with the energy consumption requirements for the building concerned.

(d) Implementation Steps.-The Secretary shall consult with the Secretary of Defense and the Administrator of General Services in developing guidelines for the implementation of this part. To meetthe requirements of this section, each agency shall-

(1) prepare and submit to the Secretary, not later than December 31, 1993, a plan describing how the agency intends to meet such requirements, including how it will-

(A) designate personnel primarily responsible for achieving such requirements;

(B) identify high priority projects through calculation of payback periods;

(C) take maximum advantage of contracts authorized under Title VIII of this Act, of financial incentives and other services provided by utilities for efficiency investment, and of other forms of financing to reduce the direct costs to the Government; and

(D) otherwise implement this part.

(2) perform energy surveys of its Federal buildings to the extent necessary and update such surveys as needed, incorporating any relevant information obtained from the survey conducted pursuant to Section 550;

(3) using such surveys, determine the cost and payback period of energy and water conservation measures likely to achieve the requirements of this section;

(4) install energy and water conservation measures that will achieve the requirements of this section through the methods and procedures established pursuant to Section 544; and

(5) ensure that the operation and maintenance procedures applied under this section are continued.

SEC. 544. ESTABLISHMENT AND USE OF LIFE CYCLE COST METHODS AND PROCEDURES.

(a) Establishment of Life Cycle Cost Methods and Procedures.-The Secretary, in consultation with the Director of the Office of Management and Budget, the Secretary of Defense, the Director of the National Institute of Standards and Technology, and the Administrator of the General Services Administration, shall-

(1) establish practical and effective present value methods for estimating and comparing life cycle costs for Federal buildings, using the sum of all capital and operating expenses associated with the energy system of the building involved over the expected life of such system of during a period of 25 years, whichever is shorter, and using average fuel costs and a discount rate determined by the Secretary; and

(2) develop and prescribe the procedures to be followed in applying and implementing the methods so established.

(b) Use of Life Cycle Cost Methods and Procedures.-
(1) The design of new Federal buildings, and the application of energy conservation measures to existing Federal buildings, shall be made using life cycle cost methods and procedures established under subsection (a).
(2) In leasing buildings for its own use or that of another agency, each agency shall, after January 1, 1994, fully consider the efficiency of all potential building space at the time of renewing or entering into a new lease.

(c) Use in Non-Federal Structures.-The Secretary shall make available information to the public on the use of life cycle cost methods in the construction of buildings, structures, and facilities in all segments of the economy.

SEC. 545. BUDGET TREATMENT FOR ENERGY CONSERVATION MEASURES.

The President shall transmit to the Congress, along with each budget that is submitted to the Congress under Section 1105 of Title 31, United States Code, a statement of the amount of appropriations requested in such budget, if any, on an individual agency basis, for-

(1) electric and other energy costs to be incurred in operating and maintaining agency facilities; and

(2) compliance with the provisions of this part, the Energy Policy and Conservation Act (42 U.S.C. 6201 et seq.) and all applicable Executive Orders, including Executive Order 12003 (42 U.S.C. 6201 note) and Executive Order 12759 (56 Fed. Reg. 16257).

SEC. 546. INCENTIVES FOR AGENCIES.

(a) Contracts.-(1) Each agency shall establish a program of incentives for conserving, and otherwise making more efficient use of, energy as a result of entering into contracts under Title VIII of this Act.

(2) The Secretary shall, not later than 18 months after the date of the enactment of the Energy Policy Act of 1992 and after consultation with the Director of the Office of Management and Budget, the Secretary of Defense, and the Administrator of General Services, develop appropriate procedures and methods for use by agencies to implement the incentives referred to in paragraph (1).

(b) Federal Energy Efficiency Fund.-(1) The Secretary shall establish a Federal Energy Efficiency Fund to provide grants to agencies to assist them in meeting the requirements of Section 543.

(2) Not later than June 30, 1993, the Secretary shall issue guidelines to be followed by agencies submitting proposals for such grants. All agencies shall be eligible to submit proposals for grants under the Fund.

(3) The Secretary shall award grants from the Fund after a competitive assessment of the technical and economic effectiveness of each agency proposal. The Secretary shall consider the following factors in determining whether to provide funding under this subsection:

(A) The cost-effectiveness of the project.

(B) The amount of energy and cost savings anticipated to the Federal Government.

(C) The amount of funding committed to the project by the agency requesting financial assistance.

(D) The extent that a proposal leverages financing from other non-Federal sources.

(E) Any other factor which the Secretary determines will result in the greatest amount of energy and cost savings to the Federal Government.

(4) There are authorized to be appropriated, to remain available to be expended, to carry out this subsection not more than $10,000,000 for fiscal year 1994. $50,000,000 for fiscal year 1995, and such sums as may be necessary for fiscal years thereafter.

(c) Utility Incentive Programs.-(1) Agencies are authorized and encouraged to participate in programs to increase energy efficiency and for water conservation or the management of electricity demand conducted by gas, water, or electric utilities and generally available to customers of such utilities.

(2) Each agency may accept any financial incentive, goods, or services generally available from any such utility, to increase energy efficiency or to conserve water or manage electricity demand.

(3) Each agency is encouraged to enter into negotiations with electric, water, and gas utilities to

design cost-effective demand management and conservation incentive programs to address the unique needs of facilities utilized by such agency.

(4) If an agency satisfies the criteria which generally apply to other customers of a utility incentive program, such agency may not be denied collection of rebates or other incentives.

(5)(A) An amount equal to fifty percent of the energy and water cost savings realized by an agency (other than the Department of Defense) with respect to funds appropriated for any fiscal year beginning after fiscal year 1992 (including financial benefits resulting from energy savings performance contracts under title VIII and utility energy efficiency rebates) shall, subject to appropriation, remain available for expenditure by such agency for additional energy efficiency measures which may include related employee incentive programs, particularly at those facilities at which energy savings were achieved.

(B) Agencies shall establish a fund and maintain strict financial accounting and controls for savings realized and expenditures made under this subsection. Records maintained pursuant to this subparagraph shall be made available for public inspection upon request.

(d) Financial Incentive Program for Facility Energy Managers.-(1) The Secretary shall, in consultation with the Task Force established pursuant to section 547, establish a financial bonus program to reward, with funds made available for such purpose, outstanding Federal facility energy managers in agencies and the United States Postal Service.

(2) Not later than June 1, 1993, the Secretary shall issue procedures for implementing and conducting the award program, including the criteria to be used in selecting outstanding energy managers and contributors who have-
(A) improved energy performance through increased energy efficiency;

(B) implemented proven energy efficiency and energy conservation techniques, devices, equipment, or procedures;

(C) developed and implemented training programs for facility energy managers, operators, and maintenance personnel;

(D) developed and implemented employee awareness programs;

(E) succeeded in generating utility incentives, shared energy savings contracts, and other federally approved performance based energy savings contracts;

(F) made successful efforts to fulfill compliance with energy reduction mandates, including the provisions of section 543; and

(G) succeeded in the implementation of the guidelines established under Section 159.

(3) There is authorized to be appropriated to carry out this subsection not more than $250,000 for each of the fiscal years 1993, 1994, and 1995.

SEC. 547. INTERAGENCY ENERGY MANAGEMENT TASK FORCE.

(No change)

SEC. 548. REPORTS.

(a) Reports to the Secretary.-Each agency shall transmit a report to the Secretary, at times specified by the Secretary but at least annually, with complete information on its activities under this part, including information on--

(1) the agency's progress in achieving the goals established by Section 543; and

(2) the procedures being used by the agency pursuant to Section 546(a)(2), the number of contracts entered into by such agency under Title VIII of this act, the energy and cost savings that have resulted from such contracts, the use of such cost savings under Section 546(c), and any problem encountered in entering into such contracts and otherwise implementing Section 546.

(b) Reports to Congress.--The Secretary shall report not later than April 2 of each year, with respect to each fiscal year beginning after the date of the enactment of this subsection, to the Congress--

(1) on all activities carried out under this part and on the progress made toward achievement of the objectives of this part, including--

(A) a copy of the list of the exclusions made under Sections 543(a)(2) and 543(c)(3); and

(B) a statement detailing the amount of funds awarded to each agency under Section 546(b), the energy and water conservation measures installed with such funds, the projected energy and water savings to be realized from installed measures, and, for each installed measure for which the projected energy and water savings reported in the previous year were not realized, the percentage of such projected savings that was not realized, the reasons such savings were not realized, and proposals for, and projected costs of, achieving such projected savings in the future.

(2) the number of contracts entered into by all agencies under Title VIII of this Act, the difficulties (if any) encountered in attempting to enter into such contracts, and the proposed solutions to those difficulties; and

(3) the extent and nature of interagency exchange of information concerning the conservation and efficient utilization of energy.

(c) Other Report.--The Secretary, in consultation with the Administrator of General Services, shall--

(1) conduct a study and evaluate legal, institutional, and other constraints to connecting buildings owned or leased by the Federal Government to district heating and district cooling systems; and

(2) not later than 18 months after the date of the enactment of this subsection, transmit to the Congress a report containing the findings and conclusions of such study, including recommendations for the development of streamlined processes for the consideration of connecting buildings owned or leased by the Federal Government to district heating and cooling systems.

SEC. 549. DEMONSTRATION OF NEW TECHNOLOGY.

(a) Demonstration Program.--Not later than January 1, 1994, the Secretary, in cooperation with the Administrator of General Services, shall establish a demonstration program to install, in federally owned facilities or federally assisted housing, energy conservation measures for which the Secretary has determined that such installation would accelerate commercial viability. In those cases where technologies are determined to be equivalent, priority shall be given to those technologies that have received or are receiving Federal financial assistance.

(b) Selection Criteria.--In addition to the determination under subsection (a), the Secretary shall select, in cooperation with the Administrator of General Services, proposals to be funded under this section on the basis of--

(1) cost-effectiveness;

(2) technical feasibility and system reliability in a working environment;

(3) lack of market penetration in the Federal sector;

(4) the potential needs of the proposing Federal agency for the technology, projected over 5 to 10 years;

(5) the potential Federal sector market, projected over 5 to 10 years;

(6) energy efficiency; and

(7) other environmental benefits, including the projected reduction of greenhouse gas emissions and indoor air pollution.

(c) Proposals.--Federal agencies may submit to the Secretary, for each fiscal year, proposals for projects to be funded by the Secretary under this section. Each such proposal shall include--

(1) a description of the proposed project emphasizing the innovative use of technology in the Federal sector;

(2) a description of the technical reliability and cost-effectiveness data expected to be acquired;

(3) an identification of the potential needs of the Federal agency for the technology;

(4) a commitment to adopt the technology, if the project establishes its technical reliability and life cycle cost-effectiveness, to supply at least 10 percent of the Federal agency--s potential needs identified under paragraph (3);

(5) schedules and milestones for installing additional units; and

(6) a technology transfer plan to publicize the results of the project.

(d) Participation by GSA.--The Secretary may only select a project for funding under the jurisdiction of the General Services Administration if the project will be carried out by the Administrator of General Services. If such project involves a total expenditure in excess of $1,6000,000, no appropriation shall be made for such project unless such project has been approved by a resolution adopted by the Committee on Public Works and Transportation of the House of Representatives and the Committee on Environment and Public Works of the Senate.

(e) Study.--The Secretary shall conduct a study to evaluate the potential use of the purchasing power of the Federal Government to promote the development and commercialization of energy efficient products. The study shall identify products for which there is a high potential for Federal purchasing power to substantially promote their development and commercialization, and shall include a plan to develop such potential. The study shall be conducted in consultation with utilities, manufacturers, and appropriate nonprofit organizations concerned with energy efficiency. The Secretary shall report to the Congress on the results of the study not later than two years after the date of the enactment of this Act.

(f) Authorization of Appropriations.--There are authorized to be appropriated to the Secretary for carrying out this section $5,000,000 for each of the fiscal years 1993, 1994, and 1995.

SEC. 550. SURVEY OF ENERGY SAVING POTENTIAL.

(a) In General.--The Secretary shall, in consultation with the Interagency Energy Management Task Force established under Section 547, carry out an energy survey for the purposes of--

(1) determining the maximum potential cost effective energy savings that may be achieved in a representative sample of buildings owned or leased by the Federal Government in different areas of the country;

(2) making recommendations for cost effective energy efficiency and renewable energy improvements in those buildings and in other similar Federal buildings; and

(3) identifying barriers which may prevent an agency's ability to comply with Section 543 and other energy management goals.

(b) Implementation.--(1) The Secretary shall transmit to the Committee on Energy and Natural Resources and the Committee on Governmental Affairs of the Senate and the Committee on Energy and Commerce, the Committee on Government Operations, and the Committee on Public Works and Transportation of the House of Representatives, within 180 days after the date of the enactment of the Energy Policy Act of 1992, a plan for implementing this section.

(2) The Secretary shall designate buildings to be surveyed in the project so as to obtain a sample of the buildings of the types and in the climates that is representative of buildings owned or leased by Federal agencies in the United States that consume the major portion of the energy consumed in Federal buildings. Such sample shall include, where appropriate, the following types of Federal facility space:

(A) Housing.
(B) Storage.
(C) Office.
(D) Services.
(E) Schools.
(F) Research and Development.
(G) Industrial.
(H) Prisons.
(I) Hospitals.

(3) For purposes of this section, an improvement shall be considered cost effective if the cost of the energy saved or displaced by the improvement exceeds the cost of the improvement over the remaining life of a Federal building or the remaining term of a lease of a building leased by the Federal Government as determined by the life cycle costing methodology developed under Section 544.

(c) Personnel.--(1) In carrying out this section, the Secretary shall utilize personnel who are--

(A) employees of the Department of Energy; or

(B) selected by the agencies utilizing the buildings which are being surveyed under this section.

(2) Such personnel shall be detailed for the purpose of carrying out this section without any reduction of salary or benefits.

(d) Report.--As soon as practicable after the completion of the project carried out under this section, the Secretary shall transmit a report of the findings and conclusions of the project to the Committee on Energy and Natural Resources and the Committee on Governmental Affairs of the Senate, the Committee on Energy and Commerce, the Committee on Government Operations, and the Committee on Public Works and Transportation of the House of Representatives, and the agencies who own the buildings involved in such project. Such report shall include an analysis of the probability of each agency achieving the 20 percent reduction goal established under Section 543(a) of the National Energy Conservation Policy Act (42 U.S.C. 8253(a)).

SEC. 551. DEFINITIONS.

(No change)

SEC. 153. GENERAL SERVICES ADMINISTRATION FEDERAL BUILDINGS FUND.

Section 210(f) of the Federal Property and Administrative Services Act of 1949 (40 U.S.C. 490(f)), is amended--

(1) in paragraph (1), by inserting "(to be known as the Federal Buildings Fund)" after "a fund"; and

(2) by adding at the end the following new paragraphs:

(7)(A) The Administrator is authorized to receive amounts from rebates or other cash incentives related to energy savings and shall deposit such amounts in the Federal Buildings Fund for use as provided in subparagraph (D).

(B) The Administrator may accept, from a utility, goods or services which enhance the energy efficiency of Federal facilities.

(C) In the administration of any real property for which the Administrator leases and pays utility costs, the Administrator may assign all or a portion of energy rebates to the lessor to underwrite the costs incurred in undertaking energy efficiency improvements in such real property if the payback period for such improvement is at least 2 years less than the remainder of the term of the lease.

(D) The Administrator may, in addition to amounts appropriated for such purposes and without regard to paragraph (2), obligate for energy management improvement programs--

(i) amounts received and deposited in the Federal Buildings fund under subparagraph (A);

(ii) goods and services received under subparagraph (B); and

(iii) amounts the Administrator determines are not needed for other authorized projects and are otherwise available to implement energy efficiency programs.

(8)(A) The Administrator is authorized to receive amounts from the sale of recycled materials and shall deposit such amounts in the Federal Buildings fund for use as provided in subparagraph (B).

(B) The Administrator may, in addition to amounts appropriated for such purposes and without regard to paragraph (2), obligate amounts received and deposited in the Federal Buildings Fund under subparagraph (A) for programs which--

(i) promote further source reduction and recycling programs; and

(ii) encourage employees to participate in recycling programs by providing funding for child care.

SEC. 154. REPORT BY GENERAL SERVICES ADMINISTRATION.

Not later than one year after the date of the enactment of this Act, and annually thereafter, the Administrator of General Services shall report to the Committee on Governmental Affairs and the Committee on Energy and Natural Resources of the Senate and the Committee on Energy and Commerce, the Committee on Government Operations, and the Committee on Public Works and Transportation of the House of Representatives on the activities of the General Services Administration conducted pursuant to this subtitle.

SEC. 155. ENERGY SAVINGS PERFORMANCE CONTRACTS.

Amends Section 801 of the National Energy Conservation Policy Act (42 U.S.C. 8287) as follows--

TITLE VIII--ENERGY SAVINGS PERFORMANCE CONTRACTS

SEC. 801. AUTHORITY TO ENTER INTO CONTRACTS.

(a) In General.--(1) The head of a Federal agency may enter into contracts under this title solely for the purpose of achieving energy savings and benefits ancillary to that purpose. Each such contract may, notwithstanding any other provision of law, be for a period not to exceed 25 years. Such contract shall provide that the contractor shall incur costs of implementing energy savings measures, including at least the cost (if any) incurred in making energy audits, acquiring and installing equipment, and training personnel, in exchange for a share of any energy savings directly resulting from implementation of such measures during the term of the contract.

(2)(A) Contracts under this title shall be energy savings performance contracts and shall require an annual energy audit and specify the terms and conditions of any government payments and performance guarantees. Any such performance guarantee shall provide that the contractor is responsible for maintenance and repair services for any energy related equipment, including computer software systems.

(B) Aggregate annual payments by an agency to both utilities and energy savings performance contractors, under an energy savings performance contract, may not exceed the amount that the agency would have paid for utilities without an energy savings performance contract (as estimated through the procedures developed pursuant to this section) during contract years. The contract shall provide for a guarantee of savings to the agency, and shall establish payment schedules reflecting such guarantee, taking into account any capital costs under the contract.

(C) Federal agencies may incur obligations pursuant to such contracts to finance energy conservation measures provided guaranteed savings exceed the debt service requirements.

(D) A federal agency may enter into a multiyear contract under this title for a period not to exceed 25 years, without funding of cancellation charges before cancellation, if--

(i) such contract was awarded in a competitive manner pursuant to subsection (b)(2), using procedures and methods established under this title;

(ii) funds are available and adequate for payment of the costs of such contract for the first fiscal year;

(iii) 30 days before the award of any such contract that contains a clause setting forth a cancellation ceiling in excess of $750,000, the head of such agency gives written notification of such proposed contract and of the proposed cancellation ceiling for such contract to the appropriate authorizing and appropriating committees of the Congress; and

(iv) such contract is governed by part 17.1 of the Federal Acquisition Regulation promulgated under section 25 of the Office of Federal Procurement Policy Act (41 U.S.C. 421) or the applicable rules promulgated under this title.

(b) Implementation.--(1)(A) The Secretary, with the concurrence of the Federal Acquisition Regulatory Council established under section 25(a) of the Office of Federal Procurement Policy Act, not later than 180 days after the date of the enactment of the Energy Policy Act of 1992, shall, by rule, establish appropriate procedures and methods for use by Federal agencies to select, monitor, and terminate contracts with energy service contractors in accordance with laws governing Federal procurement that will achieve the intent of this section in a cost-effective manner. In developing such procedures and methods, the Secretary, with the concurrence of the Federal Acquisition Regulatory Council, shall determine which existing regulations are inconsistent with the intent of this section and shall formulate substitute regulations consistent with laws governing Federal procurement.

(B) The procedures and methods established pursuant to subparagraph (A) shall be the procedures and contracting methods for selection, by an agency, of a contractor to provide energy savings performance services. Such procedures and

methods shall provide for the calculation of energy savings based on sound engineering and financial practices.

(2) The procedures and methods established pursuant to paragraph (1)(A) shall--

(A) allow the Secretary to--

(i) request statements of qualifications, which shall, at a minimum, include prior experience and capabilities of contractors to perform the proposed types of energy savings services and financial and performance information, from firms engaged in providing energy savings services; and (ii) from the statements received, designate and prepare a list, with an update at least annually, of those firms that are qualified to provide energy savings services;

(B) require each agency to use the list prepared by the Secretary pursuant to subparagraph (A)(ii) unless the agency elects to develop an agency list of firms qualified to provide energy savings performance services using the same selection procedures and methods as are required of the Secretary in preparing such lists; and

(C) allow the head of each agency to--

(i) select firms from the list prepared pursuant to subparagraph
(A)(ii) or the list prepared by the agency pursuant to subparagraph
(B) to conduct discussions concerning a particular proposed energy savings project, including requesting a technical and price proposal from such selected firms for such project;

(ii) select from such firms the most qualified firm to provide energy savings services based on technical and price proposals and any other relevant information;

(iii) permit receipt of unsolicited proposals for energy savings performance contracting services from a firm that such agency has determined is qualified to provide such services under the procedures established pursuant to paragraph (1)(A), and require agency facility managers to place a notice in the Commerce Business Daily announcing they have received such a proposal and invite other similarly qualified firms to submit competing proposals; and

(iv) enter into an energy savings performance contract with a firm qualified under clause (iii), consistent with the procedures and methods established pursuant to paragraph (1)(A).

(3) A firm not designated as qualified to provide energy savings services under paragraph (2)(A)(i) or paragraph (2)(B) may request a review of such decision to be conducted in accordance with procedures to be developed by the board of contract appeals of the General Services Administration. Procedures developed by the board of contract appeals under this paragraph shall be substantially equivalent to procedures established under section 111(f) of the Federal Property and Administrative Services Act of 1949 (40 U.S.C. 759(f)).

(c) Sunset and Reporting Requirements.--(1) The authority to enter into new contracts under this section shall cease to be effective five years after the date procedures and methods are established under subsection (b).

(2) Beginning one year after the date procedures and methods are established under subsection (b), and annually thereafter, for a period of five years after such date, the Comptroller General of the United States shall report on the implementation of this section. Such reports shall include, but not be limited to, an assessment of the following issues:

(A) The quality of the energy audits conducted for the agencies.

(B) The government's ability to maximize energy savings.

(C) The total energy cost savings accrued by the agencies that have entered into such contracts.

(D) The total costs associated with entering into and performing such contracts.

(E) A comparison of the total costs incurred by agencies under such contracts and the total costs incurred under similar contracts performed in the private sector.

(F) The number of firms selected as qualified firms under this section and their respective shares of awarded contracts.

(G) The number of firms engaged in similar activity in the private sector and their respective market shares.

(H) The number of applicant firms under this section and the reason for their nonselection.

(I) The frequency with which agencies have utilized the services of government labs to perform any of the functions specified in this section.

(J) With the respect to the final report submitted pursuant to this paragraph, an assessment of whether the contracting procedures developed pursuant to this section and utilized by agencies have been effective and whether continued use of such procedures, as opposed to the procedures provided by existing public contract law, is necessary for implementation of successful energy savings performance contracts.

SEC. 802. PAYMENT OF COSTS.

SEC. 803. REPORTS.

SEC. 804. DEFINITIONS.

For the purposes of the title, the following definitions apply:

(1) The term "Federal agency" means an agency defined in section 551(1) of title, United States Code.

(2) The term "energy savings" means a reduction in the cost of energy, from a base cost established through a methodology set forth in the contract, utilized in an existing federally owned building or buildings or other federally owned facilities as a result of--

(A) the lease or purchase of operating equipment, improvements, altered operation and maintenance, or technical services; or

(B) the increased efficient use of existing energy sources by cogeneration or heat recovery, excluding any cogeneration process for other than a federally owned building or buildings or other federally owned facilities.

(3) The terms "energy savings contract" and "energy savings performance contract" mean a contract which provides for the performance of services for the design, acquisition, installation, testing, operation, and, where appropriate, maintenance and repair, of an identified energy conservation measure or series of measures at one or more locations. Such contracts--

(A) may provide for appropriate software licensing agreements; and

(B) shall, with respect to an agency facility that is a public building as such term is defined in section 13(1) of the Public Buildings Act of 1959 (40 U.S.C. 612(1)), be in compliance with the prospectus requirements and procedures of section 7 of the Public Buildings Act of 1959 (40 U.S.C. 606).

(4) The term "energy conservation measures" has the meaning given such term in section 551(4).

SEC. 156. INTERGOVERNMENTAL ENERGY MANAGEMENT PLANNING AND COORDINATION.

(a) Conference Workshops.--The Administrator of General Services, in consultation with the Secretary and the Task Force, shall hold regular, biennial conference workshops in each of the 10 standard Federal regions on energy management, conservation, efficiency, and planning strategy. The Administrator shall work and consult with the Department of Energy and other Federal agencies to plan for particular regional conferences. The Administrator shall invite Department of Energy, State, local, tribal, and county public officials who have responsibilities for energy management or may have an interest in such conferences and shall seek the input of, and be responsive to, the views of such officials in the planning and organization of such workshops.

(b) Focus of Workshops.--Such workshops and conferences shall focus on the following (but may include other topics):

(1) Developing strategies among Federal, State, tribal, and local governments to coordinate energy management policies and to maximize available intergovernmental energy management resources within the region regarding the use of governmental facilities and buildings.

(2) The design, construction, maintenance, and retrofitting of governmental facilities to incorporate energy efficient techniques.

(3) Procurement and use of energy efficient products.

(4) Dissemination of energy information on innovative programs, technologies, and methods which have proven successful in government.

(5) Technical assistance to design and incorporate effective energy management strategies.

(c) Establishment of Workshop Timetable.--As a part of the first report to be submitted pursuant to section 154, the Administrator shall set forth the schedule for the regional energy management workshops to be conducted under this section. Not less than five such workshops shall be held by September 30, 1993, and at least one such workshop shall be held in each of the 10 Federal regions every two years beginning on September 30, 1993.

SEC. 157. FEDERAL AGENCY ENERGY MANAGEMENT TRAINING.

(a) Energy Management Training.--(1) Each executive department described under section 101 of title 5, United States Code, the Environmental Protection Agency, the National Aeronautics and Space Administration, the General Services Administration, and the United States Postal Service shall establish and maintain a program to ensure that facility energy managers are trained energy managers. Such programs shall be managed--

(A) by the department or agency representative on the Task Force; or

(B) if a department or agency is not represented on the Task Force, by the designee of the head of such department or agency.

(2) Departments and agencies described in paragraph (1) shall encourage appropriate employees to participate in energy manager training courses. Employees may enroll in courses of study in the areas described in section 151(3) including, but not limited to, courses offered by--

(A) private or public educational institutions;

(B) Federal agencies; or

(C) professional associations.

(b) Report to Task Force.--(1) Each department and agency described in subsection (a)(1) shall, not later than 60 days following the date of the enactment of this Act, report to the Task Force the following information:

(A) Those individuals employed by such department or agency on the date of the enactment of this Act who qualify as trained energy managers.

(B) The General Schedule (GS) or grade level at which each of the individuals described in subparagraph (A) is employed.

(C) The facility or facilities for which such individuals are responsible or otherwise stationed.

(2) The Secretary shall provide a summary of the reports described in paragraph (1) to the Congress as part of the first report submitted under section 548 of the National Energy Conservation Policy Act (42 U.S.C. 8258) after the date of the enactment of this Act.

(c) Requirements at Federal Facilities.--(1) not later than one year after the date of the enactment of this Act, the departments and agencies described under subsection (a)(1) shall upgrade their energy management capabilities by--

(A) designating facility energy supervisors;

(B) encouraging facility energy supervisors to become trained energy managers; and

(C) increasing the overall number of trained energy managers within such department or agency to ensure a sufficient level to ensure effective implementation of this Act.

(2) Departments and agencies described in subsection (a)(1) may hire trained energy managers to be facility energy supervisors. Trained energy managers, including those who are facility supervisors as well as other trained personnel, shall focus their efforts on improving energy efficiency in the following facilities--

(A) department or agency facilities identified as most costly to operate or most energy inefficient; or

(B) other facilities identified by the department or agency head as having significant energy savings potential.

(d) Annual Report To Secretary And Congress.--Each department and agency listed in subsection (a)(1) shall report to the Secretary on the status and implementation of the requirements of this section. The Secretary shall include a summary of each such report in the annual report to Congress as required under section 548(b) of the National Energy Conservation Policy Act (42 U.S.C. 8258).

SEC. 158. ENERGY AUDIT TEAMS.

(a) Establishment.--The Secretary shall assemble from existing personnel with appropriate expertise, and with particular utilization of the national laboratories, and make available to all Federal agencies, one or more energy audit teams which shall be equipped with instruments and other advanced equipment needed to perform energy audits of Federal facilities.

(b) Monitoring Programs.--The Secretary shall also assist in establishing, at each site that has utilized an energy audit team, a program for monitoring the implementation of energy efficiency improvements based upon energy audit team recommendations, and for recording the operating history of such improvements.

SEC. 159. FEDERAL ENERGY COST ACCOUNTING AND MANAGEMENT.

(a) Guidelines.--Not later than 120 days after the date of the enactment of this Act, the Director of the Office of Management and Budget, in cooperation with the Secretary, the Administrator of General Services, and the Secretary of Defense, shall establish guidelines to be employed by each Federal agency to assess accurate energy consumption for all buildings or facilities which the agency owns, operates, manages or leases, where the Government pays utilities separate from the lease and the Government operates the leased space. Such guidelines are to be used in reports required under section 548 of the National Energy Conservation Policy Act (42 U.S.C. 8258). Each agency shall implement such guidelines no later than 120 days after their establishment. Each facility energy manager shall maintain energy consumption and energy cost records for review by the Inspector General, the Congress, and the general public.

(b) Contents of Guidelines.--Such guidelines shall include the establishment of a monitoring system to determine--

(1) which facilities are the most costly to operate when measured on an energy consumption per square foot basis or other relevant analytical basis;

(2) unusual or abnormal changes in energy consumption; and

(3) the accuracy of utility charges for electric and gas consumption.

(c) Federally Leased Space Energy Reporting Requirement.--The Administrator of General Services shall include, in each report submitted under section 154, the estimated energy cost of leased buildings or space in which the Federal Government does not directly pay the utility bills.

SEC. 160. INSPECTOR GENERAL REVIEW AND AGENCY ACCOUNTABILITY.

(a) Audit Survey.--Not later than 120 days after the date of the enactment of this Act, each Inspector General created to conduct and supervise audits and investigations relating to the programs and operations of the establishments listed in section 11(2) of the Inspector General Act of 1978 (5 U.S.C. App.), and the Chief Postal Inspector of the United States Postal Service, in accordance with section 8E(f)(1) as established by section 8E(a)(2) of the Inspector General Act Amendments of 1988 (Public Law 100-504) shall--

(1) identify agency compliance activities to meet the requirements of section 543 of the National Energy Conservation Policy Act (42 U.S.C. 8253) and any other matters relevant to implementing the goals of such Act; and

(2) determine if the agency has the internal accounting mechanisms necessary to assess the accuracy and reliability of energy consumption and energy cost figures required under such section.

(b) Presidents Council on Integrity and Efficiency Report to Congress.--Not later than 150 days after the date of the enactment of this Act, the President's Council on Integrity and Efficiency shall submit a report to the Committee on Energy and Natural

Resources and the Committee on Governmental Affairs of the Senate, the Committee on Energy and Commerce, the Committee on Government Operations, and the Committee on Public Works and Transportation of the House of Representatives, on the review conducted by the Inspector General of each agency under this section.

(c) Inspector General Review.--Each Inspector General established under section 2 of the Inspector General Act of 1978 (5 U.S.C. App.) is encouraged to conduct periodic reviews of agency compliance with part 3 of title V of the National Energy Conservation Policy Act, the provisions of this subtitle, and other laws relating to energy consumption. Such reviews shall not be inconsistent with the performance of the required duties of the Inspector General's Office.

SEC. 161. PROCUREMENT AND IDENTIFICATION OF ENERGY EFFICIENT PRODUCTS.

(a) Procurement.--The Administrator of General Services, the Secretary of Defense, and the Director of the Defense Logistics Agency, each shall undertake a program to include energy efficient products in carrying out their procurement and supply functions.

(b) Identification Program.--The Administrator of General Services, the Secretary of Defense, and the Director of the Defense Logistics Agency, in consultation with the Secretary of Energy, each shall implement, in conjunction with carrying out their procurement and supply functions, a program to identify and designate those energy efficient products that offer significant potential savings, using, to the extent practicable, the life cycle cost methods and procedures developed under section 544 of the National Energy Conservation Policy Act (42 U.S.C. 8254). The Secretary of Energy shall, to the extent necessary to carry out this section and after consultation with the aforementioned agency heads, provide estimates of the degree of relative energy efficiency of products.

(c) Guidelines.--The Administrator for Federal Procurement Policy, in consultation with the Administrator of General Services, the Secretary of Energy, the Secretary of Defense, and the Director of the Defense Logistics Agency, shall issue guidelines to encourage the acquisition and use by all Federal agencies of products identified pursuant to this section. The Secretary of Defense and the Director of the Defense Logistics Agency shall consider, and place emphasis on, the acquisition of such products as part of the Agency's ongoing review of military specifications.

(d) Report to Congress.--Not later than December 31 of 1993 and of each year thereafter, the Secretary of Energy, in consultation with the Administrator for Federal Procurement Policy, the Administrator of General Services, the Secretary of Defense, and the Director of the Defense Logistics Agency, shall report on the progress, status, activities, and results of the programs under subsections (a), (b), and (c). The report shall include--

(1) the types and functions of each product identified under subsection (b), and efforts undertaken by the Administrator of General Services, the Secretary of Defense, and the Director of the Defense Logistics Agency to encourage the acquisition and use of such products;

(2) the actions taken by the Administrator of General Services, the Secretary of Defense, and the Director of the Defense Logistics Agency to identify products under subsection (b), the barriers which inhibit implementation of identification of such products, and recommendations for legislative action, if necessary;

(3) progress on the development and issuance of guidelines under subsection (c);

(4) an indication of whether energy cost savings technologies identified by the Advanced Building Technology Council, under section 809(h) of the National Housing Act (12 U.S.C. 1701j-2), have been used in the identification of products under subsection (b);

(5) an estimate of the potential cost savings to the Federal Government from acquiring products identified under subsection (b) with respect to which energy is a significant component of life cycle cost, based on the quantities of such products that could be utilized throughout the Government; and

(6) the actual quantities acquired of products described in paragraph (5).

SEC. 162. FEDERAL ENERGY EFFICIENCY FUNDING STUDY.

(a) Study.--The Secretary shall, in consultation with the Secretary of Treasury, the Director of the Office of Management and Budget, the Administrator of General Services, and such other individuals and organizations as the Secretary deems appropriate, conduct a detailed study of options for the financing of energy and water conservation measures required under part 3 of title V of the National Energy Conservation Policy Act (42 U.S.C. 8251 et seq.) and all applicable Executive orders. Such study shall, taking into account the unique characteristics of Federal agencies, consider and analyze--

(1) the Federal financial investment necessary to comply with such requirements;

(2) the use of revolving funds and other funding mechanisms which offer stable, long-term financing of energy and water conservation measures; and

(3) the means for capitalizing such funds.

(b) Report to Congress.--Not later than 180 days after the date of the enactment of this Act, the Secretary shall submit to the Congress a report containing the results of the study required under subsection (a).

SEC. 163. UNITED STATES POSTAL SERVICE ENERGY REGULATIONS.

(a) In General.--The Postmaster General shall issue regulations to ensure the reliable and accurate accounting of energy consumption costs for all buildings or facilities which it owns, leases, operates, or manages. Such regulations shall--

(1) establish a monitoring system to determine which facilities are the most costly to operate on an energy consumption per square foot basis or other relevant analytical basis;

(2) identify unusual or abnormal changes in energy consumption; and

(3) check the accuracy of utility charges for electricity and gas consumption.

(b) Identification of Energy Efficiency Products.--The Postmaster General shall actively undertake a program to identify and procure energy efficiency products for use in its facilities. In carrying out this subsection, the Postmaster General shall, to the maximum extent practicable, incorporate energy efficient information available on Federal Supply Schedules maintained by the General Services Administration and the Defense Logistics Agency.

SEC. 164. UNITED STATES POSTAL SERVICE BUILDING ENERGY SURVEY AND REPORT.

(a) In General.--The Postmaster General shall conduct an energy survey, as defined in section 551(5) of the National Energy Conservation Policy Act, for the purposes of--

(1) determining the maximum potential cost effective energy savings that may be achieved in a representative sample of buildings owned or leased by the United States Postal Service in different areas of the country;

(2) making recommendations for cost effective energy efficiency and renewable energy improvements in those buildings and in other similar United States Postal Service buildings; and

(3) identifying barriers which may prevent the United States Postal Service from complying with energy management goals, including Executive Orders No. 12003 and 12579. (b) Implementation–

(1) The Postmaster General shall transmit to the Committee on Governmental Affairs and the Committee on Energy and Natural Resources of the Senate, and the Committee on Energy and Commerce and the Committee on Post Office and Civil Service of the House of Representatives, within 180 days after the date of the enactment of this Act, a plan for implementing this section.

(2) The Postmaster General shall designated buildings to be surveyed in the project so as to obtain a sample of United States Postal Service facilities of the types and in the climates that consume the major portion of the energy consumed by the United States Postal Service.

(3) For the purposes of this section, an improvement shall be considered cost effective if the cost of the energy saved or displaced by the improvement exceeds the cost of the improvement over the remaining life of the facility or the remaining term of a lease of a building leased by the United States Postal Service.

(c) Report.--As soon as practicable after the completion of the project carried out under this

section, the Postmaster General shall transmit a report of the findings and conclusions of the survey to the Committee on Governmental Affairs and the Committee on Energy and Natural Resources of the Senate, and the Committee on Energy and Commerce and the Committee on Post Office and Civil Service of the House of Representatives.

SEC. 165. UNITED STATES POSTAL SERVICE ENERGY MANAGEMENT REPORT.

Not later than one year after the date of the enactment of this Act, and not later than January 1 of each year thereafter, the Postmaster General shall submit a report to the Committee on Governmental Affairs and the Committee on Energy and Natural Resources of the Senate and the Committee on Energy and Commerce and the Committee on Post Office and Civil Service of the House of Representatives on the United States Postal Service's building management program as it relates to energy efficiency. The report shall include, but not be limited to--

(1) a description of actions taken to reduce energy consumption;

(2) future plans to reduce energy consumption;

(3) an assessment of the success of the energy conservation program;

(4) a statement of energy costs incurred in operating and maintaining all United States Postal Service facilities; and

(5) the status of the energy efficient procurement program established under section 163.

SEC. 166. ENERGY MANAGEMENT REQUIREMENTS FOR THE UNITED STATES POSTAL SERVICE.

(a) Energy Management Requirements for Postal Facilities.--(1) The Postmaster General shall, to the maximum extent practicable, ensure that each United States Postal Service facility meets the energy management requirements for Federal buildings and agencies specified in section 543 of the National Energy Conservation Policy Act (42 U.S.C. 8253).

(2) The Postmaster General may exclude from the requirements of such section any facility or collection of facilities, and the associated energy consumption and gross square footage if the Postmaster General finds that compliance with the requirements of such section would be impracticable. A finding of impracticability shall be based on the energy intensiveness of activities carried out in such facility or collection of facilities, the type and amount of energy consumed, or the technical feasibility of making the desired changes. The Postmaster General shall identify and list in the report required under section 165 the facilities designated by it for such exclusion.

(b) Implementation Steps.--In carrying subsection A(a), the Postmaster General shall--

(1) not later than 1 year after the date of the enactment of this Act, prepare or update, as appropriate, a plan (which may be submitted as part of the first report submitted under section 165)--

(A) describing how this section will be implemented;

(B) designating personnel primarily responsible for achieving the requirements of this section; and

(C) identifying high priority projects;

(2) perform energy surveys of United States Postal Service facilities as necessary to achieve the requirements of this section;

(3) install those energy conservation measures that will attain the requirements of this section in a cost-effective manner as defined in section 544 of the National Energy Conservation Policy Act (42 U.S.C. 8254); and

(4) ensure that the operation and maintenance procedures applied under this section are continued.

SEC. 167. GOVERNMENT CONTRACT INCENTIVES.

(a) Establishment of Criteria.--Each agency, in consultation with the Federal Acquisition Regulatory Council, shall establish criteria for the improvement of energy efficiency in Federal facilities operated by Federal Government contractors or subcontractors.

(b) Purpose of Criteria.--The criteria established under subsection
(a) shall be used to encourage Federal contractors, and their subcontractors, which manage and operate federally-owned facilities, to adopt and utilize energy conservation measures designed to reduce energy costs in Government-owned and contractor-operated facilities and which are ultimately borne by the Federal Government.

SEC. 168. ENERGY MANAGEMENT REQUIREMENTS FOR CONGRESSIONAL BUILDINGS.

(a) In General.--The Architect of the Capitol (hereafter in this section referred to as the "Architect") shall undertake a program of analysis and, as necessary, retrofit of the Capitol Building, the Senate Office Buildings, the House Office Buildings, and the Capitol Grounds, in accordance with subsection (b).

(b) Program.--

(1) Lighting--

(A) Implementation.--

(i) In General.--Not later than 18 months after the date of the enactment of this Act and subject to the availability of funds to carry out this section, the Architect shall begin implementing a program to replace in each building described in subsection (a) all inefficient office and general use area fluorescent lighting systems with systems that incorporate the best available design and technology and that have payback periods of 10 years or less, as determined by using methods and procedures established under section 544(a) of the National Energy and Conservation Policy Act (42 U.S.C. 8254(a)).

(ii) Replacement of Incandescent Lighting.--Whenever practicable in office and general use areas, the Architect shall replace incandescent lighting with efficient fluorescent lighting.

(B) Completion.--Subject to the availability of funds to carry out this section, the program described in subparagraph (A) shall be completed not later than 5 years after the date of the enactment of this Act.

(2) Evaluation and Report.--

(A) In General.--Not later than 6 months after the date of the enactment of this Act, the Architect shall submit to the Speaker of the House of Representatives and the President pro tempore of the Senate a report evaluating potential energy conservation measures for each building described in subsection (a) in the areas of heating, ventilation, air conditioning equipment, insulation, windows, domestic hot water, food service equipment, and automatic control equipment.

(B) Costs.--The report submitted under subparagraph (A) shall detail the projected installation cost, energy and cost savings, and payback period of each energy conservation measure, as determined by using methods and procedures established under section 544(a) of the National Energy Conservation Policy Act (42 U.S.C. 8254(a)).

(3) Review and Approval of Energy Conservation Measures.--The Committee on Public Works and Transportation of the House of Representatives and the Committee on Rules and Administration of the Senate shall review the energy conservation measures identified in accordance with paragraph (2) and shall approved any such measure before it may be implemented.

(4) Utility Incentive Programs.--In carrying out this section, the Architect is authorized and encouraged to--

(A) accept any rebate or other financial incentive offered through a program for energy conservation or demand management of electricity, water, or gas that--

(i) is conducted by an electric, natural gas, or water utility;

(ii) is generally available to customers of the utility; and

(iii) provides for the adoption of energy efficiency technologies or practices that the Architect determines are cost-effective for the buildings described in subsection (a); and

(B) enter into negotiations with electric and natural gas utilities to design a special demand management and conservation incentive program to address the unique needs of the buildings described in subsection (a).

(5) Use of Savings.--The Architect shall use an amount equal to the rebate or other savings from the financial incentive programs under paragraph (4)(A), without additional authorization or appropriation, for the implementation of additional energy and water conservation measures in the buildings under the jurisdiction of the Architect.

(c) Authorization of Appropriations.--There are authorized to be appropriated such sums as are necessary to carry out this section.

ENERGY MANAGEMENT
(10 CFR PART 435, SECTION 110)

§ 435.110 Energy management.

10.1 General

10.1.1 This section contains minimum requirements for building energy management systems. It describes the energy measurement, control, testing and documentation that shall be provided to the building owner. The intent is to minimize energy use by providing the building operator with design, construction and equipment data, along with a means of testing the completed facility.

10.1.2 A building shall be considered in compliance with this section if the minimum requirements of Section 10.3 are met.

10.2 Principles of Design

10.2.1 Energy Management Control Systems

10.2.1.1 An energy management control system is critical to the effective management of building energy. Energy management systems require measurements at key points in the building system and must be capable of part-load operation recognition and be equipped with controls to match system capacity to load demands.

10.2.1.2 Controls cannot correct inadequate source equipment, poorly selected components, or mismatched systems. Energy efficiency requires a design that is optimized by realistic loads prediction, careful system selection, and full control provisions.

10.2.2 Building Operating Documentation

10.2.2.1 The building construction drawings and specifications must show system types, sizes, performance criteria, controls, and materials intended for use prior to construction. The system designer shall provide or specify that documentation be provided for the education and guidance of the building operator showing the actual elements that have been installed, how they have been installed, how they performed during testing, and how they operate as a system in the completed facility. Since minimum energy use is the ultimate goal, operating procedures are one of the major factors in controlling energy use in buildings. The activities of building occupants and operators can result in differences as great as two to one in the energy consumption of essentially similar buildings. While neither the designer nor these standards can control the way the building is actually operated, the designer shall contribute to the education and guidance of the building operator by including this documentation in the contract specifications.

10.2.2.2 The building operator shall be provided with the following:

10.2.2.2.1 As-built drawings and specifications;

10.2.2.2.2 Operating manuals with a schematic diagram, sequence of operation and system operating criteria for each and all systems installed;

10.2.2.2.3 Where the building systems are complex, a comprehensive balancing and testing program and report to demonstrate the energy performance capabilities of the system; and

10.2.2.2.4 Maintenance manuals with complete information for all major components in the facility.

10.3 Minimum Requirements

10.3.1 Each distinct utility-provided energy service shall be metered. This shall apply to central and individual tenant meters. Such meters shall be located, or arranged, so that the meter can be visually monitored.

10.3.2 Each distinct commercially-provided energy service shall have a system to measure and record the amount of energy being delivered, based on the energy content.

10.3.3 The energy delivery systems shall be arranged to allow individual measurement of occupant lighting and outlet services, production processes, auxiliary systems, service water heating, space heating, space cooling, and HVAC delivery systems.

10.3.4 Provisions shall be made for the measurement of energy inputs and outputs (flow, temperature, pressure, etc.) to determine equipment energy consumption and/or installed performance capabilities and efficiencies of all heating, cooling, and HVAC delivery systems equipment, greater than 20 kVA or 60,000 Btu/h energy input.

10.3.5 Energy Measurement Instrumentation

10.3.5.1 In buildings or tenant areas with electric service greater than 150 kVA or fuel use greater than 500,000 Btu/h, energy use shall be measured for electrical lighting, miscellaneous power outlets, HVAC systems and equipment, service hot water, and process loads and when the peak use of:

10.3.5.1.1 Production processes, including manufacturing, computers, laundries, kitchens, etc., is greater than 100 kVA or 300,000 Btu/h;

10.3.5.1.2 Auxiliary systems and service water heating is greater than 100 kVA or 300,000 Btu/h;

10.3.5.1.3 Space heating (including reheat) is greater than 100 kVA or 300,000 Btu/h;

10.3.5.1.4 Space cooling is greater than 100 kVA or 300,000 Btu/h; and

10.3.5.1.5 HVAC delivery systems is greater than 100 kVA or 300,000 Btu/h.

10.3.5.1.6 Exception to section 10.3.5.1:
(a) When there is an energy service for only 2 of the 6 categories listed, a single measurement may be made for the larger of the two energy services and the second use determined by subtraction from the primary service measurements.

10.3.6 HVAC System Controls

10.3.6.1 The designer shall designate, specify, or otherwise show in the construction documents the type of controls and control systems needed. This shall include a description or sequence of control of the system's operational procedures.

10.3.6.2 Controls may be electric, pneumatic, electronic, or direct digital. Control action may be "on/off", or proportional that can use manual, automatic, or remote reset and can have rate of action or derivative action compensation as designated by the designer. Control devices may be provided by the manufacturers of equipment or by the field installers, but all shall be compatible with the design sequence of control. The designer shall designate accuracy and long term requirements for controls.

10.3.6.3 All primary energy conversion equipment such as boilers, heat exchangers, refrigeration units, furnaces and heat pumps shall have a load activated local control loop for each piece of equipment. Controls for multiple equipment shall integrate the individual control units or provide system control for all the units.

10.3.6.4 All energy delivery systems shall have a local control loop for each system.

10.3.6.5 Energy consuming systems or components with a peak use greater than 1 kW or 3,500 Btu/h shall be provided with a means of shut-off when occupancy or weather conditions do not require its operation.

10.3.6.6 The control equipment provided for local control loops except for "on/off" and self-contained sensor devices shall be arranged so that sensing, control action, and control setting variables can be read or tested at the device.

10.3.6.7 Control loops for terminal unit zones with less than 24 hours per day or 7 days per week occupancy shall have separate control points for day and night heating and cooling. The devices shall be capable of local resetting, and have provisions for remote management system selection of the occupied or unoccupied heating or cooling mode of operation.

10.3.7 Central Monitoring and Control Systems

10.3.7.1 A central monitoring and control system shall be provided in any building or submetered tenant space exceeding 40,000 ft 2 in gross floor area.

10.3.7.2 The minimum energy management requirements for such a system shall be to:

10.3.7.2.1 Read and retain daily totals for all energy measurement instruments;

10.3.7.2.2 Total all energy values weekly and record and retain values placed on a summary report;

10.3.7.2.3 Record and plot hourly outdoor and indoor temperatures against real time and summarize and report for each year in a format compatible with degree-days or bin temperature;

10.3.7.2.4 Based on time schedules, turn on or off any HVAC or service water heating system or equipment;

10.3.7.2.5 Based on time schedules, turn on or off major building lighting and occupancy power circuits;

10.3.7.2.6 Reset local loop control systems for HVAC equipment;

10.3.7.2.7 Monitor and verify operation of heating, cooling and energy delivery systems;

10.3.7.2.8 Monitor and verify operation of lighting and occupant power, auxiliary and service hot water systems;

10.3.7.2.9 Provide readily accessible override controls so that time-based HVAC and lighting controls may be temporarily overridden during off hours; and

10.3.7.2.10 Provide optimum start/stop for HVAC systems.

10.3.8 Completion Requirements

10.3.8.1 The building construction documents shall describe the requirements for placing all energy management systems in operation. This includes check-out procedures and all controls and metering equipment operational information.

10.3.8.2 The building construction documents shall describe the requirements for balancing and check-out procedures for all HVAC systems and equipment. All HVAC system balancing shall be required to be accomplished in a manner to minimize throttling losses. In air systems, fan speeds shall be required to be adjusted to meet design conditions. Water systems shall be required to be proportionally adjusted to minimize throttling losses and then corrected to design flow conditions by trimming the pump impeller or changing pump speed. The design specifications shall state that a pump shall not be brought to final flow conditions by valving.

10.3.8.3 The building construction documents shall describe the requirements for control system testing to assure that control elements are calibrated, ranges adjusted, set points ascertained, and full travel of moveable elements assured. All elements in the control system shall be tested with the system in operation.

10.3.9 Energy Performance Testing

10.3.9.1 The building construction documents shall describe the requirements for determining building energy performance in the completed, operational building.

10.3.9.2 The building energy performance testing shall be performed in winter for heating and in summer for cooling. These tests shall ascertain the in-site capabilities of all HVAC systems and equipment. Internal building loads shall be accounted for in assessing cooling performance. Heating performance shall be determined during unoccupied night time periods during winter weather. If any internal load, such as lighting, contributes to building heating, such loads shall be accounted for in assessing heating performance.

10.3.9.3 Energy use measurements shall be made for the overall building system while HVAC system performance is being tested. Each energy management and control system shall be used to determine energy use for:

10.3.9.3.1 Utility energy;

10.3.9.3.2 Commercial service energy;

10.3.9.3.3 Occupant lighting and receptacle power;

10.3.9.3.4 Production process energy;

10.3.9.3.5 Auxiliary systems and service water heating energy;

10.3.9.3.6 Space heating energy;

10.3.9.3.7 Space cooling energy; and

10.3.9.3.8 HVAC delivery system energy.

10.3.9.3.9 Test periods shall be at least six (6) hours in duration. Hourly outdoor and indoor temperatures, solar intensity during a day test, and wind speed during a night test shall be recorded.

10.3.9.4 The building energy performance test data shall, at minimum, measure energy use and outdoor temperatures hourly for each test period.

10.3.10 Documentation Data Requirements

10.3.10.1 As-built information shall be provided for all the following energy-related features of the building:

10.3.10.1.1 Thermal and solar/optical transmission characteristics of the building envelope, including infiltration;

10.3.10.1.2 The operating characteristics of the HVAC, lighting, and service water heating equipment and systems;

10.3.10.1.3 Internal heat gain contributed by equipment and processes; and

10.3.10.1.4 The operating characteristics of controls.

10.3.10.2 A summary report shall be provided outlining the design basis data for the building envelope, the internal heat gains, the weather extremes, major heating/cooling equipment sizes and sequence of operation.

10.3.10.3 The construction documents shall require that shop drawings, schematic diagrams, control sequence, maintenance manuals, and operating instructions, with data on all HVAC, auxiliary equipment and service water heating systems be provided to the owner.

10.3.10.4 A system balancing report shall be provided that follows National Environmental Balancing Bureau or the Association of Air Balancing Council formats with an extra section summarizing the energy-related values gathered during balancing.

10.3.10.5 An energy performance test report shall be provided showing all the data gathered during the energy performance tests. The results shall be presented in a format that provides convenient comparison with design values.

7.0 UTILITY COMPANIES

Utility companies are being pressured by their regulatory bodies (i.e., public utility commissions) to reduce electrical demand by implementing demand-side management (DSM). Many of these utility companies have developed customer energy audit assistance programs. They may perform free energy audits and provide cash rebates for implementing energy conservation projects. Local utility companies can provide program information.

ENERGY TRAINING OPPORTUNITIES

Program: FEMP Training Courses
Sponsor: U.S. Department of Energy
Cost: Varies for different courses
Contact: FEMP Help Desk
(800) 566-2877
FAX (202) 586-3000

Program: Lighting Upgrade Workshop
Sponsor: U.S. Environmental Protection Agency, Green Lights Program
Cost: Free
Contact: Green Lights/Energy Star Hotline (202) 775-6650
Or mail to EPA Green Lights (6202J)
401 M street, SW, Washington, DC 20460

Program: Energy Management Diploma Program
Sponsors:
- Virginia Polytechnic Institute
- North Carolina State University

Cost: $230 to $900 per course
Contact: Mechanical Engineering Department
Virginia Polytechnic Institute
Blacksburg, VA 24060
(703) 231-6684
FAX: (703) 231-9100 or
Office of Continuing Education and Professional Development
Box 7401, McKimmon Center
North Carolina State University
Raleigh,NC 27695-7401
(919) 515-2261
FAX: (919) 515-7614

Program: Continuing Education Credit Energy Seminars
Sponsor: The Association of Energy Engineers
Cost: $500 to $900 per course
Contact: Information Service Director
Association of Energy Engineers
4025 Pleasantdale Road, Suite 420
Atlanta, GA 30340
(404) 925-9633
FAX: (404) 381-9865

Program: Energy Management Course Series
Sponsor: University of Wisconsin-Madison/Extension
Cost: $500 to $1,200
Contact: Keith J. Kempski
Program Director
Department of Engineering Professional Development

University of Wisconsin-Madison
432 North Lake St.
Madison, WI 73706
(608) 262-2061
FAX: (608) 263-3160

Program: Efficient Lighting Courses and Workshops
Sponsor: Seattle City Light
Cost: Free
Contact: Lighting Design Lab
400 East Pine Street, Suite 100
Seattle, WA 98122
(206) 325-9711

Program: Energy Issues
Sponsors: Independent Energy Producers Association
Geothermal Resources Council
Los Angeles Power Producers Association
Gulf Coast Cogeneration Association
Central California Association of Power Producers
Cost: $825 per course
Contact: Infocast, Inc.
18425 Burbank Boulevard
Suite 509
Tarzana, CA 91356
(818) 609-9145
FAX: (818) 609-9149

Program: Demand-side Management
Sponsor: Demand-Side Management Training Institute
Cost: $300 per course
Contact: Demand-Side Management Training Institute
944 Montgomery Avenue
Narberth, PA 19072
FAX: (215) 667-3346

INFORMATION SOURCES FOR ENERGY AWARENESS

The following are good sources of information for energy awareness ideas and materials.

1.0 Federal Agencies

U.S. Department of Commerce
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
(703) 487-4600

U.S. Department of Commerce
Superintendent of Documents
Washington, DC 20230
(202) 783-3238

U.S. Department of Health and Human Services
Energy Action Staff
5600 Fishers Lane, Room 10A-41
Rockville, MD 20857
(301) 443-2403

Energy Information Administration
U.S. Department of Energy
Forrestal Building, EI-231
Washington, DC 20585
(202) 586-8800

U.S. Department of Energy
Office of Scientific and Technical Information
P.O. Box 62 Oak Ridge, TN 37830
(615) 576-1188

Mr. Mark Ginsberg
Federal Energy Management Program
U.S. Department of Energy
1000 Independence Ave., S.W.
CE-44, Room 5E-080
Washington, DC 20585
(202) 586-5772

2.0 Professional Associations

Michael Tillar
Executive Director
American Institute of Plant Engineers
8180 Corporate Park Drive, Suite 305
Cincinnati, OH 45242
(513) 489-2473

Richard J. Wright
American Society of Heating, Refrigerating, and Air Conditioning Engineers
1791 Tullie Circle, NE
Atlanta, GA 30329
(404) 636-8400

Albert Thumann
Executive Director
Association of Energy Engineers
4025 Pleasantdale Road, Suite 420
Atlanta, GA 30340
(404) 447-5083

Illuminating Engineering Society
345 E 47th Street
New York, NY 10017
(212) 705-7926

3.0 Public Interest Groups

Alliance to Save Energy
1725 K Street, NW, Suite 509
Washington, DC 20006
(202) 857-0666

Alternative Energy Resources Organization
25 South Ewing, Suite 214
Helena,MT 59601
(406) 443-7272

Americans for Energy Independence
1629 K Street, NW, Suite 1201
Washington, DC 20006
(202) 466-2105

Citizen Action
1120 19th Street, NW,6th Floor
Washington, DC 20036
(202) 775-1580

Citizens Unified for Responsible Energy/Energy & Self-Reliance Center
3500 Kingman Blvd.
Des Moines, IA 50311
(515) 277-0253

Consumer Energy Council of America
2000 L Street, NW, Suite 802
Washington, DC 20036
(202) 659-0404

League of Conservation Voters
1701 L Street, NW, Suite 550
Washington, DC 20036
(202) 785-8683

Solar Energy Institute of North America
1110 6th Street, NW
Washington, DC 20001-3629
(202) 289-4411

4.0 Trade Associations

The Illuminating Company
Energy Conservation
Room 835, P.O. Box 5000
Cleveland, OH 44101
(216) 622-9800

National Electrical Contractors Association
3 Bethesda Metro Center, Suite 1100
Bethesda, MD 20814
(301) 657-3110

Malcolm O'Hagan
Executive Director
National Electrical Manufacturers Association
2101 L Street, N.W.
Washington, DC 20037
(202) 457-8400

Julie Stewart
Public Relations
American Gas Association
1515 Wilson Boulevard
Arlington, VA 22209
(703) 841-8667

American Hospital Association
840 North Lake Shore Drive
Chicago, IL 60611
(312) 280-6000

Wisconsin Hotels and Motels
Recreation Resources Center
University of Wisconsin-Extension
Madison, WI 53706
(608) 263-2621

Charles J. DiBona
C.E.O.
American Petroleum Institute
1220 L Street, NW, Suite 900
Washington, DC 20005
(202) 682-8000

Richard Morrissey or Thomas Kuhn, President
Edison Electronic Institute
701 Pennsylvania Avenue, NW
Washington, DC 20004
(202) 508-5000

James Houston
Industrial Heating Equipment Association
1901 N. Moore Street
Arlington, VA 22209
(703) 525-2513

Public Affairs Department
Federated Department Stores, Inc.
7 West Seventh Street
Cincinnati, OH 45202
(513) 579-7000

5.0 State Energy Offices

Alabama
Jim Bradford
Acting Director, Energy Division
Alabama Public Service Commission
P.O. Box 991
Montgomery,AL 36130
(205) 242-5868

Alaska
Ronald A. Garvini
Interim Executive Director
Alaska Energy Authority
P.O. Box 190869
Anchorage,AK 99519-0869
(907) 561-7877

Arizona
Jack Haenischen
Energy Director, Arizona Energy Office
Department of Commerce
3800 N. Central, Suite 1200
Phoenix,AZ 85012
(602) 280-1402

Arkansas
Jim Blakley
Director, Energy Office
1 State Capital Mall, Suite 4B-215
Little Rock, AR 72201
(501) 682-7324

California
Charles Imbrecht
Chairman, California Energy Commission
1516 Ninth Street
Sacramento, CA 95814
(916) 654-5204

Colorado
Nancy Tipton
Deputy Director, State Office of Energy Conservation
1675 Broadway, Suite 1300
Denver, CO 80202
(303) 620-4292

Connecticut
Susan Shimelman
Under Secretary for Policy Development and Planning
Energy Division
Department of Planning and Energy Policy
80 Washington Street
Hartford, CT 06115
(203) 566-2800

Delaware
Charlie T. Smisson
Energy Program-Administrator
Division of Facilities Management
O'Neill Building
Dover, DE 19901
(302) 739-5644

District of Columbia
Chuck Clinton
Director, Energy Office
613 D Street, NW, Room 500
Washington,DC 20001
(202) 727-1800

Florida
Jim Tait
Director, State Energy Office
108 Collins Building
Tallahassee, FL 32304
(904) 488-6764

Georgia
Paul Burks
Director, Office of Energy Resources
Office of Planning and Budget
270 Washington Street, SW
Atlanta, GA 30334
(404) 656-3874

Hawaii
Mufi Hannemann
Director, Energy Division
Department of Business, Economic Development and Tourism
P.O. Box 2359
Honolulu, HI 96804
(808) 587-3810

Idaho
Robert W. Hoppie
Administrator, Energy Division
Idaho Department of Water Resources
State House
Boise, ID 83720
(208) 327-7910

Illinois
John Moore
Director, Illinois Department of Energy and Natural Resources
State of Illinois Center
100 E. Randolph, Suite 11600
Chicago, IL 60601
(312) 814-3870

Indiana
Amy Stewart
Director, Office of Energy Policy
1 N. Capitol, Suite 700
Indianapolis, IN 46204-2288
(317) 232-8940

Iowa
Larry Wilson
Director, Department of Natural Resources
Wallace State Office Building
Des Moines, IA 50319
(515) 281-5145

Kansas
Bill Ayesh
Energy Program Section
1500 SW Arrowhead Road, Topeka, KS 66604
(913) 271-3170

Kentucky
John M. Stapleton
Director, Division of Energy
691 Teton Trail, Frankfort, KY 40601
(502) 664-7192

Louisiana
Diane D. Smith
Director, Louisiana Energy Division
Department of Natural Resources
P.O. Box 44156, Baton Rouge, LA 70804
(504) 342-1399

Maine
Carolyn Manson
Director,
Conservation Division of the Department of Economic and Community Development
State House Station 53
Augusta, ME 04333
(207) 624-6000

Maryland
Gerald L. Thorpe
Director, Maryland Energy Administration
45 Calvert Street
Annapolis, MD 21401
(410) 974-2788

Massachusetts
Stephen J. Remen
Commissioner, Division of Energy Resources of Massachusetts
100 Cambridge Street, Room 1500
Boston, MA 02202
(617) 727-4732

Michigan
Janet Patrick
Acting Director, Energy Division
Michigan Public Service Commission
6545 Mercantile Lane
P.O. Box 30221
Lansing, MI 48909
(517) 334-7107

Minnesota
Narv Somdahl
Manager, Department of Public Service
Division of Energy
790 American Center Building
150 East Kellogg Boulevard
St. Paul, MN 55101
(612) 296-7107

Mississippi
Chester B. Smith
Associate Director, Energy Division
Mississippi Department of Economic and Community Development
510 George Street
340 Dixon Building
Jackson, MD 39202
(601) 359-6600

Missouri
Bob Jackson
Director, Missouri Division of Energy
Department of Natural Resources
P.O. Box 176
Jefferson City, MO 66102
(314) 751-4000

Montana
Van Jamison
Administrator, Energy Division
Department of Natural Resources and Conservation
1520 E. Sixth Avenue
Helena, MT 59620
(406) 444-6697

Nebraska
Bob Harris
Director, Nebraska Energy Office
P.O. Box 96085, Lincoln, NE 68509
(402) 471-2867

Nevada
Curtis Framel
Chief, Department of Community Services Energy Bureau
400 W. King Street
Carson City, NV 89710
(702) 687-4990

New Hampshire
Jonathan Osgood
Director, Energy and Community Services
57 Regional Drive
Concord, NH 03301
(603) 271-2611

New Mexico
Anita Lockwood
Secretary, Department of Energy, Minerals and Natural Resources
2040 Pacheco Street
Santa Fe, NM 87505
(505) 827-5950

New York
Francis J. Marry, Jr.
Commissioner, New York State Energy Office
Agency Building No.2, Tenth Floor
Empire State Plaza
Albany, NY 12223
(518) 473-4375

North Carolina
Carson D. Culbreth
Director, Energy Division, Department of Commerce
430 N. Salisbury Street
Raleigh, NC 27611
(919) 733-2230

Ohio
Sara Ward
Chief, Office of Energy Efficiency
Ohio Department of Development
77 S. High Street
P.O. Box 1001
Columbus, OH 43266-0101
(614) 466-2000

Oklahoma
State of Oklahoma
Office of the Secretary of Energy
4400 North Lincoln Blvd.
Oklahoma City, OK 73105
(405) 235-4204

Oregon
Christine A. Ervin
Department of Energy
625 Marion Street NE
Salem, OR 93710
(503) 378-4131

Pennsylvania
Brian Castelli
Director, Pennsylvania Energy Office
116 Pine Street
Harrisburg, PA 17101
(717) 783-9981

Rhode Island
William Ferguson
Statewide Energy Office
1 Capitol Hill
Providence, RI 02908
(401) 277-6315

South Carolina
Dukes Scott
Interim Director, State Energy Office
915 Main Street, Columbia, SC 29201
(803) 734-3369

South Dakota
Ron Reed
Commissioner, Governor's Office of Energy Policy
217 W. Missouri, Suite 200
Pierre, SD 57501
(605) 773-3603

Tennessee
Cynthia Oliphant
Director, Energy Division
Department of Economic and Community Development
320 Sixth Avenue, N
Nashville, TN 37243-4050
(615) 741-2994

Texas
Harris Worcester
Director, Governor's Energy Office
Sam Houston Building
201 E.14th Street
Austin, TX 78701
(512) 463-1931

Utah
Richard Anderson
Director, Utah Division of Energy
Department of Natural Resources
3 Triad Center, Suite 450
355 W. North Temple
Salt Lake City, UT 84180-1204
(801) 538-5428

Vermont
Scudder Parker
Director, Vermont Energy Efficiency Division
Department of Public Service
120 State Street
Montpelier, VT 05620
(802) 828-2393

Virginia
William F. Stevens
Director, Energy Division
State Corporation Commission
1220 Bank Street
Richmond,VA 23219
(804) 786-3611

Washington
Amy F. Bell
Washington State Energy Office
809 Legion Way SE
Olympia, WA 98504-3165
(206) 956-2000

West Virginia
Jeff Herholdt
Manager, West Virginia Development Office
Fuel and Energy Division
State Capitol Complex
Building 6, Room 553
Charleston, WV 25305

Wisconsin
Nathaniel E. Robinson
Administrator, Division of Energy
Department of Administration
101 S. Webster Street
P.O. Box 7868
Madison, WI 53707
(608) 266-8234

Wyoming
John Nunley III
Director, Department of Commerce
Division of Economic and Community Development
Energy Section
Barrett Building,4th Floor North
Cheyenne, WY 82002
(307) 777-7284

DEFINITIONS OF TERMS USED FOR CALCULATING LIFE-CYCLE COST

The definitions described below are taken verbatim from 10 CFR 436:

Life-Cycle Costs (LCC)

Life-cycle costs are the sum of the present values of:

(a) Investment costs, less salvage values at the end of the study period;
(b) Non-fuel operation and maintenance costs;
(c) Replacement costs less salvage costs of replaced building systems; and
(d) Energy costs.

Net Savings

For a retrofit project, net savings may be found by subtracting life-cycle costs based on the proposed project from life-cycle costs based on not having it. For a new building design, net savings is the difference between the life-cycle costs of an alternative design and the life-cycle costs of the basic design.

Savings-to-Investment Ratio (SIR)

The SIR is the ratio of the present value savings to the present value costs of an energy conservation measure. The numerator of the ratio is the present value of net savings in energy and non-fuel operation and maintenance costs attributable to the proposed energy conservation measure. The denominator of the ratio is the present value of the net increase in investment and replacement costs less salvage value attributable to the proposed energy conservation measure.

Adjusted Internal Rate of Return

The adjusted internal rate of return is the overall rate of return on an energy conservation measure. It is calculated by subtracting 1 from the Nth root of the ratio of the terminal value of savings to the present value of costs, where N is the number of years in the study period. The numerator of the ratio is calculated by using the discount rate to compound forward to the end of the study period the yearly net savings in energy and non-fuel operation and maintenance costs attributable to the proposed energy conservation measure. The denominator of the ratio is the present value of the net increase in investment and replacement costs less salvage value attributable to the proposed energy conservation measure.

Estimated Simple Payback Time

The estimated simple payback time is the number of years required for the cumulative value of energy cost savings less future non-fuel costs to equal the investment costs of the building energy system, without consideration of future price changes or discount rates.

BUDGET PROCESS OVERVIEW

DEVELOPMENT OF PROGRAM ESTIMATES

The overall budget process begins well in advance of development of the call for estimates and can be segmented into separate areas.

Planning

The planning process is conducted through the Capital Investment Plan (CIP) mission needs process. The purpose of the planning process is to identify current or near term operating shortcomings, assess the existing capabilities to meet these deficiencies, and recommend the support necessary to overcome these problems. This process highlights critical needs, establishes priorities, and measures risk if the recommended goals are not met. Planning provides the framework for the future programming and budgeting processes.

The CIP planning process is ongoing and it solicits input from headquarters/regions/ centers for new or improved national programs. It requires the preparation of mission need statements to "revalidate" existing CIP programs. The preparation, submission, and approval of a mission need statement is a prerequisite for inclusion into the CIP for new programs. Candidate programs for inclusion in the CIP are submitted through the mission need statement (MNS) process and are reviewed for the mission validity by the Acquisition Review Committee (ARC), and the Transportation System Acquisition Review Council (TSARC) in accordance with the guidelines outlined in Order 1810.F. If approved by the ARC (and the TSARC if necessary), the program advances into the CIP at the dollar level included in the mission need statement. Once in the CIP, it must compete against all other existing CIP programs for program funding.

Programming

Programming matches dollars available against the most critical needs and priorities. After the CIP is reviewed and approved, it becomes the basis for budgeting action. Programming is the first step in the process where fiscal constraints must be matched against resource requirements and will impact alternatives selected during the planning phase. Because of extensive and complex nature of FAA operations and changes in concepts, capabilities, and requirements, the program is periodically updated to reflect price changes, production adjustments, and management actions. Through the programming process, the FAA determines the program best suited to achieve stated objectives within fiscal constraints, and identifies resource requirements associated with the program.

The CIP funding profile changes constantly to incorporate new items approved through the MNS process, revise requirements to existing programs through NAS Change Proposals (NCP's), and reflect cost growth from Financial Baseline Change Notices (FBCN's). The programs and their funding levels are reviewed based on

program urgency, delivery schedules, prior year contractual obligations, and program timing to make programmatic adjustments (either reduced funding levels or program deferrals). The outyear funding levels are also addressed in this context to ensure overall program continuity is maintained. The CIP financial baseline data is updated and distributed periodically throughout the year to incorporate CIP Steering Committee decisions and revise project funding as result of OST, OMB, and Congressional submissions and final Congressional actions on the budget.

Budgeting

Budgeting involves the refinement of detailed costs; the conversion of program structured data into budget structured data for presentation to the Office of the Secretary (OST), the Office of Management and Budget (OMB), and Congress; and the development of the actual budget submission to accomplish the approved program. The call for estimates is predicated on full accomplishment of the preceeding planning and programming processes; further, that the thorough review has ensured that the proper mixture of programs and the relative distribution of planning dollars is consistent with agency near and far-term priorities and mission requirements. The call serves as the "hand-off" from programming to budgeting and is not the proper medium to introduce programs that lack approved mission need statements or benefit/cost analyses or do not otherwise satisfy the procedural requirements for inclusion in the CIP. Likewise, the purpose of the call for estimates, and ultimately the budget submission, is to not only justify the programs for which the funding is requested, but to justify the validity of the cost estimates as well.

Because funding levels are reviewed and revised in the context of any prior year reductions, the dollar levels in the CIP, including outyears, should reflect the estimated resource requirements to accomplish a specific, identifiable increment of the program. The programs and their associated dollar levels contained in the CIP, in turn, can form the basis for the Call for the Estimates. Here, programs are reviewed on a financial basis. The gross order of magnitude cost estimates that were developed in support of the mission need statements are more carefully analyzed. The program's current budget execution is also examined to determine if the requested funding would likely be executed during its availability. The CIP programming data must also be translated into the budget item submission format.

NOTE: To qualify as a CIP program, a program must:

- Involve systemwide improvements or modifications
- Contain multiple-year resource requirements and national scope implications
- Require substantial national level implementation planning
- Have a high dollar level
- Follow criteria established in the "Airway Planning Standard Number One"

THE BUDGET PROCESS

Perhaps the best way to explain the FAA's budget process is with a description of the three major phases of the budget cycle: (1) formulation (2) presentation and (3) execution. In a single fiscal year that spans from October 1 through September 30, these three phases co-exist simultaneously with one another. That is, when the approved operating budget for the current fiscal year is in the execution phase, the proposed budget for the following fiscal year is in the presentation phase, and the request for two years hence is in the formulation phase. Thus, from the time of inception to completion of all three phases for a single budget year is nearly three calendar years. The attached chart illustrates what is occurring in any one calendar year in each of those phases.

Budget Formulation

The FAA budget cycle begins approximately 21 months before the beginning of the fiscal year to which the budget will pertain with the issuance of the Call for Estimates orders by the Office of Financial Services (ABA). This usually occurs in January of each year. There are three separate orders issued by ABA for: (1) the Facilities and Equipment appropriation (2) the Research, Engineering, and Development appropriation and (3) the Operations/Headquarters Administration appropriations. These orders establish the basis for developing funding and staffing needs for one or more future budget years. Upon receipt of these orders, the regions, centers and Washington program offices prepare their budget requests and transmit them to FAA headquarters. In developing their FY estimates, the program divisions were aided by direct communications with their straightline managers in Washington headquarters. The regional budget offices helped program divisions price-out their requirements, provided advice on the requirements and the associated justifications, and consolidated and summarized the division submissions (and the staff and support submissions) into a single regional submission. The regional administrator a) transmitted the consolidated submission without making any changes to program division requests and prepared and submitted his or her critique of the budget and its balance (or lack thereof) to the ABA. After receipt submission of the budget requests from various organizational elements, internal review of their requests is made by the Washington program offices and the ABA. Based on these reviews, recommendations are presented to the Administrator who makes the final decisions as to what is sent to the Office of the Secretary of Transportation (OST).

OST conducts its review of the FAA request and makes certain program decisions and changes to the levels of dollars, positions or full-time equivalents (FTE) requested by the FAA . Once OST has made its determinations, the FAA may appeal to the Secretary for restoration of all or part of the deleted programs or resources. After reconsideration and advice from OST on the appeal, the budget is submitted to OMB in September for further review and hearings with the agency representatives.

In late November, the OMB gives the FAA a "passback" consisting of dollars and positions/FTE that OMB will recommend to the President for inclusion in his budget request to the Congress. Depending on the nature of the OMB "passback," the FAA may decide to appeal (through and with the concurrence of OST) to the OMB for restoration of all or part of the funds or positions/FTE. Following a new decision or action by OMB, the FAA prepares its official budget to be included as part of the President's Budget to the Congress. The President's annual budget is transmitted to Congress on the first Monday in January of the new calendar year. Thus transmittal represents the culmination of the formulation phase.

Budget Presentation

Congressional review of the President's Budget formally marks the start of the presentation phase of the budget process. During this phase of the cycle, the FAA prepares a congressional budget submission consisting of more detailed data and justifications for the resources requested in the President's Budget.

Before considering appropriations for a specific program, Congress must first enact enabling legislation--legislation authorizing an agency to carry out that program. Such legislation provides the legal basis for appropriating funds to the FAA, and may also set limitations on the amount of money which can be appropriated. Programs may have permanent authorization or may be authorized to operate for a specific time-frame, at the will of Congress.

Shortly after the President's Budget is submitted to the Congress, the appropriations hearings process begins, usually with the House subcommittee. After those hearings, the subcommittee prepares a report with recommendations for appropriations to FAA and other DOT agencies. The full Appropriation Committee then reports a bill to the full House which includes proposed appropriations for the FAA . The House then votes on the bill and forwards it to the Senate. The FAA and OST may appeal to the Senate if the House has reduced programs or resources requested by the President. Then a similar process is followed with the Senate subcommittee on appropriations. If there is a difference between the amounts arrived at between the two congressional bodies, a joint conference made up of representatives from both Houses convenes and works out the differences. The end result of these deliberations is an appropriation bill, which after signature by the President, identifies specific levels of resources for the FAA for the fiscal year covered, and includes multi-year and no-year funding for certain programs.

Budget Execution

Budget execution is the phase during which funds in the approved fiscal year budget are made available to the FAA to carry out its missions, functions, and programs. Through appotionments issued by OMB, funds are made available for obligation in an appropriation or fund on a time-phased basis. Upon approval of its apportionment request by OMB, the ABA allots funds to Washington headquarters and the region/centers based on initial operating plans developed by the regions, centers and Washington program offices.

In FY 1989 the allotments issued to the regions and centers were "fenced" in that changes could not be made without the concurrence of the Executive Directors. These procedures were suspended in the month of September for which special procedures have been established to ensure the optimum utilization of funds in the Operations appropriation. For FY 1990 the procedures will be essentially the same in that the allotees will remain the regional administrators/center directors and the Director of Accounting for Washington headquarters.

There will be one significant change in that the ABA will issue "allowances," as redefined in the attached action notice to program managers in Washington and the regions based on input received from each of the Executive Directors' offices. Allowances will be similar to allotments in that they will provide obligational authority to the individual receiving the allowance. They will no longer be just an annual operating plan. As with allotments, these allowances will be adjusted based on receipt of a revised operating plan that has been approved by the appropriate Washington program office.

Throughout the fiscal year, the amounts issued in allotments/allowances may be adjusted by the ABA based on revised operating plans and/or actions recommended by the Administrator's Review Committee (ARC). For example, when additional funds are required by a program manager in a region, a request is forwarded to the Washington program office for approval and ABA issues a revised allotment/allowance to support that increase through the appropriate regional budget office. When the revision to an allotment/allowance involves cross-cutting resources distribution, such as with a supplemental or readjustments in response to funding shortfalls in programs, the ARC recommends how those will be covered. In FY 1990, the ARC will be used initially to resolve operating policy issues and make recommendations on these issues for Executive Directors' approval prior to issuance of funding adjustments during FY 1990.

IDEAS FOR ENERGY AWARENESS PROJECTS

Following is a list of recommended awareness projects that have been successful at many federal facilities in the past. Although not all-encompassing, the purpose of this list is to provide energy managers with proven ideas that work. Each energy manager should develop an implementation strategy that best fits the needs of their own facility.

- Organize Energy Awareness Month or Energy Awareness Week activities.
  - Distribute energy awareness flyers and posters.
  - Place energy awareness signs and posters around the facility.
  - Solicit a visit and an address by the local mayor or other officials.

- Get the message out using all available media.
  - Distribute flyers containing practical, energy-saving tips.
  - Make promotional energy conservation packages for facility-wide dissemination.
  - Install energy conservation bulletin boards and display changing messages.
  - Establish an energy conservation information center at the facility.

- Sponsor classes and address meetings where appropriate.
  - Organize biannual energy awareness presentations at the facility.
  - Choose opportunities to address influential or large groups on conservation issues.
  - Conduct energy conservation seminars and periodic meetings for building energy monitors.
  - Develop and present energy awareness and energy conservation training to all facility personnel.

- Issue energy usage reports.
  - Issue periodic reports on utility costs.
  - Distribute energy cost charts to facility management.

- Conduct educational walk-through audits.
  - Conduct facility walk-through audits to point out energy-saving opportunities to building occupants.
  - Perform "no-notice" inspections of energy awareness to evaluate user energy habits.

- Enlist the help of others.
  - Establish an energy management team consisting of representative membership at the facility.
  - Use brainstorming sessions to develop new energy conservation ideas and projects.
  - Use the facility suggestion box to solicit energy conservation ideas.

- Use rewards to encourage energy conservation.
  - Reward successful suggestion box ideas with coffee mugs, T-shirts, tote bags, and baseball caps.
  - Hold an energy conservation trivia contest with prizes and an award.

- Make energy-saving materials available.
  - Distribute energy-saving materials like weather stripping material and fluorescent lamps to facility occupants.

- Other energy awareness suggestions.
  - Develop checklists and operating instructions for energy-using systems to ensure continued savings.

- Awareness slogans
  - Save Energy!
    - Each time you save energy, you do three good turns: You save dollars. You conserve natural resources, which are becoming scarcer all the time. And you prevent pollution, making life safer and healthier.
  - Turn off the juice when not in use!
    - This applies to everything that runs on electricity: air conditioning, appliances, computers and lights, including fluorescent lights. Do not believe the myth that you'll wear out computers and fluorescent lights by turning them on and off.
  - Don't fight your furnace or air conditioning.
    - When they're on, keep your doors and windows closed. Leaving them open just wastes energy. (But do open windows and doors instead of using air conditioning to cool off a hot room. Window exhaust fans work well on cool summer evenings.)

USEFUL FACTS FOR PROMOTING ENERGY CONSERVATION

This appendix contains some "rules of thumb" and anecdotes that are useful for promoting energy awareness and conservation. The following tips and facts are provided as a starter. Energy managers should seek to add more which, based on their own experience, have been effective in enhancing conservation.

ENVIRONMENTAL BENEFIT

- A car emits CO_2 in an amount equal to that of it's own weight every 15,000 miles.
- Burning one gallon of gasoline by a car produces 22 pounds of CO_2.
- Every kilowatt-hour (kWh) of electricity saved avoids over two pounds of carbon dioxide being pumped into the atmosphere.
- Carbon dioxide is the single biggest contributor to the global warming problem. Table L-1 shows energy conservation measures and CO_2 savings in the home.

BUILDING INSULATION

Heat loss can occur due to lack of building insulation. The breakout for the heat loss by a typical residential home is:

- Roof/ceiling: up to 40 percent,
- Foundation walls: up to 20 percent, and
- Openings (windows/doors): up to 40 percent.

HEATING, VENTILATION, AND AIR CONDITIONING (HVAC)

- Turning down the thermostat from 70°F to 65°F saves about 10 percent of total heating costs.
- Setting the thermostat back from 70°F to 60°F for 8 hours at night saves about 10 percent of total heating costs.
- Raising the thermostat each degree can save 3 to 5 percent on air-conditioning costs.
- A well-maintained HVAC system in a family housing unit can save up to $200 per year.

HOT WATER

- A standard showerhead has a flow rate of 4 to 5 gallons per minute (gpm). Retrofitting it with a low-flow showerhead (2 to 3 gpm) can save about $50 per year.
- Insulating a water heater can save up to 4 to 9 percent on water heating bills.

LIGHTING

- In the United States, lighting uses about 20 percent of all the electricity generated.
- Incandescent light bulbs convert only 10 percent of electricity to

produce light, the rest dissipates as heat.

- Compact fluorescent light is 3 times more energy efficient than incandescent light and its life is 10 times longer. Table T-3 shows the cost savings from switching from incandescent to compact fluorescent bulbs.

ENERGY CONSERVATION OPPORTUNITIES AT FACILITIES

Table M-1 lists numerous methods for achieving energy conservation. All these methods basically fall under three categories.

The first category is conservation by reducing consumption or cutting back on operating hours or standards. These energy conservation opportunities can be achieved by establishing energy-usage policy directives. Energy managers should try to implement all opportunities available through policy options. They must balance energy conservation goals without adversely impacting the mission, safety, or the quality of life. These opportunities are coded "**D**" for "***directive***" in Table M-1.

The second category incorporates the methods as part of the maintenance routine. Energy managers should negotiate maintenance schedules with shop foremen or building managers. These opportunities are coded as "**M**" for "***maintenance***" in the table. If possible, all of these energy conservation opportunities should be implemented because they are usually very cost-effective.

The third category for achieving energy conservation improves the efficiency of energy systems by implementing engineering projects such as replacement, retrofits, and so forth. Normally, an energy audit is needed to determine the potential savings and to justify economically such projects. These opportunities are coded as "**P**" for "***project***" in the table.

If energy managers do not have enough information or the time to do energy consumption analysis, the following recommendations offer good alternatives for energy conservation. For better results, energy managers may need to seek assistance from qualified engineers to ensure the accuracy of audits findings and the proper economic analysis. Based on past experience, most energy-efficiency experts believe that these conservation options will normally produce the best energy savings results.

TABLE M-1

ENERGY CONSERVATION OPPORTUNMES AT FACILITIES

BUILDING EQUIPMENT OPERATION	Method
Reduce operating hours	
Reduce operating hours for space heating and cooling systems	D
Reduce operating hours for ventiation systems	D
Reduce operating hours for water heating systems	D
Reduce operating hours for lighting systems	D
Reduce operating hours for escalators and elevators	D
Reduce operating hours for equipment and machines	D
Adjust space temperature and humidity setpoints	
Lower heating and raise cooling temperature setpoints	D
Lower humidification and raise dehumidification setpoints	D
Set heatng setpoints back when the building is not occupied	D
BUILDING ENVELOPE	
Reduce heat conduction through ceilings and roofs	
Insulate ceilings and roofs	P
Install vapor barriers in ceilings and roofs	P
Reduce solar heat gain through roofs	
Install reflective roof surfaces	P
Reduce heat conduction throuch walls	
Insulate walls	P
Install vapor barriers in walls	P
Reduce heat conduction through floors	
Insulate floors	P
Reduce heat conduction and long-wave radiation through glazing areas	
Install storm windows and multiple-glazed windows	P
Insulate movable windows	P
Install operable windows	P
Control solar heat gain through glazing areas	
Install exterior shading	P
Install interior shading	M
Use tinted or reflective glazing or films	M
Install air-flow windows	P
Reduce infiltration	
Seal vertical shafts and stairways	M
Caulk and weatherstrip doors and windows	M
Install revolving doors or construct vestibules	P

Notes: D = directive; M = maintenance; and P = projects.

TABLE M-1

ENERGY CONSERVATION OPPORTUNITIES AT FACILITIES (Continued)

HEATING, VENTILATION, AND AIR CONDITIONING (HVAC) SYSTEMS	Method
Reduce ventilation	
Reduce ventilation rates	P
Reduce the generation of indoor pollutants	P
Install air-to-air heat exchangers	P
Install air cleaners	P
Install local ventilation systems	P
Improve chiller efficiency	
Clean evaporator and condenser surfaces of fouling	M
Raise evaporator or lower condenser water temperature	D
Isolate off-line chillers and cooling towers	P
Install evaporatively-cooled or water-cooled condensers	P
Improve boiler or furnace efficiency	
Clean boiler surfaces of fouling	M
Check flue for improper draft	M
Check for air leaks	M
Install flue gas analyzers for boilers	P
Preheat combustion air, feed water, or fuel oil with reclaimed waste heat	P
Isolate off-line boilers	P
Install automatic vent dampers	P
Install automatic boiler blow-down control	P
Install pulse or condensing boilers/f urnaces	P
Install air-atomizing burners (for oil-fired systems)	P
Install low-excess-air burners (for oil-fired systems)	P
Install modular units	P
Improve air-conditioner or heat-pump efficiency	
Clean air filters	M
Install add-on heat pumps	P
Install ground or ground-water source heat pump	P
Reduce energy used for tempering supply air	P
Install variable air volume systems	D
Reset supply air temperatures	D
Reset hot/chilled water temperatures	
Use energy-eff icient cooling systems	
Install economizer cooling systems	P
Install evaporative cooling systems	P
Install desiccant cooling systems	P
Install cooling tower cooling systems	P
Install roof-spray cooling systems	P
Create air movement with fans	P
Exhaust hot air from attics	P

Notes: D = directive; M = maintenance; and P = projects.

TABLE M-1

ENERGY CONSERVATION OPPORTUNITIES AT FACILITIES (Continued)

HVAC DISTRIBUTION SYSTEMS	Method
Reduce distribution system energy losses	
Repair ducting and piping leaks	M
Maintain or replace steam traps	M
Insulate ducts	P
Insulate HVAC system pipes	P
Reduce system flow rates	
Reduce air flow rates in ducts	D
Reduce water or steam flow rates in pipes	D
Reduce system resistance	
Clean air filters in ducts	M
Remove scale from water and steam pipes	M
Rebalance piping systems	M
Rebalance ducting systems	M
Design ducting systems to reduce flow resistance	P
Install booster pumps	P
WATER HEATING SYSTEMS	
Reduce hot water loads	
Reduce hot water consumption	D
Lower hot water temperatures	D
Preheat feedwater with reclaimed waste heat	P
Reduce hot water heating system losses	
Insulate hot water pipes	P
Insulate water storage tanks	P
Use energy-efficient water heating systems	
Install decentralized water heaters	P
Use smaller water heaters for seasonal requirements	P
Use heat pump water heaters	P
Heat waller with solar energy	P

Notes: D = directive; M = maintenance: and P = projects.

TABLE M-1

ENERGY CONSERVATION OPPORTUNITIES AT FACILITIES (Continued)

LIGHTING	Method
Reduce illumination requirements	
Clean and maintain systems	M
Reduce illumination levels	D
Reduce time of operation	D
Use task lighting	D
Install energy-efficient lighting systems	
Use high-eff iciency fluorescent lighting	P
Use high-pressure sodium lighting in selected areas	P
Install low-pressure sodium lighting in selected areas	P
Install high-efficiency ballasts	P
Remove or replace lenses	M
Use daylighting	
Install dimming controls with windows	P
Install dimming controls with skylights	P
POWER SYSTEMS	
Reduce power system losses	
Correct power factors	P
Install energy-efficient transformers	P
Install energy-efficient motors	
Replace oversized motors	P
Use high-eff iciency motors	P
Use variable speed motors	P
Reduce peak power demand	
Use load-shedding	D
Install a cogeneration system	P
Install a cool storage system	P

Notes: D = directive; M = maintenance: and P = projects.

TABLE M-1

ENERGY CONSERVATION OPPORTUNITIES AT FACILITIES (Continued)

EMCS	Method
Use energy management and control system (EMCS)	
Install temperature setup/setback control system	P
Install time-of-day control system	P
Install duty-cycling control system	P
Install supply air temperature reset control system	P
Install hot/chilled water supply temperature reset control system	P
Install ventilation purging control system	P
Install economizer cooling control system	P
Install demand limiting control system	P
HEAT RECOVERY	
Use heat reclaim systems	
Install double-bundle chillers	P
Reclaim heat from boiler blowdown	P
Reclaim incinerator heat	P
Reclaim heat from combustion system flue	P
Install water-loop heat pump systems	P
Reclaim heat from prime movers	P
Install piggyback absorption systems	P
Recover heat from light systems	P
Reclaim heat from refrigerator hot gas	P
Reclaim heat from steam condensate	P
Reclaim heat from waste water	P

Notes: D = directive; M = maintenance: and P = projects.

AUDITING INSTRUMENTS

Some knowledge of the tools and techniques available for conducting energy audits is useful, even when audits are contracted out. In this appendix we describe some of the most common instruments for use in installation energy audits[1]. Many more specialized instruments and other audit devices are available than are mentioned here. Refer to the bibliography to obtain texts having more details on audit procedures and instrumentation.

ELECTRICAL ENERGY

Voltmeter. An instrument that measures the difference in electrical potential - the voltage drop - between two points on a circuit. A measurement of the voltage drop, together with electric current, is needed to measure electrical energy use on a particular line. Many available voltmeters read upto 600 volts, the maximum that is needed in most applications.

Ammeter. An instrument that measures electrical current in amperes. Both electric current and voltage are needed to measure electrical energy use. Ammeters are rated in terms of the number of amperes they are capable of reading. Commonly available instruments usually read up to 1000 amperes continuously, while some models extend up to 4000 amperes.

Portable ammeters that can be easily attached to a circuit are useful for audits. Auditors can use such attachable, "snap-on" ammeters to monitor the variations in the current over a period of time. Snap-on ammeters can be either "indicating" - read from a meter - or produce a printout. Ammeter/voltmeter combinations are also available.

Wattmeter. An instrument that directly reads electrical energy in watts. Wattmeters are available that measure up to 300 kilowatts, 600 volts, and 600 amperes; they can measure both phase and three phase circuits.

Power Factor Meter. An instrument that measures the electrical power factor , the angle between voltage and current in alternating current circuits. The power factor is essential for calculating usage of electrical energy in alternating current circuits.

Kilowatt Hour (kWh) and Kilowatt (kW) Demand Unit. Meters that provide direct readouts of kWh and kW demand. Meters are available that provide instantaneous or continuous readouts. Portable meters are particularly useful for localizing electrical energy use within facilities that lack fixed, local meters.

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[1]Thumann, A. *Plant Engineers and Managers Guide to Energy Conservation*, 5th Edition. Liburn, Ga.: The Fairmont Press (1991), pp. 52-62.

ILLUMINATION

Light Meter/Footcandle Meter. A meter that measures illumination. Auditors use portable footcandle meters to check the illumination levels provided by lighting. Unlike photographic light meters, footcandle meters are color corrected.

TEMPERATURE AND HUMIDITY

Thermometer. Portable, battery run thermometers that measure between 50 degrees Fahrenheit (F) and 250 F are useful for general audits of HVAC systems. Separate probes measure surface, liquid, or air. Dial thermometers are good for measuring boiler stacks up to 1000 F while thermocouples measure higher temperatures.

Surface Pyrometer. An instrument to measure surface temperature. They are particularly useful for inspecting heat losses and for checking steam traps. Specialized pyrometers include suction pyrometers for measuring gas temperatures, high temperature units (over 600 F), non-contact surface pyrometers that measure infrared radiation, and optical pyrometers for measuring very hot, incandescent surfaces.

Infrared Scanning Device. These instruments are useful for checking the effectiveness of building envelopes by detecting "hot spots" that indicate energy losses. Infrared energy devices can identify poor or missing insulation, leaky windows, and other sources of building heat losses. in addition, an aerial infrared survey will detect underground steam pipe leaks, hot gas discharges, poor roof insulation, and other efficiency losses. Aerial scans are normally contracted out to specialized companies.

Psychrometer. Although it does not measure temperature, a psychrometer is a valuable instrument for evaluating HVAC systems and drying operations. It measures relative humidity based on the relation of dry-bulb temperature to wet-bulb temperature.

COMBUSTION SYSTEMS

Boiler Test Kit. A test kit consisting of analyzers for carbon dioxide, oxygen, and carbon monoxide gases.

Orsat Apparatus. An apparats used to test for concentrations of combustion products in a stack. The apparatus is time-consuming and requires an expert operator.

Fyrite Gas Analyzer. An analyzer that is easier to use and is less expensive but less accurate than the Orsat apparatus.

Combustion Analyzer. An electronic stack gas analyzer that measures gas measurements using a probe. It is faster and easier to use than the Orsat apparatus.

Draft Gauge. A gauge that measures gas pressure.

Smoke Tester. An instrument that measures the completeness of combustion. Its use requires a visual comparison of test results with a standard scale.

OTHER INSTRUMENTATION

Many other instruments are available to help the energy auditor to measure energy use directly and to help diagnose inefficient energy use. For example, drafts and leaks can be detected using inexpensive smoke pellets or anemometers. Instruments for HVAC work include various types of manometers for measuring air pressure and bourdon gauges for measuring fluid pressures.

ENERGY CONVERSION FACTORS

BTU CONTENT VALUES FOR ENERGY SOURCES

Energy sources	BTU content
Electricity	3,142,000 Btu/mWh
Natural gas	1,031,000 Btu/KCF
Coal, anthracite	25,400,000 Btu/short ton
Coal, bituminous	24,580,000 Btu/short ton
Coke	25,380,000 Btu/short ton
Purchased steam or hot water	1,340 Btu/pound of steam delivered
Fuel oil, distillate	5,825,000 Btu/barrel
Fuel oil, residual	6,287,000 Btu/barrel
Fuel oil, mixed	6,000,000 Btu/barrel
Fuel oil, reclaimed	5,000,000 Btu/barrel
Propane/LPG/butane	95,000 Btu per gallon
Photovoltaic	3,413 Btu per kWh
Solar thermal	1,000,000 Btu per MBtu
Wind power	3,413 Btu per kWh
Wood	17,000,000 Btu per short ton
Geothermal (heat)	1,340 Btu per pound of steam delivered 3,413 Btu per kWh
Geothermal (electicity)	3,413 Btu per kWh
Refuse-derived fuel	6,000,000 Btu per short ton
Hydroelectric	3,413 Btu per kWh

UNIT OF MEASUREMENT CONVERSION FACTORS

1 US barrel	= 42 US gallons
1 atmosphere	= 14.7 pounds per square inch absolute (psia)
1 atmosphere	= 760mm (29.92 in) mercury with density of 13.6 grams per cubic cm.
1 pound per square inch	= 2.04 inches of mercury
	= 2.31 feet head of water
1 inch head of water	= 5.20 pounds per square foot
1 foot head of water	= 0.433 pound per square inch
1 British thermal unit (Btu)	= heat required to raise the temperature of 1 pound of water by 1 °F
1 therm	= 100,000 Btu
1 kilowatt (kW)	= 1.342 horsepower (hp)
1 kilowatt-hour (kWh)	= 3412 Btu[1]
1 ton of refrigeration	= 12,000 Btu per hour[2]
1 standard cubic foot	= volume measured at standard conditions of 60°F and 14.7 psia
1 degree day	= 65°F minus mean temperature of the day,°F
1 year	= 8,760 hours
1 MBtu	= 1 million Btu
1 kW	= 1,000 watts
1 trillion barrels	= 1×10^{12} barrels
1 US gallon	= 3.785 liters
1 liter	= 1,000 cm^3 or cubic centimeters (cc)
1 inch	= 2.54 centimeters (cm)
1 foot	= 12 inches
1 mile	= 5,280 feet
1 meter (m)	= 100 centimeters (cm)
1 kilometer (Km)	= 1,000 meters
1 pound	= 16 ounces
1 kilogram	= 1,000 grams
1 short ton	= 2,000 pounds

Note: In these conversions, inches and feet of water are measured at 62°F (16.7°C), and inches and millimeters of mercury at 32°F (0°C).

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[1]To generate 1 kilowatt-hour (kWh) requires 10,000 Btu of fuel burned by average utility.

[2]One ton of refrigeration requires about 1 kW (or 1.341 hp) in commercial air conditioning

ENERGY CONSERVATION BIBLIOGRAPHY

The following is a select list of useful energy conservation publications. This list is only a reference for new energy managers who can use it as a starting point in their search for additional information and for understanding the tasks involved in efficient energy resources management.

1.0 BOOKS AND MANUALS

1.1 The following books and manuals can be ordered from:

AIE Energy Books
Department 756
P.O. Box 1026
Liburn, GA 30226
Telephone: (404) 925-9558

Cilia, John P. A guide for Building and Facility Automation Systems.

Criswell, John W. Planned Maintenance for Productivity and Energy Conservation.

Ganapathy, V. Waste Heat Boiler Desk Book.

Garay Paul N. Pump Application Desk Book.

Gelling Clark W. and Chamberlin, John H. Demand-Side Management Planning.

Gupton, Guy W. HVAC Controls; Operations and Maintenance.

Hay, Nelson E. Guide to Natural Gas Co-generation.

Hunsen, Shirley J. Managing Indoor Air Quality.

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Lindsey, Jack L. Applied Illumination Engineering.

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McGowan, John J. Networking for Building Automation and Control Systems.

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Office of Industrial Technologies, Office of Assistant Secretary for Conservation and renewal Energy, Energy from Municipal Waste Program: Program Plan.

Office of Technology Assessment, U.S. Congress, Facing America's Trash: What Next for Municipal Solid Waste.

Orlando, Joseph A. Cogeneration Planners Handbook.

Pansini, Anthony J. Electrical Distribution Engineering.

Pansini, Anthony J. Power Systems Stability Handbook.

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Payne, William F. Efficient Boiler Operations Sourcebook.

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Seevers, O.C. Power Systems Handbook: Design, Operations, & Maintenance.

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Thumann, Albert and Mehta, D. Paul. Handbook of Energy Engineering.

Thumann, Albert. Plant Engineers and Managers Guide to Energy Conservation.

Thumann, Albert. Introduction to Efficient Electrical Systems Design.

Thumann, Albert. Lighting Efficiency Applications.

Thumann, Albert. Optimizing HVAC Systems.

Traister, John E. Handbook of Electric Motors: Use and repair.

Turner, Wayne C. Energy Management Handbook.

Wendes, Herbert C. Variable Air Volume Manual.

Williams, Anna Fay. Software Applications and Directory for Energy Analysis.

1.2 The following books can be ordered from:

American Council for Energy-Efficient Economy
1001 Connecticut Avenue, NW
Suite 535
Washington, DC 20036
Telephone: (202) 429-8873

dePont, Peter and Morrill, John. Residential Indoor Air Quality and Energy Efficiency.

Hirst, Eric; Clinton, Jeane; Geller, Howard; and Kruner, Walter. Energy Efficiency in Building Progress and Promise.

Kempton, Willett and Neiman, Max. Energy Efficiency: Perspectives on Individual Behavior.

Nadal, Steve; Michael Shepherd; Greenberg; Steven; Katz, Gale. Energy-Efficient Motor Systems: A Handbook on Technology, Program and Policy Opportunities.

Vine, Edward and Crawley Drury. State of the Art of Energy Efficiency: Future Directions.

Weedall, Mike; Weisenmiller, Robert; and Shepherd, Michael. Financing Energy Conservation.

Wilson, Alex and John Morrill. 1991 Consumer Guide to Home Energy Savings.

2.0 PERIODICALS

Independent Energy, 1

To order: 1-800-922-3736

Energy Engineering

To order: (404) 935-9558

ENERGY USE INDEX WORKSHEET

An Energy Use Index (EUI) measures how much energy a facility consumes, in British thermal units (Btu) per gross conditioned square foot per period of time (usually 1 year). The following Energy Use Index Worksheet can be used to determine the EUI for most facilities. The worksheet does not include space for certain types of energy consumption – for example, propane or purchased chilled water. If the facility uses these energy sources, either convert a column that does not apply to the facility or add a new column.

ENERGY USE INDEX WORKSHEET

Year:
Building:
Gross conditioned square feet:

			Purchased Electricity								
Month (1)	Heating Degree-Days (2)	Cooling Degree-Days (3)	kWh Cost (4)	Demand Charge (5)	Power Factor Adjustment (6)	Fuel Adjustment (7)	Total Cost (8)	Billed Demand (kW) (9)	Actual Demand (kW) (1)	kWh Used (11)	Mbtu (12)
January											
February											
March											
April											
May											
June											
July											
August											
September											
October											
November											
December											
Year Total											

Conversion Factors

Electricity _____ kWh X 3,413 = _____ Mbtu

ENERGY USE INDEX WORKSHEET (continued)

Year:
Building:
Gross conditioned square feet:

	Purchased Steam							Oil, Heavy		
Month	Steam Commodity Cost (13)	Steam Demand Charge (14)	Total Steam Cost (15)	Actual Demand (lbs/hr) (16)	Billed Demand (lbs/hr) (17)	Steam Used M lbs (18)	MBtu (19)	Total Cost (20)	Gallons Used (21)	MBtu (22)
January										
February										
March										
April										
May										
June										
July										
August										
September										
October										
November										
December										
Year Total										

Conversion Factors

Purchased Steam _____ kWh X 1,000 = _____ Mbtu

Oil _____ Gallons X 149(#6 Oil)* = _____ Mbtu

* Use actual values if known.

ENERGY USE INDEX WORKSHEET (continued)

Year:
Building:
Gross conditioned square feet:

	Oil, Light			Natural Gas					Coal		
Month	Total Cost (23)	Gallons Used (24)	Mbtu (25)	Commodity Cost (26)	Demand Charge (27)	Total Cost (28)	Mcf Used (29)	Mbtu (30)	Total Cost (31)	Tons Used (32)	Mbtu (33)
January											
February											
March											
April											
May											
June											
July											
August											
September											
October											
November											
December											
Year Total											

Conversion Factors

Oil _____ Gallons X 138 (#2 Oil)* = _____ Mbtu

Natural Gas _____ Mcf X 1,030* = _____ Mbtu

Propane _____ Mcf X 2,500* = _____ Mbtu

Coal _____ Short Tons X 26,000* = _____ Mbtu

*Use Actual Values if known.

ENERGY USE INDEX WORKSHEET (continued)

Year:
Building:
Gross conditioned square feet:

	Totals			
Month	Total Cost (31)	Cost + Square Feet (35)	Total Mbtu Used (36)	EUI (37)
January				
February				
March				
April				
May				
June				
July				
August				
September				
October				
November				
December				
Year Total				