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Greening Federal Facilities

An Energy, Environmental, and Economic Resource Guide for Federal Facility Managers

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Greening Federal Facilities:

An Energy, Environmental, and Economic Resource Guide for Federal Facilities Managers

"Then I say the earth belongs to each…generation during its course, fully and in its own right, no generation can contract debts greater than may be paid during the course of its own existence."

Thomas Jefferson, September 6, 1789

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About the Contributing Organizations

The U. S. Department of Energy

The U.S. Department of Energy (DOE) contributes to the welfare of the Nation by providing resources to achieve efficiency in energy use, diversity of energy sources, a more productive and competitive economy, improved environmental quality, and a secure national defense. DOE provides scientific and technical information, and educational resources to Federal agencies and the public.

Office of Energy Efficiency and Renewable Energy

DOE's Office of Energy Efficiency and Renewable Energy leads the Nation to a stronger economy, a cleaner environment, and a more secure future through the development and deployment of sustainable energy technology.

The Federal Energy Management Program

The Federal Energy Management Program (FEMP) reduces the cost of government by advancing energy efficiency, water conservation, and the use of solar and other renewable energy. FEMP accomplishes its mission by creating partnerships, leveraging resources, transferring technology and providing training and support. Each of these activities is directly related to achieving not only the goals set forth in law, Energy Policy Act of 1992 and Executive Order No. 12902, but also those which are inherent in sound management of Federal financial and personnel resources.

Greening America

Greening America is a nonprofit foundation that educates the public and private sectors about energy efficient and environmentally sound design, innovation, and technology. Greening America, which had its genesis in the Greening of the White House, produces videos, publications, on-line technical resources, and other materials that show practical examples of how sound energy and environmental decision-making makes good economic sense.

Sustainable Systems, Inc.

Sustainable Systems, Inc. is a consulting firm that is dedicated to implementing the principles of sustainability in development. Multi-disciplinary teams of technical professionals, social scientists, economists, and business administrators address problems—from community development to technological issues—from the viewpoint of minimizing the resource and environmental impacts of the activities of its clients, without compromising quality of life.

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Executive Summary

In his 1993 Earth Day address, President Bill Clinton made a commitment to make the White House a model for energy efficiency and waste reduction. He called for an energy and environmental upgrade and retrofit of the White House complex, and said:

"For as long as I live and work in the White House, I want Americans to see it not only as a symbol of clean government, but also a clean environment. We're going to identify what it takes to make the White House a model for efficiency and waste reduction. And then we're going to get the job done. I want to make the White House a model for other federal agencies, for state and local governments, for businesses, and for families in their homes."

The actions that resulted from the President's request came to be known as *The Greening of the White House*.

The Federal Energy Management Program (FEMP) is the lead federal agency for helping transfer the energy and environmental technologies used in *The Greening of the White House* to all Federal buildings. Through this effort FEMP is working toward fulfillment of Executive Order 12902 to reduce Federal energy consumption by 30% between 1985 and 2005.

Greening Federal Facilities is a nuts-and-bolts resource guide compiled to increase energy and resource efficiency, cut waste, and improve the performance of Federal buildings and facilities. The guide highlights practical actions that facility managers, design and construct staff, and facility planners can take to save energy and money, improve the comfort and productivity of employees, and benefit the environment. It is another step in a national effort to promote energy and environmental efficiency in the nation's 500,000 Federal buildings and facilities.

Greening Federal Facilities encompasses actions ranging from improved landscaping, to materials selection, to recycling, to water conservation, to energy-efficient lighting, heating and cooling. It highlights best practices to:

- invest in improvements that have quick paybacks and make economic sense;
- increase productivity, comfort, and health of employees and building occupants;
- maximize innovative financing and partnering opportunities;
- facilitate interagency cooperation;
- work within the ongoing operations and procedures of facilities management staff; and reduce environmental impacts.

To develop and review *Greening Federal Facilities*, FEMP, with support from Greening America, assembled an inter-agency team consisting of experts within DOE, DOD, GSA, EPA, the Office of the Federal Environmental Executive, and many other Federal agencies. It also brought together an expert team from DOE Labs, including Lawrence Berkeley National Laboratory (LBNL), Pacific Northwest National Laboratory (PNNL), and the National Renewable Energy Laboratory (NREL). A special advisory group also included a 30-member team comprised of many of the nation's leading private-sector experts in architecture, engineering, building operations, and energy and environmental management.

Greening Federal Facilities reflects a long-standing commitment to make government work better and cost less, to use the Federal government's enormous purchasing power to stimulate markets for American energy and environmental technologies, and to save taxpayers money through reduced material costs, waste disposal costs, and utility bills.

Greening Federal Facilities is a resource guide for Federal facility managers to assist them in reducing energy consumption and costs, improving the working environment of the facilities they manage, and reducing the environmental impacts of their operations. Showcase initiatives such as *The Greening of the White House* serve as models for initiating environmental and energy upgrades for Federal facilities.

Sustainability is a term that covers the wide range of actions needed to reduce the impact of the built environment on the natural environment and, with respect to this guide, is synonymous with "greening". At its very heart, sustainability is about leaving a high quality of life for this nation's many future generations. For our society to be sustainable we must (1) use all resources (energy, water, material, and land) efficiently and minimize waste; (2) protect the natural environment, the source of all our resources; and, (3) create a healthy built environment for future generations. This guide concentrates on sustainable building actions that are practical and cost-effective.

This guide was developed by the Federal Energy Management Program (FEMP) and places key energy and environmental information along with appropriate economic data at the fingertips of the facility manager to assist the decision-making process. The guide is intended to provide a quick introduction and reference to the many technologies and practices involved in greening efforts. It suggests actions that are likely to be successful as first steps in saving energy, water, and resources. Each section is condensed, and identifies additional resources for facility managers to consult for detailed information. The reader is encouraged to consult these resources and the on-line version of this guide that has even more resources available to the user. Section 1.3 is a tour of this guide and shows facility managers how to effectively use it to "green" their operations. *Greening Federal Facilities* emphasizes preventing waste and pollution instead of focusing on the compliance process.

Issues

So who are these facility managers and why are they important? Facility managers are the people who manage several hundred thousand facilities worldwide on behalf of the United States. They can be in-house energy managers, solid waste managers or others with similar responsibilities. In DOD they are the Base Civil Engineers (BCE) and Directors of Engineering and Housing (DEH). They are middle-level managers with huge responsibilities and declining human and financial resources. Some facility manager facts for consideration:

1 The Federal facility manager community operates and maintains over 500,000 buildings owned and leased by the Federal Government!

2 The area of these buildings is in excess of 3,100,000,000 (3.1 billion) square feet of floor space.

3 These buildings are the homes, working places, and support systems for almost two million Federal workers and many contract staff. They comprise everything from office buildings to power plants, and include aircraft hangers, libraries, hospitals, tourist attractions, and prisons.

4 These Federal buildings consume in excess of 60,000,000,000 kilowatt-hours of energy each year. This energy costs more than $3.5 billion each year.

5 The water utilized by these buildings and other facilities is staggering in quantity—several hundred cubic miles each year!

6 Facility managers purchase billions of dollars of materials annually for operations, maintenance, repair, and renovation. Their procurement decisions dramatically affect the types of products created and manufactured by a wide range of businesses, from paper products to steel panels, from

cleaning fluids to hydraulic fluids, from medicines to pesticides.

The bottom line is this: Facility managers probably manage more resources and have more impact on the environment than any other group in the world. Entire changes in direction relative to energy and environmental quality are possible through their collective action. This guide is designed to provide facility managers with the information needed to make wise energy and environmental decisions that not only reduce energy consumption and protect the environment, but also save money and improve the productivity of Federal workers.

Did you know? The cost of operating an average Federal building, including the amortized construction cost, is about $15 per square foot annually. The cost of the Federal government employees in these buildings is on the order of $315 per square foot each year! The meaning of this factor of 20 difference between building and occupant costs is clear. If you increase the productivity of the work force by a mere 5% by improving the working environment, the resulting annual savings will exceed the annual cost of building ownership and operation!! This guide shows facility managers how to make these positive changes, save energy, increase productivity, and greatly reduce facility environmental impacts.

What are the potential savings that facility managers can produce to both reduce costs and U.S. dependence on foreign energy sources? The Electric Power Research Institute (EPRI) estimates an aggressive drive to reduce energy costs can reduce electricity use by 24% to 44%. The Rocky Mountain Institute goes even further and claims potential cost-effective electricity savings of 75%.

Cost of Building/Year:	$15/sq ft
Employee Cost/Year:	$315/sq ft
5% Productivity Improvement:	$16/sq ft
10% Productivity Improvement:	$31/sq ft

The key principles for facility managers to follow to reduce energy and environmental impacts of their operations are:

1. **Reduce resource consumption**: energy, water, land.
2. **Reduce resource waste**: energy, water, materials.
3. **Increase equipment and system efficiency:** no-cost or low-cost tune-ups, modifications, replacement.
4. **Emphasize source and waste reduction** to all facility users.
5. **Create healthy environments** for Federal workers: air, light, noise, temperature, humidity.

Contacts

Federal greening initiatives, including the on-line version of this guide and The Greening of the White House, are located on the internet at http://www.eren.doe.gov/femp/greening.html.

The FEMP Help Desk at (800) DOE-EREC offers technical support on a wide range of topics to assist facility managers in greening their facilities.

There is a wide variety of Federal laws, Executive Orders, and Executive Memoranda that facility managers are required to follow to reduce the energy and environmental impacts of the buildings they manage. These laws and regulations already direct facility managers to be proactive in their efforts to reduce resource consumption, reuse and recycle materials, and dramatically reduce the impacts of Federal government activities on the environment. Although they are required to comply with the many specific directives in these documents, many facility managers may be unaware of the actions they can take with regard to implementation. In this section, the major Federal regulations governing energy and environmental actions, together with their important provisions, are listed in chronological order.

Federal Laws & Executive Orders

1 **Energy Policy and Conservation Act (EPCA) of 1975.** EPCA was the first major piece of legislation to address Federal energy management. This law directed the President to develop a comprehensive energy management plan. EPCA has largely been overtaken by later legislation.

2 **Resource Conservation and Recovery Act (RCRA) of 1976.** RCRA §6002 established a Federal mandate to "Buy Recycled." RCRA §1008 and §6004 require all Federal agencies generating solid waste to take action to recover it.

3 **National Energy Conservation Policy Act (NECPA) of 1978.** NECPA specified the use of a life-cycle costing methodology as the basis for energy procurement policy and specified the rate for retrofit of Federal buildings with cost-effective energy measures. Title V of NECPA was codified as the Federal Energy Initiative.

4 **Comprehensive Omnibus Budget Reconciliation Act (COBRA) of 1985.** COBRA, a one-year funding bill, provided Federal agencies with an alternative source of funding for energy-efficiency investments. For the first time, agencies were encouraged to seek private financing and implementation of energy-efficiency projects through "shared energy savings" (SES) contracts.

5 **Federal Energy Management Improvement Act (FEMIA) of 1988.** It mandated a 10% reduction in per-square-foot energy use by Federal buildings between 1985 and 1995, marking the first time that Congress specified the level of savings that had to be achieved.

6 **Executive Order 12759**, "Federal Energy Management," April 17, 1991. This Order extended the FEMIA energy reduction requirements for Federal buildings to 2000, requiring a 20% reduction in per-square-foot energy usage from 1985 levels. This executive order was replaced by Executive Order 12902 (number 13, next page).

7 **Energy Policy Act of 1992 (EPACT).** This Act increases conservation and energy-efficiency requirements for government and consumers; for Federal agencies, requires a 20% reduction in per-square-foot energy consumption by 2000 compared to a 1985 baseline; provides authorization for DOE to issue rules and guidance on Energy Savings Performance Contracts (ESPCs) for Federal agencies; requires Federal agencies to train and utilize energy managers; directs the Office of Management and Budget to issue guidelines for accurate assessment of energy consumption by Federal buildings; and directs GSA to report annually on estimated energy costs for leased space.

8 **Executive Order 12843**, "Procurement Requirements and Policies for Federal Agencies for Ozone-Depleting Substances," April 21, 1993, requires Federal agencies to maximize the use of safe alternatives to ozone-depleting substances by: (1) revising procurement practices; (2) modifying specifications and contracts that require the use of ozone-depleting substances; (3) substituting non-ozone-depleting substances to the extent economically practicable; and (4) disseminating informa-

tion on successful efforts to phase out ozone-depleting substances.

9 **Executive Order 12844**, “Federal Use of Alternative Fueled Vehicles,” April 21, 1993. This requires the Federal government to adopt aggressive plans to acquire, subject to availability of funds and considering life-cycle costs, alternative fueled vehicles, in numbers that exceed by 50% the requirements for 1993 through 1995, set forth in the Energy Policy Act of 1992.

10 **Executive Order 12845**, “Requiring Agencies to Purchase Energy-Efficient Computer Equipment," April 21, 1993. Order 12845 requires all acquisitions of microcomputers, monitors, and printers to meet EPA Energy Star requirements for energy efficiency, including low power standby features as defined by EPA Energy Star Standards. Agencies must make Federal users aware of the economic and environmental benefits of energy saving equipment through information and training classes.

11 **Executive Order 12856**, “Federal Compliance with Right-to-Know Laws and Pollution Prevention Requirements,” August 4, 1993. Explains how Federal agencies are to comply with Emergency Planning and Community Right-to-Know (EPCRA) reporting requirements and offers “leadership options” for Federal agencies in meeting the goals of the Order.

12 **Executive Order 12873**, “Federal Acquisition, Recycling, and Waste Prevention,” October 20, 1993. This Executive Order addresses the government’s purchasing power, incorporates environmental considerations into decision making, and encourages waste prevention and recycling in daily operations. Federal agencies: (1) must set goals for waste reduction; (2) must increase the procurement of recycled and other environmentally preferable products; and, (3) can retain some of the proceeds from the sale of materials from recycling or waste-prevention programs.

13 **Executive Order 12902**, “Energy Efficiency and Water Conservation at Federal Facilities,” March 8, 1994. For Federal agencies it requires: (1) a 30% reduction in per gross square foot energy consumption by 2005 compared to 1985 to the extent that these measures are cost effective; (2) a 20% energy efficiency increase in industrial facilities by 2005 compared to 1990 to the extent that these measures are cost effective; (3) the implementation of all cost-effective water conservation projects; and, (4) the procurement of products in the top 25% of their class in energy efficiency where cost-effective and where they meet the agency’s performance requirements. In addition to available appropriations, agencies shall utilize innovative financing and contracting mechanisms including, but not limited to, utility DSM and ESPCs to meet the goals and requirements of EPACT and this order.

14 **Executive Memorandum** on “Environmentally and Economically Beneficial Practices on Federal Landscaped Grounds,” April 26, 1994. This requires Federal grounds and Federally funded projects, where cost-effective and practicable, to use regionally native plants for landscaping. It also requires facility managers to promote construction practices that minimize adverse effects on the natural habitat; minimize use of fertilizers and pesticides; use integrated pest management techniques; and, recycle green waste. Water-efficient practices, such as minimizing runoff, using mulches, irrigating using efficient systems, and performing water audits, are also required. Agencies must also establish areas that demonstrate these principles.

15 **10CFR435** establishes performance standards to be used in the design of new Federal commercial and multifamily high rise buildings. Some of the guidelines are relevant to retrofits.

16 **10CFR436** establishes procedures for determining the life-cycle cost effectiveness of energy conservation measures, and for prioritizing energy conservation measures in retrofits of existing Federal buildings.

Contacts

For more information on Federal rules and regulations relative to energy and environmental actions, contact FEMP's Help Desk at (800) DOE-EREC.

This section describes how this guide is organized to deliver key decision-making information to the facility manager as effectively as possible.

How this guide is particularly useful to facility managers

Greening Federal Facilities uses “Action Moments” as the focal points for assisting facility managers in making changes that will "green" their operations. An Action Moment is a point in time when there is an opportunity to make major positive changes in facility operations that will reduce environmental and energy impacts. A good example of an Action Moment is roof repairs. The need to replace a roof presents opportunities to improve insulation, install skylights to provide daylighting, and improve the Indoor Environmental Quality (IEQ) of interior spaces beneath the roof.

Guide Organization

The guide is organized into three separate parts:

Part I—Introduction, simply defines the playing field for facility managers and suggests ways to pay appropriate attention to energy and environmental issues. It also contains a section on decision-making tools a facility manager can use to make difficult and sometimes expensive decisions in an era of personnel and resource reductions.

Part II—Energy/Environmental Decision Making, is the technical part of the guide and provides guidance on how to reduce energy, water, and other resource consumption. It quickly highlights the issues, provides solutions, shows success stories related to the subject at hand, and points to sources of further information.

Part III—Opportunities For Change, gets to the heart of the facility manager's job and suggests ways to use the information in Parts I and II on a daily basis. Part III provides the facility manager with approaches that can be used during operations and maintenance where the energy and environmental impacts are significant. Again, success stories in the form of brief examples are used to provide real world examples of how appropriate changes can be successfully made.

Icons

The guide is organized with the help of icons to rapidly direct the facility manager to the most useful information. These icons are used as the situation dictates, and are reasonably self-explanatory. Note that all icons are listed on the inside of the front cover for ready reference.

- Technical Information
- Rule of Thumb or Tip
- Good Idea
- Operations and Maintenance
- Financial, Economic, or Life Cycle
- Cautionary Note
- Environmental Information
- Recycling Information
- Examples

Examples are used to show concrete instances of exactly how the particular ideas for lower environmental and energy impacts can be used. The example designated by the file folder icon is a short summary of a very specific application.

References in the hard copy version of this guide are limited due to space. Please visit our on-line web site under "Greening Initiatives" at http://www.eren.doe.gov/femp.

Many of the decisions required of the facility manager with respect to energy or environmental actions require a logical, step-by-step analysis of the available options. This rigorous analysis complements other steps in the decision-making process, such as identifying the problem, working with affected parties to develop options, selling the idea to decision makers, developing a funding package, and getting buy-in from affected building users.

The analysis method used should take into account all the major criteria, appropriately weight the criteria depending on their relative importance, and rank each of the options relative to each criterion. The preferable result is a set of scores that can be used as a basis for selecting one of the available options. Although there are many decision-making techniques, the method described here, the Criteria Weighting Method (CWM), is one the facility manager can easily utilize and apply to help make relatively complex decisions in a fairly logical and rigorous manner.

Technical Information

The first step in decision-making is to list the available options. All possible options should be listed as an exercise in ensuring completeness. Only the top options need be carried forward into the formal decision-making process.

Note that one of the options can be "Do Nothing!"

After listing the available options the criteria relative to the situation should be listed. Some of the criteria that can be chosen are: quality, life-cycle cost, durability, performance, appearance, availability, weight, physical size, safety, reliability, noise levels, conformance with building codes, color, aesthetics, weather resistance, U.S. manufacturer, and subcontractor performance.

Note that life-cycle cost must be included as one of the criteria for each option. It is assumed that the life-cycle cost has been determined prior to the final decision-making process.

The process described here places the options on the horizontal axis of a decision matrix and the criteria on the vertical axis. The first step in the process is to determine the relative weights of the various criteria. This determination is accomplished by a pair-wise comparison of the criteria to establish which of the two criteria is more important. When this process has been completed, the weights are calculated and written into the matrix. The various options can then be ranked for each criterion and the final scores computed.

The use of this decision-making technique is described below.

Criteria Weighting Method

Instructions: The first step in the Criteria Weighting Method (CWM) is to develop the Criteria Weights. Once the weights are determined, they are applied to the problem at hand. Two simple matrices are used to assist this process as described below: the Criteria Matrix and the Analysis Matrix.

1 **Developing Criteria Weights:** (1) On the left side of the following page is an example Criteria Matrix used to determine weights for a sample decision on exterior wall types. The process begins with "Cost" (Criterion A) being compared to "Maintainability" (Criterion B), and the more important of the two is placed in the box along with the preference weight for the more important. In this case Cost is the more important and there is a *minor difference* which has a weight of 1. Consequently "A1" is entered in the box at the intersection of these two criteria. Comparing Cost (A) with Redesign Time (F), the more important is Cost and the difference is between *major* and *medium*, a weight of 4. "A4" is entered in the intersection of the two criteria. (2) Continue this process to complete the pair-wise comparison of all criteria. (3) At the end of the comparison add the weight factors for each criterion both horizontally and vertically and write the total by each criterion on the right. In this case, Cost (A) has a total weight of 13 and Proven Quality (D) has a total of 9. The rank is written in the right column based on these totals.

2 **Applying the Criteria Weights:** (1) Below right is the Analysis Matrix which continues the example with the criteria and their associated weights written across the top of the matrix. (2) The options available are written vertically by criterion. For example, cost is compared for each of the options first, then the other criteria are also compared. A score of 1 to 5 (higher is better) is used and then the weight is applied. In the first column, a "cost" score of 1 was given to "Steel Stud with Brick Veneer" and then multiplied by the weight of 13 derived from the first matrix. (3) The total score is computed on the right and the various options are ranked. In the case shown here the highest score is 166, and thus the number one choice is "Exposed Concrete Block with Split Face Finish."

CRITERIA MATRIX

Study Title: Exterior Walls

CRITERIA									
A COST	B MAINTAINABILITY	C AESTHETICS	D PROVEN QUALITY	E HVAC IMPACT	F REDESIGN TIME	G	H	SUM OF SCORES IN BOTH VERTICAL & HORIZONTAL	RANK
A	A1	A3	A2	A3	A4			A 13	1
	B	B5	D1	E3	B2			B 7	4
		C	D3	C4	C4			C 8	3
			D	E3	D5			D 9	2
				E	F3			E 6	5
					F			F 3	6
						G		G	
								H	

To each box under SCORE, be sure to write both the letter representing the PROBLEM AREA and the numeral or cipher representing the WEIGHTING for the choice you feel is most important. Preference weightings:
0=no difference, 1=minor, 3=medium, 5=major

ANALYSIS MATRIX

Study Title: Exterior Walls

Basic Function: Control Elements/Support Load

Desired Criteria →	A COST	B MAINTAINABILITY	C AESTHETICS	D PROVEN QUALITY	E HVAC IMPACT	F REDESIGN TIME	G	TOTAL	RANK
Weight from Criteria Matrix →	13	7	8	9	6	3			
Concrete Block, Painted	5 / 65	2 / 14	1 / 8	1 / 9	2 / 12	3 / 9		117	#5
Steel Stud with Brick Veneer	1 / 13	4 / 28	4 / 32	4 / 36	4 / 24	1 / 3		136	#4
Steel Stud with Stucco	3 / 39	3 / 21	3 / 24	3 / 27	4 / 24	1 / 3		138	#3
Exposed Concrete Block with Split Face Finish	4 / 52	4 / 28	4 / 32	3 / 27	3 / 18	3 / 9		166	#1
Concrete Block with Stucco Exterior	4 / 52	3 / 21	3 / 24	2 / 18	2 / 12	3 / 9		136	#2

List the best ideas from ranking and comparisons techniques. Determine which one stacks up best against the desired criteria.
Excellent = 5 Very good = 4 Good = 3 Fair = 2 Poor = 1

Justifying a decision to make changes that improve the energy performance or reduce the environmental impacts of a facility requires close attention to the economics of the situation. There are several key economic analysis methods the facility manager should be familiar with and utilize for this purpose, the most important of which is Life-Cycle Costing (LCC). Other analysis tools include Cost-Benefit Analysis and Life-Cycle Analysis (LCA).

Technical Information

Although the names sound alike, LCC and LCA are in fact very different.

LCC analyzes building or facility changes to include amortized system costs, maintenance and insurance costs, replacement costs, energy costs, and other significant costs over the assumed life of the measure or facility. It combines all costs into a net annual cost and then reduces these annual costs to a net total cost, usually the Net Present Value. LCC must be performed by facility managers.

LCA is used to analyze the impacts of a single product, for example a type of paint or a variety of concrete, for its energy and environmental impacts. Sometimes referred to as Product Life Cycle Assessment (PLCA), it is useful for understanding choices between products from an environmental impacts point of view. Unlike LCC, which expresses the outcome in a single monetary unit, PLCA expresses the results in energy units, mass units of pollutants, or other appropriate units. A single, simple representation of the outcome is not really possible. PLCA does not deal with economic issues.

Economic Analysis Tools

There are several readily available tools the facility manager can use to perform a good economic analysis for use in the decision-making process.

1 **The National Institute of Standards and Technology's Building Life-Cycle Cost (BLCC)** computer program provides economic analysis of proposed capital investments that are expected to reduce long-term operating costs of buildings or building systems/components. It is especially useful for evaluating the costs and benefits of energy conservation projects in facilities, and can be readily adapted for water conservation and other programs. BLCC 4.21 and later versions can calculate annual and life cycle CO_2, SO_x, and NO_x emissions for building energy systems. The Quick Input (QI) program included with BLCC can be used to rapidly set up multiple project alternatives for LCC analysis in a single file. Both software programs are designed to run on IBM-compatible computers and both are updated annually. BLCC is designed to comply with 10CFR436.

2 **BLCC**, in addition to comparing two or more alternatives, computes the Net Savings, Savings-to-Investment Ratio, Adjusted Internal Rate of Return, and Years to Payback.

General Study Parameters for LCC

(1) Type of analysis: Federal, military, private sector
(2) Treatment of inflation: constant or current dollars
(3) Base Date: the date to which all future costs are discounted
(4) Service Date: the date at which the facility will be occupied or system put into service
(5) Study Period: usually the life of the facility or product
(6) Discount Rate: the investor’s opportunity cost or the minimum acceptable return
(7) Applicable Tax Rates: for private sector analyses

Other Important Parameters for LCC

(1) Annual O&M costs
(2) Non-annually recurring O&M costs
(3) Energy and water quantities and costs
(4) Salvage value

References

The following programs and resources are available through the FEMP Help Desk and Home Page.

NIST Publications and Tools: The following are available from the National Institute of Standards and Technology (NIST). For ordering information, contact the NIST Inquiries Office, Room A-903 Administration Building, Gaithersburg, MD 20899 (301) 975-3058, or the NIST Office of Applied Economics at (301) 975-6132.

Building Life-Cycle Cost (BLCC) Computer Program, User's Guide and Reference Manual, (NISTIR 5185-2). This is the "NIST Building Life-Cycle Cost (BLCC) program and guide" referenced on the previous page. The FEMP Help Desk at (800) DOE-EREC will provide copies, and information about schedules for training courses offered in various locations throughout the country.

DISCOUNT: A Program for Discounting Computations in Life-Cycle Cost Analyses, (NISTIR 4513). A software program for computing discount factors. Be sure to ask for the latest version.

Present Worth Factors for Life-Cycle Cost Studies in the Department of Defense, (NISTIR 4842-2). A separate version of the report listed above, for DOD analyses.

Videos: Three video training films offering an introduction to FEMP life-cycle costing (LCC) methods are available from Video Transfer Inc.: (1) "An Introduction to Life-Cycle Cost Analysis"; (2) "Uncertainty and Risk"; and, (3) "Choosing Economic Valuation Methods." For ordering information, contact them at 5709-B Arundel Ave., Rockville, MD 20852 or at (301) 881-0270.

Training Programs: *Building Life-Cycle Cost (BLCC) Computer Program* training courses are offered in various locations throughout the country. Contact the FEMP Help Desk at (800) DOE-EREC for information.

Contacts

The FEMP Help Desk at (800) DOE-EREC or FEMP's home page at http://www.eren.doe.gov /femp

Society for Environmental Toxicology and Chemistry (SETAC), Pensacola, FL at (904) 465-1500 is a good source of information about Product Life Cycle Assessment (PLCA). The SETAC PLCA methodology is the most widely accepted procedure for determining the environmental impacts of materials or products.

NIST Home Page at http://www.nist.gov

Energy and Conservation Issues 3.1

The Federal Government is the largest single user of energy in the United States and purchases an estimated $10-20 billion in energy-related products. In Federal buildings, annual energy costs are approximately $1.23 per square foot. The Energy Policy Act of 1992 and Executive Order 12902 set goals for energy reduction and provide some guidelines for implementing conservation measures. FEMP provides information on technologies that have been proven in field testing or recommended by reliable sources, such as the DOE National Laboratories.

Photovoltaic panels, such as these powering an irrigation system, can displace electricity purchased from a utility.

Action Moment

The time for planning, evaluating, and implementing is now! Facility managers should first implement energy- and demand-reducing measures in their operations and then look for opportunities to cost-effectively replace conventional technologies with ones using renewable energy sources.

Facility managers should also set goals for their operations that follow Federal mandates. Executive Order 12902 requires an energy reduction in Federal buildings of 30% from 1985 levels by the year 2005. In addition, where possible, facility managers are required to install all energy and water conservation measures with payback periods of less than 10 years. When energy-using equipment needs replacement, guidance for purchasing products that meet or exceed Executive Order 12902 procurement goals is available through FEMP's Product Energy Efficiency Recommendations series.

Technical Information

The Energy Systems and Conservation section of this guide describes systems that provide key opportunities for energy savings. The following are some of these opportunities:

1 **HVAC systems** improvements offer the greatest potential for energy savings in most facilities. Opportunities include replacing equipment with more efficient models, improving controls, upgrading maintenance programs, and retrofitting existing equipment to operate more efficiently. Central plants contain many interrelated components, and upgrading them takes careful planning, professional design assistance, and careful implementation. This guide covers chillers, boilers, steam traps, variable-air-volume systems, and other HVAC technologies.

2 **Electric motor systems** that operate continuously or for many hours a year consume electricity that costs many times the price of the motor. This makes inefficient, large horsepower motors excellent targets for replacement. If the driven load operates at reduced speed for a majority of the time, installing electronic motor controls would both reduce energy consumption and save operating costs.

3 **Lighting.** $250 million could be saved annually if all Federal facilities upgraded to energy-efficient lighting. Light energy savings of up to 40% can be achieved in interior applications by replacing lamps and ballasts. Savings of 80% are possible by designing and implementing an integrated approach to lighting system retrofits.

4 **Electrical power systems** can be made more efficient through (1) maintenance practices focused on identifying potential trouble areas such as loose electrical connections, and (2) selection of efficient equipment, such as transformers.

5 **Office equipment** is becoming an ever greater proportion of building loads. "Green" appliances that feature automatic power shutdown and more efficient electronics can help reduce energy consumption.

6 **Water heating** is a major fuel consumer in facilities with kitchens and laundries. Beyond reducing the use of hot water, various heat recovery and solar technologies can help reduce operating cost.

7 **Energy Management and Control Systems** (EMCSs) are critical in avoiding energy waste and monitoring energy consumption. Control technology should be applied intelligently for each situation, and an optimized mix of local and central control should be used.

8 **Building shells** are the physical barrier controlling external heat gain and heat loss. The best opportunities for energy efficiency are in facility design, building orientation and configuration; fenestration; and envelope design. These have substantial impact on building performance. There are many retrofit strategies that can improve the energy efficiency of existing buildings. Window and door treatments can minimize energy transmission through the shell. Understanding the local microclimate can help facility managers take advantage of passive measures.

$ **Energy Savings Performance Contracts (ESPCs)** provide Federal agencies a means of increasing the investment in energy saving technologies. With appropriated funds shrinking for many agencies, ESPCs provide a means for agencies to secure financing from Energy Service Contractors (ESCOs) for identifying and implementing energy conservation measures. In effect, agencies can defer the initial costs of equipment and pay for equipment via the utility bill savings. FEMP assists Federal agencies with ESPCs.

Super ESPCs are a broadened form of ESPC. They are a type of regional agreement where delivery orders are placed against a contract with selected ESCOs. The Super ESPC allows individual facilities to negotiate contracts directly with the selected companies, greatly reducing the complexity of the ESPC process.

Basic Ordering Agreements (BOAs) are written understandings negotiated between GSA and a utility or other business, that set contract guidelines for energy-consuming products and services. For example, the GSA Chet Holifield Federal Center in Laguna Niguel, CA contracted with their electric utility for thermal energy storage, energy-efficient chillers, variable-frequency drives, efficient motors, and lighting system retrofits. The contractor invested $3,800,000, and the government's share of the savings is $1,400,000 over 14 years. The GSA retains the equipment after the contract term. One prominent BOA specifying energy-efficient chillers for Federal procurement has been developed between GSA and the five major chiller manufacturers in the United States. Other BOAs are being developed and will be available soon. See section 9.4 for additional information on ESPC, Super ESPC, and BOA programs.

References

Department of Energy, *Architect's and Engineer's Guide to Energy Conservation in Existing Buildings,* (DOE/RL/018-30P-H4), Washington, DC, 1990.

Contacts

For FEMP's *Product Energy-Efficient Recommendations* series or for more information on financing alternatives, visit the FEMP Home Page at http:/www.eren.doe.gov/femp or call the FEMP Help Desk at (800) DOE-EREC.

Heating, ventilating, and air conditioning (HVAC) systems can be the largest energy consumers in Federal buildings. HVAC systems provide heating, cooling, humidity control, filtration, fresh air makeup, building pressure control, and comfort control, all with infrequent interaction between the occupants and the system. Properly designed, installed, and maintained HVAC systems are efficient, provide comfort to the occupants, and inhibit the growth of molds and fungi. Well-designed, and efficient HVAC systems are essential for Federal buildings and employee productivity. Boilers, steam traps, variable-air-volume systems, chillers, and new HVAC technologies are covered in the following sections.

Action Moment

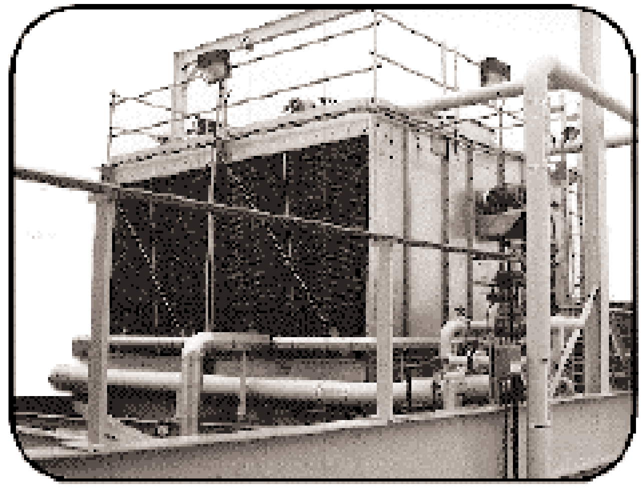
Consider upgrading or replacing existing HVAC systems with more efficient ones: if current equipment is old and inefficient; if loads have changed due to other conservation measures or changes in building occupancy; if control is poor; if implementing new ventilation standards has caused capacity problems; or, if moisture or other indoor air quality problems exist. Be sure to have a plan in place for equipment change-out and failure. The phaseout of chlorinated fluorocarbons (CFCs) presents an added factor encouraging chiller replacement.

Technical Information

Some common opportunities for reducing HVAC operating costs in large facilities are:

1 **Reduce HVAC loads.** By reducing building loads, less heating and cooling energy is expended. Load reduction measures include: adding insulation; shading harsh wind and sun exposures with trees, shadescreens, awnings, or window treatments minimizing use of heat-producing equipment, such as office equipment and computers; daylighting; controlling interior lighting; and capturing heat from exhaust air.

2 **Incorporate building automation/control systems.** These systems can be added or upgraded



Cooling towers, which are usually components of large HVAC systems, can be made more efficient by controlling their operation times and by retrofitting their motors with variable frequency drives.

to improve the overall performance of the building, including the HVAC equipment. Perhaps the simplest measure and the first to be considered is to ensure that HVAC systems are in "setback" mode during unoccupied periods. Existing control systems will often accommodate this very simple measure. Section 3.8 discusses these systems in more detail.

3 **Optimize for part-load conditions**. Buildings usually operate under conditions where the full heating or air conditioning capacity is not required. Therefore, the greatest overall annual efficiency improvements will result from giving special consideration to part-load conditions. Staging multiple chillers or boilers to meet varying demand greatly improves efficiencies at low and moderate building loads. Pairing different-sized chillers and boilers in parallel offers greater flexibility to central plant equipment. Units should be staged with microprocessor controls to optimize system performance.

4 **Isolate off-line chillers and boilers.** In parallel systems, off-line equipment should be isolated from cooling towers and distribution loops. With

reduced pumping needs, circulation pumps can be shut off or modulated with variable speed drives.

5 **Use economizers**. In climates with seasons having moderate temperatures and humidity, adding economizer capabilities can be cost effective. When ambient conditions are suitable, outside air provides space conditioning without the use of the cooling plant. To prevent inappropriate introduction of outside air, economizer logic, controls, and maintenance need careful attention.

6 **Ventilation systems in buildings have tremendous impacts on energy use** due to the high costs associated with heating or cooling outside air. Buildings should be ventilated according to ASHRAE Standard 62. The elevated outside air introduction requirements (15-20 cfm in most commercial buildings) of Standard 62's most recent version (62-1989) do not apply to buildings constructed before its publication, although for new additions of 25% or more, this "grandfathering" is not permitted by the major building codes. The indoor air quality benefits of complying with ASHRAE 62-1989, such as higher productivity and decreased sick-leave, may often deem the added expense worthwhile, even when not required by law.

7 **Upgrade cooling towers.** Large savings are possible by retrofitting cooling towers with new fill, efficient transmissions, high-efficiency motors, and variable frequency drives. Good water chemistry is critical to minimize the use of environmentally hazardous chemical biocides. Ozone treatments also may be useful.

Importance of Maintenance

Proper maintenance prevents: loss of HVAC air balance (return, supply, and outdoor air); poor indoor air quality; poor refrigerant charge; fouling of evaporator coils by dust and debris; poor water quality in cooling towers; and, water damage from condensate.

1 **Air handler maintenance.** To achieve better indoor air quality and reduce operating costs, steam clean evaporator coils and air handlers on a minimum three-year rotation. Also, filters should be changed frequently.

2 **Ventilation.** A good balance report is required. Air flows can then be periodically checked. Periodically lubricate dampers and check their operation by manually operating them.

3 **Air distribution system leakage.** In residential and small commercial buildings, air duct leakage can be a huge energy waster. Leaks in return duct systems also cause energy, comfort, and air quality problems. Check ventilation rates after duct repair to ensure that ASHRAE Standards are met and that building zones are not unintentionally depressurized.

4 **Improper refrigerant charge.** Direct expansion refrigerant systems require precise levels of refrigerant to operate at peak capacity and efficiency, and to best control interior humidity in moist climates. The most common causes of improper refrigerant charge are: failure to use nitrogen- purging when soldering; failure to evacuate lines and coils using recommended methods; failure to leak-test before charging; and failure to use properly calibrated gauges.

5 **When upgrading or replacing equipment**, ease of maintenance and indoor air quality are important considerations. Consider specifying protection for air handler insulation to prolong effectiveness, filter doors with easy-opening mechanisms, high quality grilles and diffusers, diagnostic capabilities, and appropriate humidity removal. For air distribution system design, use computer-modeled duct design, proper duct- sealing materials and techniques, ducts with smooth interiors, and low-face-velocity coils.

References

American Society of Heating, Refrigerating and Air Conditioning Engineers, *ASHRAE Standard 62*.

Contacts

HVAC retrofits and maintenance opportunities are thoroughly covered in the FEMP-sponsored "Trained Energy Manager" course. Contact the FEMP Help Desk at (800) DOE-EREC.

For written material and software to assist with evaluating HVAC systems, contact the EPA Energy Star Building Hotline at (202) 775-6650.

Most medium-to-large facilities use boilers to generate hot water or steam for space heating, food preparation, and industrial processes. For boilers to run at peak efficiency, operators must attend to water chemistry, pumping and boiler controls, boiler and pipe insulation, fuel-air mixtures, burn-to-load ratio, and stack temperatures.

Action Moment

Every effort should be made to upgrade boiler systems to peak efficiency to reduce operating costs and environmental impacts. When replacing old equipment or installing new equipment, consider the advantages that multiple boiler systems offer. Multiple boiler systems are more efficient than single boilers, especially under part-load conditions. Also, consider solar-assisted systems or biomass-fired boilers in place of conventional boiler systems.

Technical Information

Recent trends in boiler systems include: installing multiple small boiler units; lowering system pressures; decentralizing systems; and installing direct digital control (DDC) systems. Boilers that have efficiencies over 90% are available. Because these systems capture the latent heat of vaporization from combustion water vapor, flue gas temperatures are low enough to vent the exhaust though PVC pipes. PVC resists the corrosive action of flue gas condensate.

1 **Add radiator controls.** Radiators that operate at full output are common in older office buildings. Adding thermostatic valves that control hot water or steam output to each radiator enables occupants to maintain comfort without opening windows in the winter. In some situations, adding radiator controls can cut steam or hot water use by one-third.

2 **Replace inefficient boilers.** In newer units, more fuel energy goes into creating steam, so both stack temperatures and excess oxygen are lower. Estimate efficiencies of existing units by measuring excess air, flue and boiler room temperatures, and percent of flue gas oxygen and carbon dioxide. Some utilities will provide this service free of charge.

3 **Decentralize systems.** Several smaller units strategically located around a large facility reduce distribution losses and offer flexibility in meeting the demands of differing schedules, and steam pressure and heating requirements. Estimate standby losses by monitoring fuel consumption during no-load periods.

4 **Downsize.** Strive to lower overall heating demands through prudent application of energy conservation measures. Smaller boilers may be staged to meet loads less expensively than large central plants. Many new units are designed to ease retrofit by fitting through standard doorways.

5 **Modernize boiler controls.** Direct digital controls (DDC) consist of computers, sensors, and software.

DDCs allow logic-intense functions such as optimizing fuel/air mixture based on continuous flue gas sampling, managing combustion, controlling feedwater and drum levels, and controlling steam header pressure.

6 **Install an economizer.** Install a heat exchanger in the flue to preheat the boiler feedwater. Efficiency increases about 1% for every 5.5˚C (10˚F) increase in feedwater temperature. If considering an economizer, ensure: (1) that the stack temperature remains higher than the acid dew point in order to prevent flue damage; and (2) that excess flue temperature is due to insufficient heat transfer surfaces in the boiler rather than scaling or other maintenance problems.

7 **Install oxygen trim system.** To optimize fuel/air ratio, these systems monitor excess oxygen in the flue gas and modulate air intake to the burners accordingly.

8 **Install automatic flue dampers** to reduce the amount of boiler heat that is stripped away by natural convection in the flue after the boiler cycles off.

9 **Retrofit gas pilots** with electronic ignition systems that are readily available.

10 **Install air pre-heaters** that deliver warm air to the boiler air inlets through ducts. The source of warm air can be the boiler room ceiling, solar panels, or solar-preheat walls. Managers should check with boiler manufacturers to ensure that alterations will not adversely alter the performance, void the warranty, or create a hazardous situation.

11 **Add automatic blowdown controls.** Uncontrolled, continuous blowdown is very wasteful. A 10% blowdown on a 200 psia steam system results in a 3% efficiency loss. Add automatic blowdown controls that sense and respond to boiler water conductivity and pH.

12 **Add a waste heat recovery system to blowdowns.** By capturing blowdown in recovery tanks and using heat exchangers to preheat boiler feedwater, system efficiency can be improved by about 1%.

13 **Consider retrofitting boiler fire tubes with turbulators** for greater heat exchange, after checking with your boiler manufacturer. Turbulators are baffles placed in boiler tubes to increase turbulence, thereby extracting more heat from flue gases.

14 **Detect and repair steam leaks.** Leaks in underground distribution pipes can go undetected for years. Monitor blowdown and feedwater to help detect these leaks.

15 **Reduce excess air to boiler combustion.** The common practice of using 50% to 100% excess air decreases efficiency by 5%. Work with the manufacturer to determine the appropriate fuel/air mixture.

16 **Insulate boiler and boiler piping.** Reduce heat loss though boiler walls and piping by repairing or adding insulation. The addition of 2.5cm (1 inch) of insulation can reduce heat loss by 80% to 90%.

O/M **Proper operation and maintenance** is the key to efficient boiler operation. Any large boiler plant should maintain logs on boiler conditions as a diagnostic tool. When performance declines, corrective action should be taken.

Reduce soot and scale. Deposits act as insulation on heat exchangers and allow heat to escape up the flue. If the stack temperature rises over time under the same load and fuel/air mixture, and deposits are discovered, adjust and improve water chemistry and fuel/air mixture accordingly. Periodically running the system lean can remove soot.

On systems operating with negative pressure, air may enter the system after the combustion process and give false indications of excess air measured with flue gas oxygen.

References

Brecher, Mark L., “Low-Pressure System Gets High Marks from College,” *Heating/Piping/Air Conditioning,* Sept 1994.

Payne, William, *Efficient Boiler Operations Sourcebook*, 3rd Ed., Fairmont Press, 1991.

Washington State Energy Office, Boiler Efficiency Operations, (WAOENG-89-24), Olympia, WA, 1989.

Steam traps are components of steam systems that vent air and drain condensate formed in steam distribution systems, and prevent live steam from exiting when condensate lines are vented. Condensate formed after the steam releases its latent heat of vaporization must be removed to prevent interference with steam flow. Condensate is usually returned to the boiler where heating it again re-creates steam. Steam traps are subject to extremely harsh conditions, and there are no cure-all solutions for steam trap failure. The traditional recommendations of proper sizing, selection, installation and maintenance still apply.

Action Moment

Proactive steam trap maintenance is critical in using steam efficiently. Facility managers should ensure that all facilities using steam follow good maintenance procedures. Establish an effective preventive maintenance program. Determine the optimum maintenance schedule for each trap and follow it. The table on the next page lists conditions that may indicate a failed steam trap.

Technical Information

Developments over the years have led to steam traps that better distinguish between steam and liquid. Conventional traps fit one of three categories: mechanical, thermostatic, or thermodynamic. Each type of trap has a different application.

Most traps are designed to fail in the open position in order to protect the steam generation process. However, at failure, the trap dumps live steam continuously to the condensate return. This return line pressure can cause other traps to fail in a cascading manner.

In a single day, steam loss can cost more than the trap and labor required to replace it. As shown in the table, the annual cost of a single failed trap with a 1 cm (3/8”) orifice in a 690 kPa (100 psi) system where steam cost is $15 per 375kg (1000 lbs) is $57,000. References, such as *Steam Efficiency Improvement,* list leak rates at specific pressures and orifice diameters.

1 **Avoid fixed-orifice traps.** Fixed-orifice traps continually blow off live steam and have no way to compensate for variable rates of condensation.

Traps subject to freezing temperatures may be damaged by water held inside the trap when the steam system is shut down. Replace traps subject to freeze damage with self-draining types.

2 **Install valves to facilitate testing.** At each trap, install two valves in parallel. One is normally open and leads to the condensate return. The other valve leads to the atmosphere, and is normally closed. Periodic monitoring will indicate condensate removal rate and presence of live steam.

3 **Establish appropriate steam trap diagnostics.** Troubleshooting may involve visual, thermal, or sonic techniques. Visually observing trap discharge dumped temporarily to the atmosphere is the most straightforward and reliable method. Methods that rely on temperature differences across the trap to indicate proper operation can miss both small and large leaks. Sonic methods are very popular and employ hollow pipes, stethoscopes, or sonic detectors placed on the trap. For each type of trap tested, maintenance personnel must distinguish between sounds associated with proper operation and failure.

Loss @ 100 psi, 3/8 "	475 lbs/hour
Cost of steam production	$15 per 1000 lbs
Operating time	8000 hours/year
Cost of leaking trap	$57,000 per year

Type of Trap	Maintenance Characteristics
Float-type mechanical traps	Float-operated valve located under water level prevents steam escape. Does not vent air and gas, and usually has integral thermostatic vent.
Inverted bucket mechanical trap	Fairly resistant to water hammer and steam leaks. Prone to freezing. Vents only limited amounts of air.
Bellows actuated thermostatic trap	Prone to water hammer damage.
Bimetallic thermostatic trap	Not vulnerable to water hammer.
Thermodynamic disk trap	Upon startup, air, gas, and cool condensate freely vented. Will dump live steam if cool air surrounds trap. May need insulation for proper operation.

4 **Evaluate failures.** If failure rates are high, dirt, corrosion, water hammering, and freezing are the usual causes.

5 **Reduce debris in lines.** Dirt can be from a variety of causes, and cannot always be avoided. Strainers help prevent dirt from damaging traps.

6 **Reduce corrosion.** Take immediate action to discover where corrosive elements are entering the system.

7 **Reduce water hammering.** Moving steam carries liquid condensate along with it at velocities of up to 160km/h (100 mph) until it suddenly reaches a trap or valve, causing water hammer. Install traps at any low point or at intervals of 46m (150 feet) to reduce this physical shock.

Checklist Indicating Possible

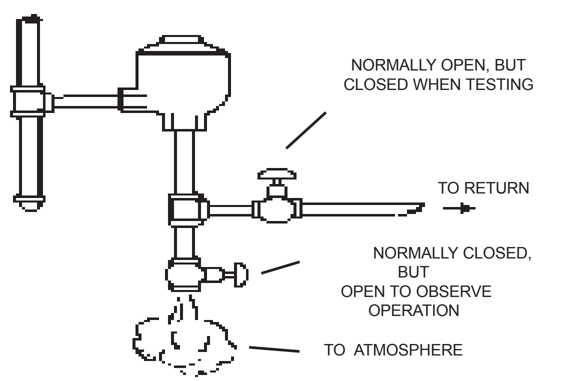
Steam Trap Failure

- Abnormally warm boiler room.
- Condensate receiver venting steam.
- Condensate pump water seal failing prematurely.
- Overheating or underheating in the conditioned space.
- Boiler operating pressure difficult to maintain.
- Vacuum in return lines difficult to maintain.
- Water hammer.
- Steam in condensate return lines.
- Higher than normal energy bill.
- Inlet and outlet lines to trap nearly the same temperature.

8 **Insulate traps.** Convective and radiative heat losses from steam traps can cost hundreds of dollars, depending on the size and temperatures of the trap and surrounding air.

9 **When visually checking trap operation,** consider the pressure in the condensate return line. If condensate pressure is less than atmospheric pressure, the visual method is useless.

TO TEST TRAPS IN SERVICE



References

Dyer, David, Glennon Maples and Timothy Maxwell, *Steam Efficiency Improvement*, Boiler Efficiency Institute, Auburn University, Auburn, AL, 1987.

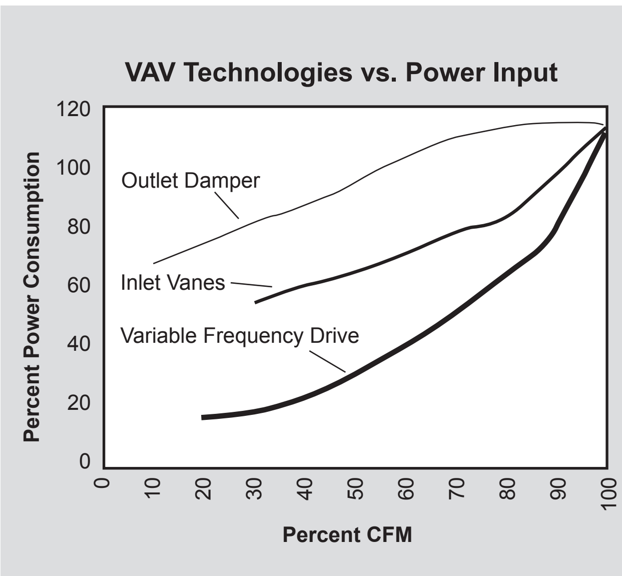
Contacts

For seminars concerning steam traps, contact the FEMP Help Desk at (800) DOE-EREC.

Fan motors in air handlers can account for 20% or more of energy usage in a commercial building. Energy costs of air distribution systems can be significantly decreased by: (1) converting constant-volume systems to variable-air-volume systems (VAV) or (2) increasing the efficiency of existing VAV systems.

Action Moment

Good candidates for VAV conversion are constant-volume (CV) systems with dual-ducts or terminal reheat that use backward-inclined or airfoil fans.



On existing VAV systems, convert airflow control from inlet vanes or outlet dampers to variable frequency drives (VFDs). Notice on the graph above how energy consumption using VFDs is far lower than using outlet dampers or inlet vanes.

Technical Information

Several strategies for making VAV systems more efficient while still providing necessary ventilation are outlined below.

1 **Convert constant-volume (CV) systems** to variable-air-volume (VAV). The airflow in many duct systems is fixed. A constant volume of air is heated or cooled regardless of the actual volumes needed to satisfy the temperature and humidity requirements of the space. The inefficiency of dual-duct and terminal reheat CV systems can be virtually eliminated by converting the system to deliver only the volume of air needed for conditioning the actual load.

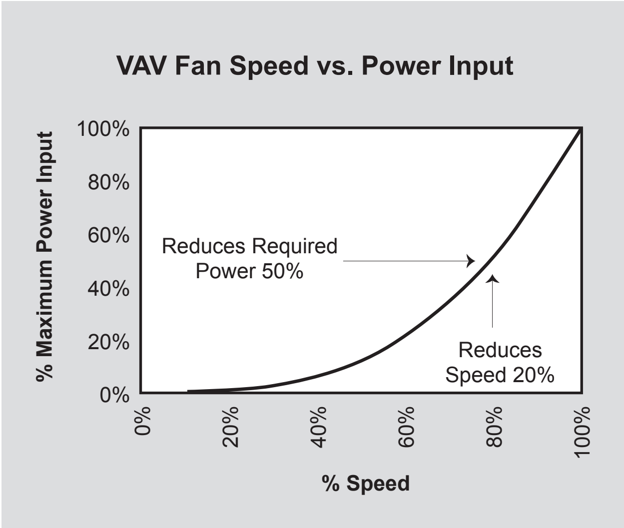
2 **Install a variable frequency drive (VFD) on fan motors** to achieve speed control. Electronically controlling the fan motor's speed and torque provides an efficient way to continually match fan speed with changing building load conditions. Rather than running at full speed 90% to 95% of the time, a fan motor controlled by a VFD can operate at speeds of 80% or less. Notice on the graph on the next page how this reduces energy consumption of fan motors by 50%.

3 **Match fan speed to the reduced building loads**. The EPA found 58% of the buildings they surveyed had fans oversized more than 10%, with the oversizing averaging 72%. Two steps to match fan speed to the building load are:

- **Assess fan performance** by taking measurements on a peak cooling day. If vanes and dampers are closed more than 20%, the fan RPM may be reduced.
- **Lower fan speed** by increasing the fan pulley diameter or reducing the motor pulley diameter. A 10% speed reduction will lower energy usage by 27%. A 20% speed reduction saves approximately half the energy.

4 **Replace existing motors** with properly sized energy-efficient models. Compared to standard motors of equivalent-rated horsepower, high-efficiency motors use 3% to 8% less energy. They also run cooler, are more reliable, and usually have longer warranties.

Be certain that proper ventilation and humidity control is provided by VAV systems, even when heating and cooling needs are low. Space ventilation can be reduced below acceptable limits



during mild weather if fans are allowed to respond only to space temperature requirements. This is a very important indoor air quality issue.

An energy-efficient motor has less phase lag and therefore runs faster. Unless pulley sizes are adjusted, some of the savings will be lost by operating the fan at higher RPMs.

Experience has shown that VFDs installed on existing VAV systems using vane or damper airflow controls will save 30% to 60% of fan motor energy and reduce electrical demand from fans by 27%. Simple paybacks of appropriate retrofits average 2.5 years.

Facility managers can evaluate the benefits of reducing equipment sizes of fan systems in facilities by running EPA's QuikFan software. The software is available to Green Lights and Energy Star Building Partners.

Reference

Environmental Protection Agency, *Variable Air Volume Systems: Maximum Energy Efficiency and Profits*, (430-R-95-002), 1995.

The Ideal Fan Laws

The three ideal fan laws relating fan speed to capacity, static pressure, and horsepower are:

(1) $CFM_1/CFM_2 = RPM_1/RPM_2$ volume flow rate (CFM) is proportional to the speed (RPM);

(2) $SP_1/SP_2 = (RPM_1/RPM_2)^2$ static pressure (SP) varies as the square of speed; and,

(3) $BHP_1/BHP_2 = (RPM_1/RPM_2)^3$ brake horsepower (BHP) varies as the cube of speed.

For example, assume a fan moves 30,000 CFM of air, develops a static pressure of 2" w.g, rotates at 400 RPM, and draws 12 BHP. The ideal fan laws can be used to find the capacity, pressure, and horsepower if the speed is increased to 500 RPM.

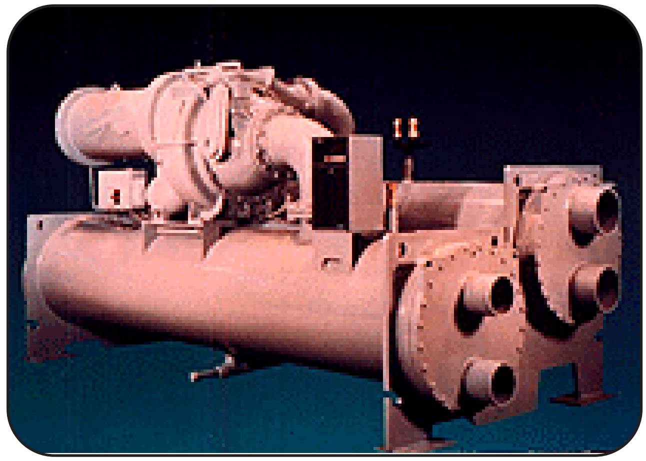
(1) Capacity: $CFM_2 = CFM_1*RPM_2/RPM_1 = 30{,}000*(500/400) = 37{,}500$ CFM

(2) Static pressure: $SP_2 = SP_1*(RPM_2/RPM_1)^2 = 2*(500/400)^2 = 3.1$" w.g.

(3) Brake horsepower: $BHP_2 = BHP_1*(RPM_2/RPM_1)^3 = 12*(500/400)^3 = 23.4$ BHP

Caution should be used when applying the ideal fan laws to actual conditions. Note that the ideal fan laws apply only when all flow conditions are similar.

In large Federal facilities, the equipment used to produce chilled water for HVAC systems can account for up to 35% of a facility's electrical energy use. If replacement is determined to have the best life-cycle cost, there are some excellent new chillers on the market . The most efficient chillers currently available operate at efficiencies of 0.50 kilowatts per ton (kW/ton), a savings of 0.15 to 0.30 kW/ton over existing equipment. When considering chiller types and manufacturers, part-load efficiencies must also be compared.



Some manufacturers have completely re-engineered their new chillers to operate at high efficiencies with HCFC and HFC refrigerants.

Action Moment

Consider chiller replacement where existing equipment is more than ten years old and the life-cycle cost analysis confirms that retrofit is worthwhile. New chillers can be 30% to 40% more efficient than existing equipment. Consider integrating other energy conservation measures along with a chiller retrofit. For example, using more efficient lighting may reduce cooling loads, allowing a smaller replacement chiller. Be aware that there can be lead times of six months or more for delivery of new chillers.

Technical Information

Electric chillers use a vapor compression refrigerant cycle to transfer heat. Basic components of an electric chiller are: electric motor, refrigerant compressor, condenser, evaporator, expansion device, and controls. Both the heat rejection system and building distribution loop can use water or air as the working fluid. Wet-condensers usually incorporate one or several cooling towers. Evaporative condensers can be used in some climates. Air-cooled condensers incorporate one or more fans to cool refrigerant coils, and are common on smaller packaged rooftop units. Air-cooled condensers may also be located remotely from the chillers.

1 **The refrigerant issues currently facing facility managers** arise from concerns about protection of the ozone layer and the buildup of greenhouse gases in the atmosphere. The CFC refrigerants traditionally used in most large chillers were phased out of production on January 1, 1996 to protect the ozone layer. CFC chillers still in service must be: (1) serviced with stockpiled refrigerants or refrigerants recovered from retired equipment; or (2) chillers must be converted to HCFC-123 (for the CFC-11 chillers) or HFC-134a (for the CFC-12 chillers); or (3) the chillers must be replaced with new chillers using EPA-approved refrigerants.

2 **All refrigerants listed for chillers by the EPA Strategic New Alternatives Program (SNAP) are acceptable.** These include HCFC-22, HCFC-123, HFC-134a, and ammonia for vapor-compression chillers. HCFC-22 will be phased out in the year 2020. HCFC-123 will be phased out in the year 2030. Chlorine-free refrigerants such as HFC-134a and water/lithium-bromide mixtures, are not currently listed for phaseout.

3 **A chiller operating with a CFC refrigerant** is not directly damaging to the ozone, provided the refrigerant is totally contained during the chiller's operational life and the refrigerant is recovered upon retirement. In fact, indirect global damage from releases at power plants will be minimized by using highly efficient chillers no matter what fully-contained refrigerant a chiller has used.

4 **Many older chillers contain refrigerants that are no longer produced,** giving facility managers an additional incentive to replace equipment. Some new chillers have been completely re-engineered to use refrigerants that are not currently scheduled for phaseout. Proper refrigerant handling is a requirement for any of the options relating to chillers operating with CFC refrigerants. The three options are containment, conversion, or replacement.

EPA Comparison of Refrigerant Alternatives

Criteria	HCFC-123	HCFC-22	HFC-134a	Ammonia
Ozone Depletion Potential	0.016	0.05	0	0
Global Warming Potential	85	1,500	1,200	0
Ideal kW/ton	0.46	0.5	0.52	0.48
Occupational Risks	low	low	low	low
Flammable	no	no	no	yes

5 **Containing refrigerant** in existing chillers is possible with retrofit devices that ensure that refrigerant leakage is eliminated. Containment assumes that phased-out refrigerants will continue to be available by recovering refrigerants from retired systems.

6 **Converting chillers** to use alternative refrigerants will lower their performance and capacity. The capacity loss may not be a problem with converted units, since existing units may have been oversized when originally installed, and there may have been load reduction through energy conservation activities.

7 **Replacing existing chillers** should be considered as a method for complying with refrigerant phaseout requirements provided the life-cycle cost analysis determines replacement to be cost-effective. Absorption chillers use water/lithium bromide or ammonia/water mixtures, and use an energy source such as natural gas or steam to generate chilled water. DOE and GSA have established a Basic Ordering Agreement (BOA) to greatly simplify procurement of energy-efficient water-cooled chillers.

8 **Electric chiller classification** is based on the type of compressor they contain. Common types of compressors for electric chillers include: centrifugal, screw, and reciprocating. The scroll compressor is another type frequently used for smaller applications of 20 to 60 tons. Hydraulic compressors are a fifth type still under development.

Chiller improvements in recent years include units completely re-engineered for use with new HCFC and HFC refrigerants. New machines have full-load efficiencies down to 0.50 kW/ton in the 170 to 2,300 ton range. Some have built-in refrigerant containment, are designed to leak no more than 0.1% refrigerant per year, and do not require purging.

Other improvements include larger heat transfer surfaces, microprocessor controls for chiller optimization, high efficiency motors, variable frequency drives, and optional automatic tube-cleaning systems. To facilitate replacement, new equipment is available from all manufacturers which can be unbolted for passage through conventional doors into equipment rooms. Many positive-pressure chillers are approximately one-third smaller than negative-pressure chillers of similar capacity.

1 **Thermal energy storage** may be added when replacing chillers, and may enable the use of smaller chillers. Operating costs may be reduced by lowering electrical demand charges and by using cheaper, off-peak electricity. Thermal storage systems commonly use one of three thermal storage media: water, eutectic salts, or ice. These systems can store 1 ton-hour of cooling per approximately 0.33, 0.07, and 0.04 m^3 (11.4, 2.5 and 1.5 ft^3), respectively.

2 **Multiple chiller operations** may be made more efficient by using unequally-sized units. With this configuration, the smallest chiller can efficiently meet light loads. The other chillers are staged to meet higher loads after the lead chiller is operating near full capacity. If chillers operate frequently at part-load conditions, it may be cost effective to replace a large chiller with multiple chillers staged to meet varying loads.

3 **Double-bundle chillers** have two possible pathways for rejecting condenser heat. One pathway is a conventional cooling tower. The other pathway is heat recovery for space heating or service water heating. Candidates for these chillers are facilities in cold climates with substantial hours of simultaneous cooling and heating demands. Retrofitting existing water heating may be difficult due to the low temperature rise available from the heat recovery loop.

4 **Steam or hot water absorption chillers** use mixtures of water/ lithium-bromide or ammonia/water that are heated with steam or hot water to provide the driving force for cooling. This eliminates global environmental concerns about refrigerants used in vapor-compression chillers. Double-effect absorption chillers are significantly more efficient than single-effect machines.

5 **Specifying and procuring chillers** should include load reduction efforts, equipment sizing, and good engineering. Proper sizing is important in order to save on both initial costs and operating costs. Building loads often decrease over time as a result of conservation measures, so replacing a chiller should be accomplished only after recalculating building loads. Published standards such as ASHRAE 90.1 and DOE standards provide guidance for specifying equipment. Procuring energy-efficient water-cooled electric chillers has been made considerably easier for facility managers. DOE and GSA have developed a Basic Ordering Agreement (BOA) that specifies desired equipment parameters.

Several alterations may be considered to make existing chiller systems more energy efficient. Careful engineering is required before implementing any of these opportunities to determine the practicality and economic feasibility.

1 **Variable frequency drives** (VFD) provide an efficient method of reducing the capacity of centrifugal chillers. Note that VFD drives are typically installed at the factory. Savings can be significant, provided: (1) loads are light for many hours per year; (2) the climate does not have a constant high wet-bulb temperature; and, (3) the condenser water temperature can be reset higher under low part-load conditions. VFDs are usually needed on only one chiller per installation, because the fixed-speed chillers can be staged for base load, with the VFD chiller varying capacity according to swings in the load.

2 **Chiller bypass** systems can be retrofitted into central plants enabling waterside economizers to cool spaces with chillers off-line. In these systems, cooling tower water provides chilled water either directly with filtered cooling tower water or indirectly with a heat exchanger. These systems are applicable when: (1) chilled water is required many hours per year; (2) outdoor temperatures are below 13˚C (55˚F); (3) economizer cycles cannot be used; and, (4) cooling loads below 13˚C (55˚F) do not exceed 35% to 50% of design full loads.

3 **Other conservation measures** to consider when looking at the chiller system are:

- Separate primary and secondary pumps
- High efficiency pumps and motors

Overall HVAC system efficiency should be considered when altering chiller settings. The complex interrelationships of chiller system components can make it difficult for operators to understand the effects of their actions on all components of the systems. For example, one way to improve chiller efficiency is to decrease condensing water temperature. However, this requires additional cooling water pumping and cooling tower operation that may actually increase total operating costs.

Increasing chilled water temperature to save energy may unacceptably reduce humidity removal in humid climates.

Rooftop retrofits. Many Federal buildings are cooled via roof-mounted direct-expansion (DX) air conditioners. Where many of the individual rooftop DX units that cool a building are old and inefficient, it may be possible to retrofit them to use a single high-efficiency chiller (18 and greater EER). In the retrofit process, the existing evaporator coils are adapted to use glycol that is cooled by the chiller. Ice storage may be incorporated as part of the rooftop retrofit. The chiller can be operated at night to make ice, which would provide or supplement cooling during the day. This retrofit system provides an efficient means of reducing on-peak electric demand, previously discussed on page 22 under Thermal Storage. FEMP estimates a very high savings potential from this system. If all rooftop DX systems used in Federal buildings were be replaced by chillers, more than 50% of the electricity used by rooftop units could be saved. Available space for the chiller and, if included, the ice storage, is a consideration for this type of retrofit.

References

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General Services Administration, Facility Management Division, *Energy Management: A Program to Reduce Cost and Protect the Environment*, Washington, DC, 1994.

Electric Power Research Institute, *Electric Chiller Handbook*, (TR-105951s), Pleasant Hill, CA, 1995. (510) 934-4212

Fryer, Lynn, *Electric Chiller Buyer's Guide: Water-Cooled Centrifugal and Screw Chillers*, Technical Manual, E-Source, Inc., Boulder, CO, 1995. (303) 440-8500

Space Cooling Manual, E-Source, Inc., Boulder, CO, 1995. (303) 440-8500

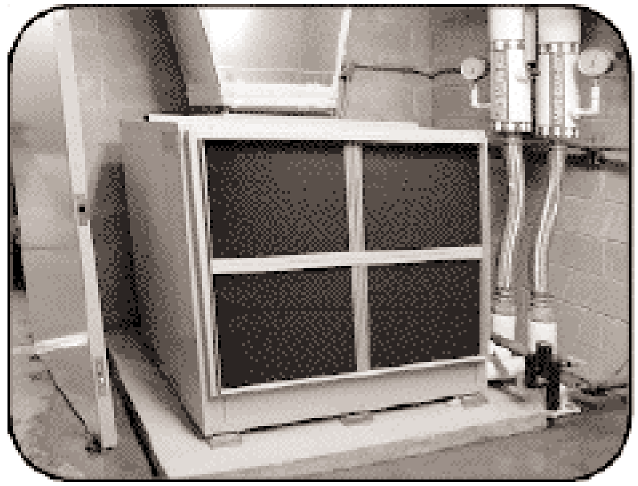
Contacts

For more information about the Basic Ordering Agreement (BOA) for energy-efficient water-cooled chillers, contact the General Services Administration at (817) 978-2929.

New HVAC technologies can help facility managers achieve the goals of lowering energy costs, being more environmentally friendly, and enhancing indoor environmental quality. Information is provided here to help facility managers consider these new technologies. New technologies may only be available from one manufacturer and their energy savings claims may not be widely supported. *Federal Technology Alerts* provide additional information on some new HVAC technologies.

Action Moment

Where indoor humidity is either too high or is controlled with reheat systems, consider adding desiccants, heat pipes, and subcool systems. Where electrical power demand costs are high, consider gas absorption cooling or geothermal heat pumps.



Multiple water-source heat pumps can be connected to a common ground-coupled water loop.

Ground-Source Heat Pumps

Ground-source heat pumps use the earth's mass as a thermal reservoir—a heat sink during the summer and heat source during the winter. Ground source systems are generally more efficient than air-source systems, provided water pumping costs are minimal. Although both initial cost and maintenance cost are higher than for air-source systems, the advantages warrant their consideration. Ground-source heat pumps come in two basic types: (1) closed systems using buried plastic pipe with an antifreeze solution as the heat transfer medium; and (2) open systems that pump groundwater for use in heat exchangers. Several configurations are available for different applications.

Large tonnage ground source heat pumps often consist of multiple water-source heat pumps ranging in size from 1 to 15 tons. These unitary heat pumps are typically connected to a common ground-coupled water loop. With this arrangement, each small heat pump is responsible for an individual control zone, yet each can take advantage of the stable heat source and heat sink temperatures of the ground-coupled loop. The individual water-source heat pumps are factory charged, usually eliminating the need for field adjustment of the refrigerant amounts. Variations in the basic configuration of the ground loops that can lower initial costs or reduce operating costs include supplementing with a cooling tower or solar panels, or adding a hot water recovery/desuperheater system.

1 **Cooling Tower Supplemented Systems** can reduce the total size of the ground loop required to meet the cooling demand. A cooling tower is added to the ground-coupled loop by means of a heat exchanger.

2 **Solar Assisted Systems** can help supplement the heating in northern climates. This strategy adds solar panels designed to heat water to the ground-coupled loop, thereby reducing the size needed for heating.

3 **Hot Water Recovery/Desuperheating** is an option to provide hot water that is available for most heat pump systems. With the heat pump operating in cooling mode, hot-water recovery increases the operating efficiency of the system, and produces essentially free hot water. With the heat pump in heating mode, hot water is produced at a lower cost compared to other technologies.

Small earth-coupled geothermal systems that use sealed pipes buried horizontally or vertically may be used for space heating or hydronic ice melting in critical high-traffic areas.

Use of heat pump systems is complicated by the need to keep heat exchangers clean while avoiding chemical discharge into surface or groundwater. After use for heat exchange, inject groundwater into the source aquifer.

Consider ground-source heat pumps to reduce demand charges under severe weather conditions. Since ground temperature does not get as hot or cold as the air temperature, the ground-source heat pump has the potential to operate more efficiently when heating in extremely cold weather or cooling in extremely hot weather. See the *Federal Technology Alert* on this subject.

Transpired Air Collectors

A transpired air collector heats up ventilation makeup air passively via a large solar collector. These collectors usually consist of south-facing building facades that have been constructed to include air channels under the outer building skin. Makeup air is drawn through the collector before it enters the building. Fort Carson uses a transpired air collector wall to warm outside fresh air before it enters an aircraft hanger. These systems preheat intake air by 17˚C to 28˚C (30˚F to 50˚F). It has been reported that these systems can reduce annual heating cost by $1 to $3 per square foot of collector wall, depending on fuel type, and can reduce demand on boiler systems.

Natural Gas Engine-Driven Cooling

An engine-driven cooling system is similar to a conventional electric cooling system, except the compressor is driven by a natural gas engine rather than an electric motor. Configurations include chillers, packaged direct expansion units, and heat pumps in sizes from 3 tons to 4,000 tons. Engine-driven systems are variable speed, have higher part-load efficiencies, generate high-temperature waste heat, and may save operating costs.

Consider engine-driven natural gas cooling to reduce electrical peak demand or to take advantage of low cost fuel.

Natural Gas Absorption Cooling

Gas absorption units use "thermal compressors" that circulate water or ammonia rather than mechanical compressors that use conventional refrigerants. Heat drives the process. Direct-fired machines use integral gas burners, and indirect-fired machines are powered by steam, hot water, or waste heat. Double-effect units that contain a second generator and condenser are more efficient than single-effect machines. Sizes range from 3 to 1700 tons.

Consider absorption cooling where electric power is expensive, natural gas is relatively cheap, or waste heat is adequate to supplement the process. Natural gas absorption machines are minimal contributors to ozone depletion because they do not contain CFC refrigerants.

Cooling Equipment With Enhanced Dehumidification

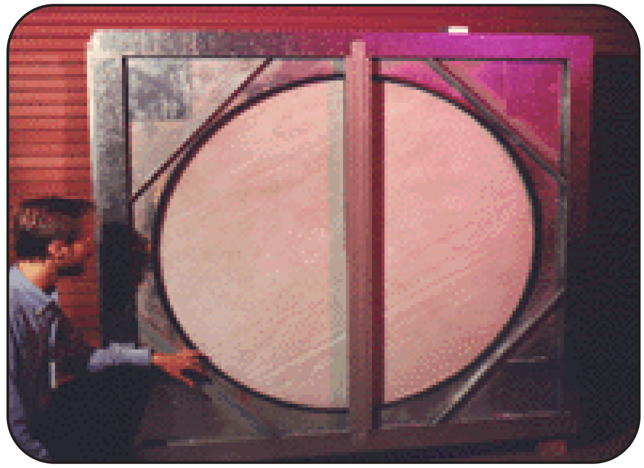
Reducing indoor humidity is a prime factor in discouraging microbiological growth in the indoor environment. Several technologies applicable to direct-expansion (DX) cooling can efficiently remove moisture.

Heat pipes enable DX coils to remove more moisture by precooling return air. Heat absorbed by the refrigerant in the heat pipe can then be returned to the over-cooled, dehumidified air coming out of the DX coils. The system is passive, eliminating the expense of active reheat systems. Somewhat more fan energy is required to maintain duct static pressure, as is the case when adding any new element to the ventilation system, but no additional pumps or compressors are required. Increased fan energy must be considered when calculating system energy savings. Energy savings up to 30% have been reported. At least one manufacturer builds a variable dehumidification system for DX equipment that pre-cools liquid refrigerant rather than the air stream.

Desiccant systems

1 **A desiccant system converts humidity** (latent load) into sensible heat, and then efficiently removes that energy through heat exchange with outdoor or exhaust air. If needed, further sensible cooling is provided by evaporative pads or cooling coils. In the case of coils, since they do not need to condense moisture, they are operated at a relatively high temperature where they are most efficient. Where humidity is a significant factor, and the load is calculated so that it is broken into its constituents of latent and sensible loads, a desiccant system can be used to handle the latent load, while the DX or chilled-water coils may be able to be substantially down-sized from that required in a traditional HVAC system.

2 **Desiccant systems exchange heat and humidity** between supply and regenerative air streams. The supply air stream, which may be outdoor air or HVAC return air, surrenders moisture to a desiccant. Rotating desiccant wheels or pumped liquid desiccants transport moisture to the regenerative air stream. Desiccant regeneration, or "drying out," is fueled by heat supplied from boilers, natural gas burners, electric heaters, or waste heat sources. Systems from 1,000 to 84,000 CFM are available.



Desiccant systems effectively remove moisture from buildings, and can be "regenerated" from heat supplied from waste heat sources.

3 **Desiccant systems are most cost effective** in applications with high latent loads, due to internal loads or humid climates. Also consider desiccant cooling systems to: eliminate reheat; efficiently treat large make-up airflows for improved indoor air quality; down-size ductwork in renovations; effectively extend chiller capacity by allowing coils to handle sensible load only, and thus run more efficiently; reduce electric peak demand; or use cogeneration energy.

Refrigerant Subcooling

1 **Refrigerant subcooling systems** save energy in air conditioners, heat pumps, or reciprocating, screw and scroll chillers by altering the vapor-compression refrigerant cycle. There are three types of refrigerant subcooling technologies being manufactured, each of which adds a heat exchanger on the liquid line after the condenser: (1) suction-line heat exchangers, which use the suction-line as a heat sink; (2) mechanical subcoolers that use a small, efficient, secondary vapor-compres-

sion system for subcooling; and (3) external heat sink subcoolers that used a mini-cooling tower or ground-source water loop as a heat sink. Subcoolers increase energy efficiency, cooling capacity, and expansion valve performance (decrease flash gas).

2 **Applications for heat sink subcooling** include: (1) where units are being replaced; (2) where building expansion is planned; or (3) where current capacity is inadequate. The best applications include climates that are hot year-round—1200 or more base-65˚F (18˚C) cooling degree days—and direct expansion systems. With external heat sink subcooling, condensing units and compressors should be down-sized, making the technology more appropriate where existing equipment is being replaced, where construction or expansion is planned, or where current cooling capacity is inadequate. Pacific Northwest National Laboratory's (PNL's) evaluation of sub-cooling in Federal facilities is contained in a *Federal Technology Alert* available from FEMP.

Liquid Refrigerant Pumping

1 **Liquid refrigerant pumping** (LRP) systems provide a simple means of increasing the cooling capacity and energy efficiency of new and existing refrigeration and HVAC systems. LRP systems consist, at minimum, of a small, reliable pump installed on the liquid refrigerant line after the condenser. The pump reduces compressor load by providing an efficient way to compensate for pressure drop through the liquid line and filter/dryer. This virtually eliminates flash gas (refrigerant boiling before the metering device) and allows the compressor discharge pressure setpoint to be lowered to obtain significant savings in cool weather.

2 **LRP applications include direct-expansion equipment** having metering devices to control refrigerant flow. Suitable equipment includes those with a thermostatic expansion valve, an evaporator pressure regulator, or a capillary tube—nearly all packaged or split air conditioning systems and reciprocating chillers. Savings result from lowered condensing temperatures obtained by lowering the setpoint of the condenser head pressure. Potential candidates for application of LRP systems are: computer room air conditioners; refrigerated display cases; off-peak cold storage systems; refrigerated warehouses; process cooling applications; air conditioning systems and heat pumps. Pacific Northwest National Laboratory's evaluation of LRP in Federal facilities is contained in a *Federal Technology Alert* available from FEMP.

References

Department of Energy, Federal Energy Management Program, "Geothermal Heat Pumps," *Federal Technology Alert,* 1995

Department of Energy, Federal Energy Management Program, “Ground-Source Heat Pumps Applied To Commercial Facilities,” *Federal Technology Alert,* 1995.

Department of Energy, Federal Energy Management Program, “Liquid Refrigerant Pumping,” *Federal Technology Alert,* 1995.

Department of Energy, Federal Energy Management Program, “Polarized Refrigerant Oil Additive,” *Federal Technology Alert,* 1995.

Department of Energy, Federal Energy Management Program, “Refrigerant Subcooling,” *Federal Technology Alert,* 1995.

Department of Energy, Federal Energy Management Program, “Solar Ventilation Preheat,” *Federal Technology Alert,* 1995.

American Gas Cooling Center, *Natural Gas Cooling Equipment Guide*, Arlington, VA, 1995.

Contacts

For information about all types of gas cooling equipment, contact the American Gas Cooling Center, Arlington, VA (703) 841-8409.

For the *Federal Technology Alerts* listed above, and other information about new HVAC technologies, contact the FEMP Help Desk at (800) DOE-EREC. The FEMP Home Page is at http://www.eren.doe.gov/femp.

International Ground-Source Heat Pump Association, (405) 744-5175.

Electric motors vary greatly in performance. The selection of energy-efficiency motors for HVAC equipment installed in renovation or new construction can result in greatly reduced energy consumption during their operational lifetimes. Recent developments in energy-efficient motors and motor controls provide excellent opportunities for facility managers to have long-term impacts on lowering energy consumption in Federal facilities.

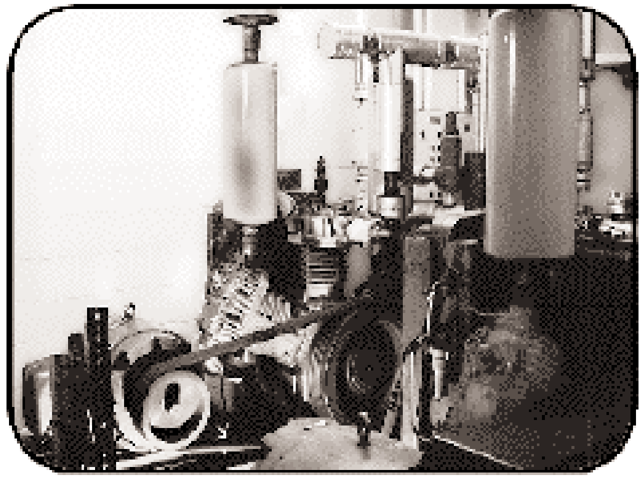
Action Moment

Facility managers should inventory all motors in their facilities, beginning with the largest and those with the longest run-times. This inventory enables facility managers to make informed choices about replacement either before or after motor failure. Field testing motors prior to failure enables the facility manager to properly size replacements to match the actual driven load. The software mentioned below can help with this inventory.

Technical Information

1 **The Motor Challenge Program** was developed by DOE to assist industrial customers in increasing their use of energy-efficient motor systems. Federal facility managers can also benefit from Motor Challenge through a special arrangement with FEMP, and receive technical assistance, training, software, and other materials.

2 **Motor Master Plus** is a PC-based software tool that helps inventory and select motors. A database of 12,000 new motors contained in the software includes horsepower, speed, enclosure type, manufacturer, model name, catalog number, voltage, nominal efficiencies at various loads, torque and current characteristics, power factor, warranty, and list price. The software allows users to simulate replacement scenarios to determine the lowest life cycle cost options for existing motors.



Motor Master Plus software can help facility managers proiritize the replacement of electric motors such as the motor on this compressor.

3 **The inventory features in Motor Master Plus** assist facility managers in tracking existing motors, including a motor's location and electrical measurements needed to determine loading. Developing an inventory is the first step in establishing a motor rewind/replacement policy that could result in significant reductions in operating expenses. Since motors are typically replaced or rewound when the motor fails, having an inventory will allow facility managers to quickly determine the most economical approach, and assist with proper selection. Inventoried motors also can be evaluated to prioritize replacement of functioning motors with premium-efficiency motors.

Turn off unneeded motors. Locate motors that operate needlessly, even for a portion of the time they are on. For example, there may be multiple HVAC circulation pumps operating when demand falls, cooling tower fans operating when target temperatures are met, ceiling fans on in unoccupied spaces, exhaust fans operating after ventilation needs are met, and escalators operating after closing.

Reduce motor system usage. The efficiency of mechanical systems affects the run-time of motors. For example, reducing solar load on a building will reduce the amount of time the air handler motors would need to operate. The table below contains a list of energy reducing strategies for motors.

Reduce Motor System Usage

- Reduce loads on HVAC systems.
  - Improve building shell.
  - Manage restorations better.
  - Improve HVAC conditions.
  - Check refrigerant charge.
- Reduce refrigeration loads
  - Improve insulation
  - Add strip curtains on doors
  - Calibrate control setpoints
  - Check refrigerant charge
- Check ventilation systems for excessive air
  - Re-sheave fan if air is excessive
  - Downsize motors if possible
- Improve compressed air systems
  - Locate and repair compressed air leaks
  - Check air tool fittings for physical damage
  - Turn off air to tools when not in use
- Repair duct leaks

Sizing motors is important. Do not assume an existing motor is properly sized for its load, especially when replacing motors. Many motors operate most efficiently at 75% to 85% of full load rating. Under-sizing or over-sizing reduces efficiency. For large motors, facility managers may want to seek professional help in determining the proper sizes and actual loadings of existing motors. There are several ways to estimate actual motor loading: the *kilowatt technique,* the *amperage ratio technique*, and the less reliable *slip technique* . All three are supported in the Motor Master Plus software.

Instead of rewinding small motors, consider replacement with an energy-efficient version. For larger motors, if motor rewinding offers the lowest life-cycle cost, select a rewind facility with high quality standards to ensure that motor efficiency is not adversely affected. For sizes of 10 hp or less, new motors are generally cheaper than rewinding. Most standard efficiency motors under 100 hp will be cost-effective to scrap when they fail, provided they have sufficient run-time and are replaced with energy-efficient models.

References

Department of Energy, *Energy-Efficient Electric Motor Handbook*, Revision 3, Washington, DC, 1993.

Hoslida, Robert K., “Electric Motor Do’s and Don’ts,” *Energy Engineering*, Vol 19, No 1, pp 6 - 24.

Nadel, Steven, et al., *Energy Efficient Motor Systems: A Handbook on Technology Programs, and Policy Opportunities,* American Council for an Energy-Efficient Economy, Washington, DC, 1991.

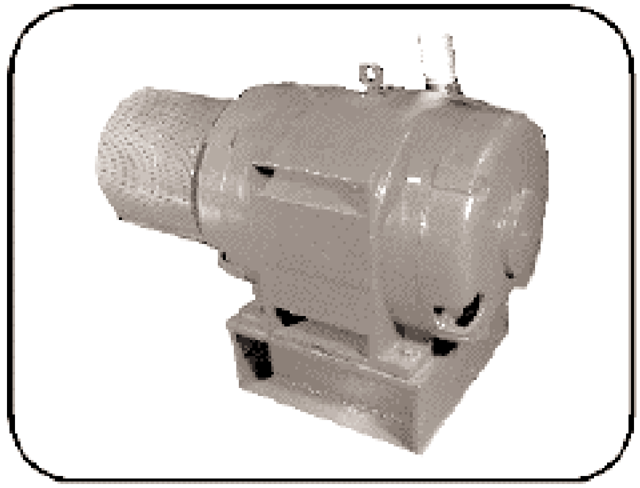
Contacts

FEMP is offering training to facility managers on the use of Motor Master Plus and other motor system management topics. Contact the FEMP Help Desk at (800) DOE-EREC, or the FEMP Home Page at http://www.eren.doe.gov/femp.

DOE's Motor Challenge Hotline at (800) 862-2086 provides information, software, and publications.

Motor Challenge Home Page at http://www.motor.doe.gov includes discussion forums, frequently asked questions, and application information.

Energy-efficient electric motors reduce energy losses through improved design, better materials, and improved manufacturing techniques. With proper installation, energy-efficient motors run cooler and consequently have higher service factors, longer bearing and insulation life, and less vibration. To be considered energy efficient, a motor must meet performance criteria published by the National Electrical Manufacturers Association (NEMA). Most manufacturers offer lines of motors that significantly exceed the NEMA-defined criteria.



Priority opportunities for motor replacement in Federal buildings include HVAC fan motors and pumps.

Action Moment

Facility managers should consider installing an energy-efficient motor when faced with a motor purchase decision. This includes adding an application, replacing a failed motor, or considering rewinding a failed motor. Replacing a functional motor may be justifiable solely on the electricity cost savings derived from an energy-efficient replacement. This is especially true if the motor runs continuously, electricity rates are high, the motor is significantly oversized for the application, or its nominal efficiency has been reduced by damage or previous rewinds. Priority opportunities are HVAC fan motors and circulation pumps.

Technical Information

1 **In converting electrical energy** into mechanical energy, motors incur losses in several ways: electrical losses, iron (core) losses, mechanical (friction and windage) losses, and stray losses dependent on design and manufacturing. Energy-efficient motors reduce losses by better design, materials, and manufacturing.

2 **Manufacturers use many terms** to describe their most efficient motors, including adjectives such as “high,” “super,” “premium,” and “extra.” These terms create confusion when comparing motors, so purchasers should always consult the *nominal efficiency rating* and the *minimum efficiency rating*. Nominal efficiency, an average efficiency of motors of duplicate design, is listed in manufacturer literature and in the Motor Master Plus software discussed in section 3.3. Even within the group of duplicate designs, there is a some variation in actual efficiencies due to variations in motor materials and manufacturing. Minimum efficiency ratings can be used as the basis for the manufacturer's guarantee.

3 **Table 12-10 of NEMA Standard MG-1** delineates efficiency "bins" that form the basis of the "NEMA nominal efficiency" ratings listed on nameplates. The bins provide ranges of efficiencies, such that actual nominal efficiencies are less than or equal to NEMA nominal efficiencies. For example, a motor with an actual nominal efficiency of 92.0 would have a nameplate efficiency listed as 91.7, since the NEMA bracket is 91.7, then 92.4. This standard applies only to A and B designs in the horsepower range of 1 to 500. The standard does not cover other sizes and designs, including C, D, vertical and specialty motors.

4 **Energy-efficient motors tend to last longer**, and may require less maintenance. At lower temperatures, bearing grease lasts longer, lengthening the required time between re-greasing. Lower temperatures translate to longer lasting insulation. Generally, motor life doubles for each 10^{O}C reduction in operating temperature.

Inspect motors for misalignment or excessive vibration.

Inspect wires and connections on motors and incoming power for damage, corrosion, or looseness.

Check motor bearings, and, on single-phase motors, check for wear on internal switches.

Clean dirt and grease from the cooling fan and grill on totally enclosed, fan-cooled motors.

Select energy-efficient motors with a 1.15 service factor, and design for operation at 85% of the rated motor load.

Electrical power problems can affect the operation of energy-efficient motors. For example, plant personnel in one manufacturing operation blamed motor failures on the energy-efficient designs of their motors. However, further investigation revealed poor incoming power quality. Investigators suggested addressing the power quality instead of replacing the energy-efficient motors.

Speed control is crucial in some applications. In polyphase induction motors, slip is a measure of motor winding losses. The lower the slip, the higher the efficiency. Less slippage in energy efficient motors results in speeds about 1% faster than in standard counterparts.

Starting torque for efficient motors may be lower than for standard motors. Facility managers should be careful when applying efficient motors to high torque applications.

Facility managers can easily estimate operating savings of energy efficient motors for a particular application, given the efficiency at rated load, the partial load factor (PLF), the annual operating hours, and the electricity rate.

$/year = hp x PLF x 0.746 kW/hp x hours/year x $/kWh / efficiency

Facility managers can also use Motor Challenge's Motor Master Plus software to estimate operating and energy savings. FEMP is offering training to facility managers on the use of Motor Master Plus software.

References

Department of Energy, *Energy-Efficient Electric Motor Selection Handbook*, 1993.

Electric Power Research Institute, *Energy-Efficient Motors and Controls*, Palo Alto, CA, 1987.

Nadel, Steven, et al., *Energy-Efficient Motor Systems: A Handbook on Technology, Programs, and Policy Opportunities*, American Council for an Energy-Efficient Economy, Washington, DC, 1991.

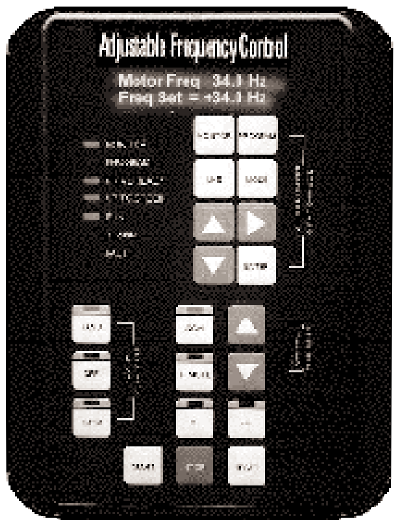
National Electric Manufacturers Association, *NEMA Standard MG-1*.

Skaer, Mark, "Energy-Efficient Motors: Are They Really More Efficient?" *Air Conditioning, Heating & Refrigeration News*, 1995.

Example of calculating savings from motor replacement. Determine the savings from replacing a 20 hp motor that operates 80% loaded (PLF) for 8,760 hours per year where electricity costs 5.5 cents per kilowatt-hour. Assume efficiencies are 0.88 and 0.92 for standard and energy-efficient motors, respectively. Notice that this does not include savings from reducing electrical power demand.

Standard motor:	20 hp x 0.80 x 0.746 kW/hp x 8760 hr/yr x $0.055 per kWh / .88	= $6535 per year
Efficient motor:	20 hp x 0.80 x 0.746 kW/hp x 8760 hr/yr x $0.055 per kWh / .92	= $6251 per year
Savings:	$6535 - $6251	= $ 284 per year

Variable frequency drives (VFDs), a type of variable speed drive, are motor controllers that vary the speed of squirrel cage induction motors. VFDs save substantial energy when applied to variable-torque loads, and result in reductions in electricity bills in most facilities. These energy savings are possible with variable-torque loads, such as fans and pumps, because torque varies as the square of speed, and horsepower varies as the cube of speed. For example, if fan speed is reduced by 20%, motor horsepower (and energy consumption) is reduced by 50%. VFDs generate variable voltage and frequency output in the proper volts/hertz ratio for the motors from the fixed utility-supplied power. VFDs can be retrofitted into existing motor systems, and can operate both standard and high-efficiency motors ranging in size from 1/3 hp to several thousand hp. Unlike mechanical or hydraulic motor controllers, they can be located remotely and do not require mechanical coupling between the motor and the load. This simplifies installation and alignment of motor systems.



Action Moment

Variable-flow applications where throttling or bypass devices are used to modulate flow are good candidates for VFDs. These include centrifugal fans, pumps (centrifugal, propeller, turbine), agitators, and axial compressors. If HVAC fans have inlet vanes or outlet dampers to throttle full air output installed in variable-air-volume systems, these dampers or vanes typically can be removed or disabled and retrofitted with VFDs. Circulation pumps for chilled water often have throttling or bypass valves that can be retrofitted with VFDs.

Technical Information

Three major VFD designs are commonly used: pulse width modulation (PWM), current source inverter (CSI), and variable voltage inverter (VVI). A fourth type, the flux vector PWM drive, is gaining popularity but is considered too expensive and sophisticated for normal applications. Knowing the characteristics of the load is critical for evaluating the advantages and disadvantages of each available technology.

1 **Pulse width modulation** (PWM) is the dominant VFD design in the 1/2 HP to 500 HP range because of its reliability, affordability and availability. PWM outputs emulate sinusoidal power waves by varying the width of pulses in each half cycle. Advantages of PWMs are low harmonic motor heating, excellent input displacement power factor, high efficiencies at 92% to 96%, and ability to control multiple motor systems with a single drive.

2 **Current source inverter** (CSI) designs are quite reliable due to their inherent current-limiting characteristics and simple circuitry. CSIs have regenerative power capabilities, meaning that CSI drives can reverse the power flow back from the motor through the drive. However, CSIs "reflect" large amounts of power harmonics back to the source, have poor input power factors, and produce jerky motor operations (cogging) at very low speeds. CSIs are typically used for large (over 300 hp) induction and synchronous motors.

3 **Voltage source inverter** (VSI) designs are similar to CSI designs, but VSIs generate variable-frequency outputs to motors by regulating voltage rather than current. Harmonics, power factor, and cogging at low frequencies can be problems.

The best applications for VFDs are large motors that can operate for many hours each year at reduced speeds. Some opportunities common in facilities include the following.

1 **Variable-air-volume HVAC fans**. Air flow in older VAV systems is usually controlled by opening and closing dampers or inlet vanes. Because the systems often operate at low air flow, large energy savings are possible by conversion to VFDs. VFDs vary motor speed in order to match fan output to varying HVAC loads.

2 **Cooling tower fans**. Cooling towers may be good candidates for VFDs because motors are large, fans can operate for long periods of time, and loads can vary both seasonally and diurnally

3 **Circulating water pumps** for chillers and boilers. Pumping systems can be made variable by sequencing fixed-speed pumps and a single variable speed pump. This will save the cost of installing VFDs on each pump.

4 **Special industrial applications** such as grinding and materials handling where precise speed control is required. The economics depend on the size and run-time of the motors involved.

VFDs should be properly installed to avoid damage to their electronics. This includes proper grounding, mounting, connection, voltage, and cooling.

1 **Installing VFDs** intended for wall mounting as free standing units will interfere with the “chimney effect” cooling of the heat sink. Always install wall-mounted units against a smooth, flat, vertical surface or install a piece of plywood or sheet metal to create the required cooling channels.

2 **Ensure that the power voltage** supplied to VFDs is stable within plus or minus 10% to prevent tripping faults.

3 **Motors operating at low speeds** can suffer from reduced cooling. For maximum motor protection on motors to be run at low speeds, install thermal sensors that interlock with the VFD control circuit. Standard motor protection responds only to over-current conditions.

4 **Speed control wiring**, which is often 4 mA to 20mA or 0 VDC to 5 VDC, should be separated from other wiring to avoid erratic behavior. Parallel runs of 115V and 24V control wiring may cause problems.

Precautions for specifying, installing and operating VFDs are numerous. Improper installation and start-up accounts for 50% of VFD failures.

1 **Use the VFD start-up sheet** to guide the initialization check prior to energizing the VFD for the first time.

2 **Corrosive environments**, humidity above 95%, ambient air temperatures exceeding 40˚C (104˚F), and conditions where condensation occurs may damage VFDs.

3 **If a VFD is started** when the load is already spinning, the VFD will try to pull the motor down to a low, soft-start frequency. This can result in high current and a trip unless special VFDs are used.

4 **Switching from grid power** to emergency power while the VFD is running is not possible with most types of VFDs. If power switching is anticipated, include this capability in the specification.

5 **If electrical disconnects** are located between the VFD and motor, interlock the run-permissive circuit to the disconnect.

6 **If a motor always operates at rated load**, a VFD will increase power use, due to electrical losses in the VFD.

7 **Use "inverter duty" motors** on new installations that will have VFDs.

References

Murphy, Howard G., “Power Quality Issues with Adjustable Frequency Drive - Coping with Power Loss and Voltage Transients,” *Iron and Steel Engineer*, February 1994.

Turkel, Solomon S., “Understanding Variable Speed Drives (parts 1 to 6),” *Electrical Construction and Maintenance*, February to July 1995.

Induction motors, magnetic ballasts, and transformers require two types of power to operate. Active power (also called true or real power) produces work or heat, is used by all electrical devices, and is expressed in kilowatts (kW). Reactive power is used by inductive devices to generate magnetic fields. It does not perform useful work, and is expressed as kVARs (kilovolt-amps reactive). Total power, or apparent power, is the vector sum of active and reactive power and is expressed in kVA (kilovolt-amps). A power factor is the ratio of active power to total power and quantifies the portion of power used by a facility that does electrically useful work. Power companies generally charge an additional fee to facilities having power factors less than 85% to 95% in order to capture costs not reflected by the electric energy (kWh) meter. Improving the power factor can increase current-carrying capacity, improve voltage to equipment, reduce power losses, and lower electric bills.

Action Moment

Improve power factors if: (1) power factors are below 90% to 95% and penalties charged by the electrical utility are high; (2) electrical problems within the facility can be eliminated by improving the power factor; or (3) rewiring with large wire for capacity needs can be deferred.

Technical Information

Electric motors are large contributors to poor power factors because many generally operate under light loads. Lower power factors do not necessarily increase peak kVA demand because of the reduction in load. For example, the power factor of an electric motor is lowest when the motor is lightly loaded. This occurs when both its power draw and contribution to the electrical peak demand is the least.

Power factor correction capacitors are designed to provide the reactive current needed by inductive loads. Capacitors may be installed to improve the power factor of a single load or an entire power system, and come in sizes from 1 to 600 kVARs.

Power factor monitoring can help increase current-carrying capacity and reduce the cost of electrical power.

Automatic power factor correcting equipment switches banks of capacitors on- and off-line depending on the power factor. These may provide good solutions where reactive loads vary in magnitude over time.

Locate capacitors upstream of motor controllers unless full-voltage, non-reversing, across-the-line starters are used.

Replace standard motors with energy-efficient motors with high power factor ratings. Beware that even high-efficiency motors will have poor power factors under low load conditions. Note that efficiency is more important than power factor. Be sure not to sacrifice efficiency for power factor. Avoid operating equipment above its rated voltage. Minimize operation of lightly loaded or idling motors.

Shut down a lightly-loaded motor in situations where a smaller, parallel motor can do the same job. For example, when chilled water demand drops, parallel pumps may be removed from service until loads increase.

Be aware that installing power factor correction capacitors on the load side of a motor overload protection device may require reducing the overload size. The capacitor manufacturer will have tables to assist in re-sizing.

Avoid over-sizing capacitors installed on the load side of motor controllers because they can discharge into the motor when the controller is turned off. Damaging voltages may occur if kVAR current exceeds motor no-load current.

The amount saved by improving the power factor will be the sum of several savings: reduction in power company fees; improved motor efficiency with proper voltage; and savings from released electrical capacity. Motor life may also be extended because motors with voltage that is too high or too low, run hotter, perform worse, and fail sooner.

Beware of applications where there are significant harmonics (VFDs and other non-linear loads). The harmonics can cause resonances with the capacitors and damage them. If harmonies exist, consider harmonic filters which also typically improve power factor.

Do not exceed manufacturer's recommendation on maximum capacitor size.

Power factor is less than one when energy is quickly stored and released in a piece of equipment so that the voltage and current are out of phase by the angle Θ.

$$\text{Power factor} = \frac{\text{watts}}{\text{volts*amps}} = \text{Cos}\ \Theta$$

Additional power is not consumed but bigger wires and transformers are required to handle the additional amps needed by the load. Low power factor of large inductive loads, such as motors, can be improved by adding capacitors to the load. Current through a capacitor has the effect of cancelling out the lagging current.

References

Bonneville Power Administration, *Energy-Efficient Motor Selection Handbook*, (DE-B179-93-B08158), 1993.

Bonneville Power Administration, “Reducing Power Factor Cost,” *Technology Update*, April 1991.

Morgan, Robert, “Improving Power Factor for Greater Efficiency,” *Electrical Construction and Maintenance*, Sept and Nov 1994.

Lighting accounts for 25% of the electricity used in the Federal sector. If new lighting technologies were used everywhere in the Federal sector, electricity required for lighting would be cut by 50%, electrical demand reduced, and working environments improved. Although every application must be judged separately, some lighting retrofits are generally applicable, especially for aging lighting systems. For example, most existing fluorescent lighting systems can be cost-effectively upgraded to T-8 lamps and electronic ballasts. Compact fluorescent lights (CFLs) are available in a wide range of sizes and wattages, making them good replacements for incandescent lamps, especially where burning hours are long (>4000 hours/year). Mercury vapor lamps can be replaced with metal halide lamps that are much more efficient. If lighting is left on wastefully in unoccupied spaces, occupancy sensors, which detect the presence (or absence) of people, can effectively eliminate waste.

Action Moment

Consider retrofitting the lighting system whenever undertaking any renovations or new additions. As the usage in a facility changes, the old lighting system may be inappropriate and consume more energy than necessary for the new tasks being performed. Adding partitions or changing workspace locations may reduce a lighting system's effectiveness, thus presenting a good time to upgrade the ceiling lighting system and add task lighting where appropriate. Always consider the effect of lighting loads when replacing HVAC systems. By upgrading the lighting system and reducing lighting loads at the same time the HVAC system is changed, it may be possible to specify a smaller HVAC system, resulting in first cost capital savings.

Lighting Technical Issues

FEMP's Federal Relighting Initiative is a program that provides facility managers with lighting evaluation tools and lighting retrofit information. Relighting a building can dramatically reduce the amount of energy used for lighting, improve the working environment, and reduce lighting maintenance costs. Lighting power densities of 2.5 watts per square foot (typical for many office buildings) can be reduced to 1 watt per square foot in new buildings and major renovation by: (1) installing modern, efficient luminaires; (2) replacing ballasts and lamps with modern components; (3) implementing task/ambient lighting; and, (4) installing lighting controls. The lower lighting power densities that can result from sensitive design and refurbishment can surpass ASHRAE 90.1 guidelines.

1 **Lighting Technology Screening Matrix (LTSM)** software evaluates different lighting technologies on per-fixture basis. The algorithms are based on lumen equivalents, but the user can adjust for areas that are overlit or underlit. The LTSM program is primarily a financial tool that generates a list of potential cost-effective lighting retrofits.

2 **Lighting Systems Screening Tool (LSST)** software allows managers to evaluate system retrofits on a facility-wide basis. It can either make assumptions about existing lighting for a first cut, or allow more precise evaluation using actual data entered for the facility.

3 **The Federal Lighting Expert (FLEX)** is an expert system that can assist facility managers in optimizing lighting retrofit projects. It is user-friendly, can be used by non-experts, and has a product database with performance specifications and cost information.

4 **The Master Specifications (Version 2.03)** is a generic specification for energy-efficient lighting systems targeted at Federal Facilities. It addresses lamp, ballasts, reflectors and luminaires. Parts of the specification can be "lifted" verbatim to assist in the preparation of technical specifications for specific projects.

Lighting design that provides visual comfort at low energy costs is more of an art than generally thought. If you lack the in-house expertise, it makes good economic sense to contact a specialized lighting consultant to get some sound expert advice before embarking on an expensive lighting retrofit project. To use the consultant's time most effectively, first consider these key factors:

- Is the lighting system older than 15 to 20 years?
- Have the visual tasks changed (i.e., greater use of computers)?
- Are there complaints about the existing system?

If all the above are true, then consider replacing the existing fixtures rather than simply upgrading the ballasts and lamps. On the other hand, if there is asbestos in the ceiling, it may be cost-prohibitive to replace the fixtures because the asbestos hazard would need to be abated as well. Under these circumstances, replacing the T-12 lamps with T-8 lamps, installing electronic ballasts, and (possibly) installing reflectors may be the best bet.

1 **Look at the task.** Consider whether current lighting needs are being met by the existing lighting system. Invest in an inexpensive light meter ($100 to $200) so you can measure existing light levels. Check the Illuminance Selection Tables in the IESNA Lighting Handbook to see if your existing light levels are appropriate to the expected tasks. Take into account the fact that light levels may go up after a lighting retrofit because of the new lamps and fixtures (see maintenance section below).

2 **Choose efficient fixtures**. If you elect to replace the existing fixtures, make sure you select fixtures that are efficient and have the appropriate light distribution for the expected tasks. For example, in areas with computers, consider replacing "prismatic lens" fixtures with efficient "parabolic" fixtures which minimize high angle light that can cause reflected glare in computer screens. The fixture efficiency, which quantifies the percentage of the lamp's light that exits the fixture, is nearly always available from the manufacturer. Forward-thinking lighting companies will also publish a luminaire efficacy rating (LER) for their major fluorescent fixture lines. LER includes the influence of the lamp and ballast and is therefore a superior method for comparing the overall energy efficiency performance of similar class luminaires than simple fixture efficiency.

3 **Use high coloring rendering lamps.** Modern, efficient fluorescent lamps use rare earth phosphors to provide good color rendition. The color rendition index (CRI) describes how a light source affects the appearance of a standardized set of colored patches. The CRIs of lamps can only be compared if the lamps are approximately the same color temperature (see below). A lamp with a CRI of 100 will not distort the appearance of the patches compared to a reference lamp. A lamp with a CRI of 50 will significantly distort colors (to the same extent as a Warm White fluorescent lamp). T-8, T-l0, and compact fluorescent lamps all have CRIs greater than 70; some are as high as 90. The minimum acceptable CRI for most applications is 70 (except for special cases, such as signage). Fluorescent lamps with CRIs over 80 are available but at a premium.

4 **Consider color temperature.** This measures the color of the lamp itself and is expressed in the Kelvin temperature scale. Color temperatures are: 2,700K for "warm"; 3,500K for balanced color applications; and 4,100K for "cool" bluer applications.

References

Department of Energy, *Advanced Lighting Guidelines: 1993*, Washington DC, Report Number: DOE/EE—0008, NTIS Order Number DE94005264. Provides acceptable lighting levels for various applications.

American Society of Heating, Refrigerating, and Air Conditioning Engineers, *ASHRAE Standard 90.1*

Illuminating Engineering Society of North America, *IES Lighting Handbook*, New York, NY, (212) 248-5000 or http://www.ies.org.

Contacts

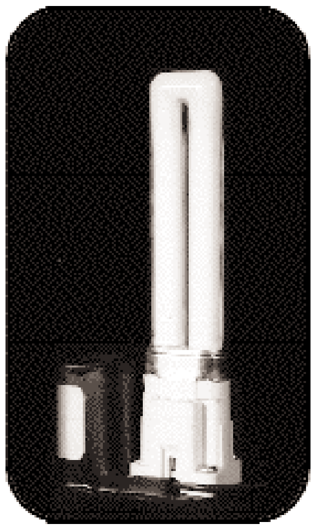
The FEMP Help Desk at (800) DOE-EREC has information about the Relighting Initiative, training courses devoted to lighting technologies and techniques, and software.

"ProjectKalc" software is available from the EPA Green Lights Hotline at (202) 775-6650.

Compact Fluorescent Lighting 3.4.1

Compact fluorescent lamps (CFLs) are energy-efficient, long-lasting substitutes for incandescent lamps. Introduced in the early 1980s, these lamps use about one-half to one-tenth the energy to produce the same light output, and last up to thirteen times longer than the incandescent lamps they replace, providing an attractive return on investment.

Action Moment



Compact fluorescent lamps should be substituted for incandescent lamps, especially where burn hours are more than one hour per day. Substitution is best done by re-fixturing or re-socketing rather than by screw-in adapters. This will help to ensure that incandescent lamps are not later substituted when the CFL fails.

Technical Information

1 **Compact fluorescent lamps** have excellent color rendition and are available with a wide variety of sizes, shapes, and wattages. They are suitable both in new buildings and in renovations.

As a rule of thumb, 1 watt of compact fluorescent can replace 3 to 4 watts of incandescent lighting. For example, replace a 60 watt incandescent lamp with 15 to 20 watts of compact fluorescent. If the fixture efficiency can also be improved during retrofitting (for example by replacing a bare incandescent lamp in a recessed can fixture with a reflectorized screw-in CFL) up to 5 watts of incandescent can be replaced by 1 watt of fluorescent. But remember that the light output of fluorescent lamps is sensitive to both temperature and burning position while an incandescent bulb is not.

2 **Fixtures for compact fluorescent lamps** come in a variety of styles to meet many lighting situations. CFL fixtures contain ballasts required to operate the lamps and special sockets to retain the lamps in their proper position. Retrofit lamps are available that contain integral ballasts and screw-base sockets. See the caution on the next page regarding retrofit lamps.

3 **Lighting surveys** are the first step toward planning replacement of incandescent lamps with CFLs. Although not every incandescent lamp has a compact fluorescent equivalent, facility managers can establish a plan to gradually change over to these more cost-effective alternatives. The table below shows some good opportunities. Software such as the Lighting Technology Screening Matrix (LTSM) and the Lighting System Screening Tool (LSST) can help in the planning and the financial assessment. See section 3.4 for a description of these tools and how to obtain them.

End Use	Compact Fluorescent Application
Outdoor Safety Area	Use for walkways, stairways, and other relatively small areas above 32°F (unless low-temperature ballasts are used).
Outdoor Decorative	Compacts are excellent candidates for walkways, common areas, and landscaping, above 32˚F (unless low temperature ballasts are used).
Storage Areas	Compacts are a good choice for small storage areas used more than one hour per day, especially where tight beam control is not important.
Restrooms, Lobbies, Hallways	CFLs in downlights or wall-packs can replace incandencents used for general bathroom lighting. Good color rendition is advised near mirrors.

Lamp life of CFLs is up to 10,000 hours, five to thirteen times longer than incandescent lamps. Long life helps provide a favorable life-cycle cost and labor savings for lamp replacement.

Over-lighting is common, so direct one-for-one replacement of incandescent lamps with their CFL equivalent may result in ongoing over-lighted conditions. As part of a lighting survey, it is important to determine the lowest wattage lamp that can be used for the application.

Look for applications with long burn hours. Interior and exterior hallways and walkways provide excellent cost-effective replacements for incandescent fixtures, since these locations typically have long burn hours. Wall packs and sconces containing CFLs make excellent retrofit fixtures for these applications.

The National Electric Code forbids the use of incandescent fixtures in small clothes closets and other locations where the heat from incandescent lamps can be a fire hazard. CFLs can be used in many of these applications due to their low heat generation.

When replacing incandescent lamps in existing recessed cans with screw-in CFLs, it is often best to use a CFL with a built-in reflector or a retrofit CFL reflector fixture.

Replacing incandescent fixtures with compact fluorescent fixtures will typically achieve a 35% annual return on investment.

Replacing long-burning (greater than 4000 hours/year) incandescent fixtures with compact fluorescent lamp fixtures will pay back in under 3 years—a 35% return on investment. Although utility rebate money is drying up, many utilities still offer direct rebates for installing screw-in compact fluorescent lamps (expect $5/lamp rebate) or hardwire CFL units (expect a $15/lamp rebate).

Retrofit lamps that contain the lamp, ballast, and screw base all in one unit for easy retrofit are widely available. As a rule, however, these units should be avoided for several reasons: (1) they are often replaced by incandescent lamps when they fail; (2) often the geometry of the bulky retrofit makes it difficult to place the lamp in a good location in the fixture for proper light exit; (3) the ballasts should out-last lamps by a factor of five or more, and disposing of the ballast after each lamp life is wasteful; (4) depending on the manufacturer and configuration, the heat from the integral ballast cannot dissipate very well, and both lamp life and ballast life is short compared to the alternative of re-fixturing; and, (5) it is too easy for the relatively expensive retrofits to be stolen. It is much wiser to re-fixture or re-socket initially.

Some lamps take a second to turn on and flicker initially, and some do not. Consult your supplier about this issue.

Places to avoid using CFLs:

1. where there is a requirement for tight light beam control CFLs cannot focus their output as well as halogens and should be avoided.
2. in spaces with ceiling height over 20 feet. For high bay spaces, too many CFL fixtures would be required to achieve a satisfactory light level. Consider metal halide lamps instead. For medium bay spaces (12 to 20 foot ceilings) fixtures holding multiple high output CFLs may be appropriate, especially if used with occupancy sensors.
3. in areas where the temperature is likely to remain below 32^{o}F for extended periods of time, avoid CFLs or use low temperature ballasts.
4. in exit signs. Replace incandescent lamps with LED retrofits, which are an even more cost-effective alternative.

References

Western Area Power Administration, *Electric Utility Guide to Marketing Efficient Lighting,* (ref. contract DE-AC65-86WA00467), Golden, CO, 1990.

Contacts

Defense Logistics Agency, Defense Supply Center, Richmond, VA (800) DLA-BULB, or at http://www.dgsc.dla.mil

New technologies for 4-foot and 8-foot fluorescent lamps are available. They produce more light for the electricity consumed and enable better light control in new fixtures. Manufacturers generally offer better color rendition only in efficient lamps because their smaller tube diameter minimizes the use of expensive phosphor coatings.

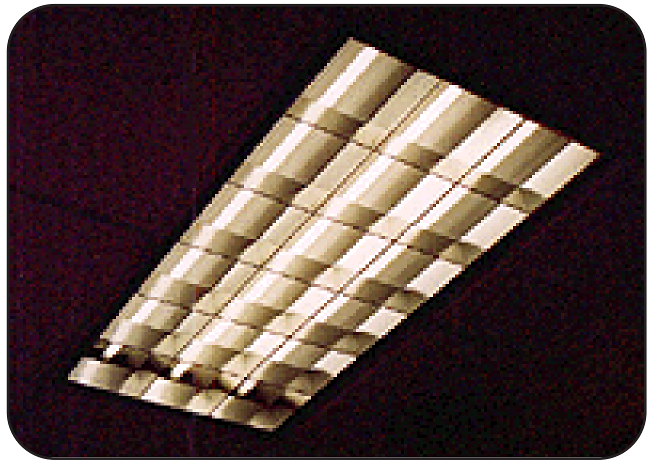
Action Moment

Renovating, moving to, or leasing an interior space usually offers the opportunity and need to revisit lighting. Changing the location of workspaces, adding or moving interior partitions, replacing ceilings, painting walls, or wallpapering all change the effectiveness of existing lighting. Where existing space includes defined task areas, yet a uniform lighting grid illuminates the area, substantial savings are possible. When specifying a new space, require lighting to be efficient.

Technical Information

1 **Fluorescent lighting is the best source** for most Federal lighting applications because it is efficient and can be easily switched and controlled. Modern fluorescent lamps have good color rendering and are available in many styles. Lamps are classified by (1) length, (2) form (straight or folded), (3) wattage, (4) pin configuration, (5) electrical type (rapid- or instant-start), and (6) phosphor type. When specifying a lighting system make sure that the lamp and ballast are electrically matched and the lamp and fixture optically matched.

2 **T-8, T-l0 and T-12 fluorescent lamps** have diameters of 1", 1-1/4" and 1-1/2" (the T-x gives the diameter in 1/8's of an inch) and are (usually) straight. They are most often used in 2x4, 1x4 and 8 foot fixture types. T-5 lamps are 5/8" diameter and are always folded. Folded lamps are good for smaller square fixtures (lxls or 2x2s). Refer to the table which illustrates the advantage of T-8s.



New fluorescent lighting fixtures that incorporate T-8 lamps, electronic ballasts, and good reflectors are key to better lighting at lower cost.

Comparison of 4-foot, fluorescent lamps

Lamp Type	T-12	T-10	T-8	T-12ES
Watts	40	40	32	34
Lumens	3200	3550	3050	2850

3 **When selecting a fixture,** make sure the fixture type is matched to the tasks being performed. Reflectorized industrial fixtures are very efficient and good for production and assembly areas but inappropriate for office applications. Lensed fluorescent fixtures ("prismatic lens" style) produce too much reflected glare off computer screens to be a good choice for today's electronic office. Instead, use parabolic louver fixtures that restrict light above 55˚ (0˚ is straight down), or use direct/indirect pendant-mounted fluorescent fixtures if high quality lighting is desired.

4 **After the fixture type has been identified,** make sure that it is efficient. The new Luminaire Efficiency Rating (LER) used by some fluorescent fixture manufacturers makes this comparison easier. Since LER includes the effect of the lamp and ballast type as well as the optical properties of the

Luminaire Efficiency Rating = (Fixture efficiency,% x Lamp lumens x # of lamps x Ballast factor) / Input watts fixture, it is a better indicator of the overall energy efficiency than simple fixture efficiency. An LER of 60 is good for a modern electronically-ballasted T-8 fluorescent fixture; 75 is very good and close to "state-of-the-art."

5 **Where possible and permitted** by code, install dual level lighting (tandem or split-wiring) so that a 50% lighting level can be obtained when desired. This provides the occupant increased lighting flexibility and may save energy compared to an on-off only system.

6 **Where 4-lamp T-12 fixtures provide** adequate lighting, a good retrofit may be to replace the T-12s with half the number of T-10 lamps. Remove all four lamps, disconnect power to the inner ballast, and install two T-10s at the outside lamp positions. Using the outer lamp positions places the lamps further from the ballast heat and normally provides good light distribution. However, if light is blocked by the fixture itself, then the inner lamp position should be used.

The use of retrofit reflectors that fit into existing fixtures should be generally avoided. Except for one- and two-lamp industrial strips, fixtures already have reflectors consisting of the painted white surfaces inside the fixture. Because highly-reflective specular reflectors often produce striated patterns on the surfaces being lit and cause light to "dump" beneath the fixture, they can produce worse lighting than the original diffuse reflectors. Given the high cost of retrofit reflectors, it is often better to purchase new fixtures. An exception is where fixture replacement is not practical due to ceiling disruption—reflectors specially designed for the particular trough and application may be used.

Avoid inappropriate retrofits. If original lighting conditions are poor and cause visual discomfort or poor light utilization due to poorly placed fixtures, then conversion to T-10s alone will not help. While energy usage and electrical demand may be reduced, complete lighting redesign, retrofit, and even complete ceiling replacement to accommodating re-fixturing may be justified. Any retrofit should include a lighting design analysis.

New lighting design and re-fixturing with T-8 technology should be considered in any office renovation. It may be a better midterm choice than a T-10 retrofit.

Always transport and store fluorescent lamps horizontally to prevent phosphorous coatings from settling to the ends of the tubes.

Above 12 feet, high intensity discharge (HID) fixtures are usually a better choice. Fluorescent lighting is a good choice for general lighting for work areas, multipurpose rooms, bathrooms, offices, storage areas, and drafting areas.

Be sure to recycle all fluorescent lamps. Phosphor coatings contain harmful materials that should be eliminated from landfills. Waste recycling firms recover lamp material for industrial reuse.

Fort Lewis Army Base is undergoing extensive lighting renovations involving fixture replacement with T-8 lamps, electronic ballasts, dimmer controls, daylighting controls, and occupancy sensors.

References

Lighting guide specifications for lamps, ballasts, luminaires and reflectors have been developed under the FEMP Federal Relighting Initiative. Software to assist in system selection and design also is available from the FEMP Help Desk at (800) DOE-EREC, or from the FEMP Home Page at http:// www.eren.doe.gov/femp.

The *Lighting Upgrade Manual* may be downloaded at http://www.epa.gov/docs/CGDOAR/gcd_pubs.html#glpubs.

Environmental Protection Agency, Office of Air and Radiation, *Lighting Waste Disposal,* (6202J), 1994.

Western Area Power Association, *Electric Utility Guide to Marketing Efficient Lighting*, Golden, CO, 1990. (303) 231-7504

Contacts

EPA Green Lights and Energy Star Programs Hotline at (202) 775-6650.

Electronic ballasts (sometimes called solid-state) are efficient replacements for standard magnetic ballasts. Since the lamp and ballast form a system, the lamp is generally changed along with the ballast. Used with the right fluorescent lamp, electronic ballasts produce energy-efficient lighting while eliminating the flicker, hum and poor color rendition associated with conventional fluorescent lighting. Electronic ballasts capable of driving up to four lamps are available. These will continue to drive three lamps even after one has failed. For added cost, some electronic ballasts can also be dimmed, although this generally requires an additional low voltage control circuit.

Action Moment

Investing in new fixtures with electronic ballasts should be considered if the existing lighting system: is old and prone to failure; is inappropriate for current and future use; operates many hours daily; produces flicker, glare, or other discomfort to occupants; causes problems with sensitive electronics in the facility; or produces lighting levels that are too low or too high. Entire areas are commonly re-fixtured to save on installation costs and to allow implementation of integrated design, however, ballasts can be replaced in existing fixtures.

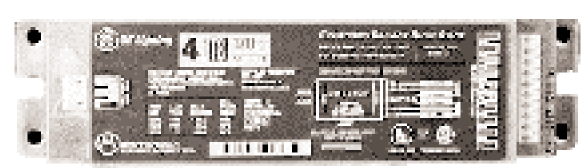
Technical Information

1 **Ballast specifications include:**

- Input voltage (usually 277 or 120 VAC)
- Number and type of lamps
- Power factor
- Total harmonic distortion (THD)
- Circuit type (instant-start or rapid-start, series or parallel operation)
- Ballast factor (BF)
- Ballast efficacy factor
- Minimum starting temperature

Good guidance for specifying these parameters is given in the Master Specifications Version 2.03 or Advanced Lighting Guidelines.

2 **"Instant-start" electronic ballasts** operate T-8 lamps in instant start mode. This mode of operation is slightly more efficient than rapid-start operation but comes with some degradation in lamp life (instant- start operation generally reduces 1amp life by about 25% using 15,000 hours rather than 20,000 hours). Rapid start operation is required for "reduced-output" ballasts (which have BF-70%) and for dimming applications. Parallel operation is generally preferable to series operation. If one lamp fails with a parallel circuit ballast, the other lamp(s) will continue operate. With series operation, neither lamp will operate if one fails.



Electronic ballast with "poke-in" connections for fast retrofitting.

3 **Dimming is available as an option** for some electronic ballasts. These are always of the rapid start, type and the dimming ballast will have two extra wires for a low voltage control signal (typically 0-10 VDC). By connecting a simple wall-mounted potentiometer to the low-voltage control wiring, an occupant can "dial-up" light levels between approximately 20% and 100% of maximum light output. Alternatively, the control wires can be connected to a ceiling-mounted photocell which will adjust the electric light level to supplement available daylight, thus saving energy (see Lighting Quality section 7.2).

4 **Power factor** indicates how effectively the input power and current are converted into usable watts of power delivered to the ballast. High-power-factor ballasts reduce current loads on building wiring and transformers. Specify power factors of 0.90 or higher for ballasts that drive large fluorescent lamps

5 **Ballast factor (BF)** or **relative light output** quantifies the light-producing ability of fluorescent lamps from a commercially available ballast compared to a laboratory reference ballast. Specify ballasts with a ballast factor or relative light output of between 85% and 100% to maximize light output from a specific lamp/ballast combination without over-driving the lamps. Over-driving lamps can shorten lamp life. A ballast may have one ballast factor for standard lamps and another for energy efficient lamps.

6 **Ballast efficacy factor** is the ratio between light output (lumens) of lamps operating on a ballast compared with input watts to the ballast. Ballast efficacy factor is useful in comparing ballasts within a type of lighting system, for example for the class of 4-foot fluorescent lamps.

7 **Total harmonic distortion** (THD) defines the effect a device has on the ideal electrical sinusoidal waveform. Harmonics within a facility can cause problems with electronic and communications equipment, overload transformers, and cause unexpected loading of the neutral in a three-phase system. Although other equipment can be responsible for harmonic distortion, ballasts are often blamed for these power quality problems. To avoid problems, specify ballasts with a THD of 20% or less. Ballasts with a THD of 5% or less are available for areas with sensitive electronic equipment or other special needs.

Many ballasts have a minimum starting temperature rating of 10˚C (50˚F), and may not be suitable for unconditioned locations. Other ballasts offer low-temperature starting down to -17˚C (0˚F).

One way to significantly reduce energy costs in overlit spaces is to replace existing magnetic ballasts with "reduced output" T-8 electronic ballasts (ballast factor around 70%) and re-lamp with T-8 lamps. Although the T-8 lamp output will be reduced 30% from the rated value, the new levels will be more appropriate and more energy is saved than using "normal" BF ballasts.

To avoid a significant reduction in ballast life, promptly replace fluorescent lamps that strobe or have blackened ends.

Unless there is a reason to do otherwise, specify electronic ballasts with the following performance:

- Ballast factor: 85% to 100%
- Power Factor: greater than 90%
- THD: 20% to 33%

Ballasts capable of operating four lamps can be wired to lamps in several fixtures, saving both initial equipment costs and operating costs.

Ballasts manufactured prior to 1979 may contain polychlorinated biphenyls (PCBs). PCBs are hazardous because they cause cancer, do not readily breakdown in the environment, and accumulate in plants and animals. PCB-containing ballasts must be sent to chemical waste landfills or high-temperature incinerators, or be recycled. Ballast recycling firms salvage reusable metals, reducing the volume of PCB-containing material for disposal.

References

Environmental Protection Agency, Office of Air and Radiation, *Lighting Waste Disposal,* (EPA 420-R-94-004) 1994.

Defense Logistics Agency, *Energy Efficient Lighting Catalog*, 1996. A good source of equipment information.

BC Hydro, *Design Smart: Energy-Efficient Architectural Design Strategies*, Burnaby, BC, Canada, 1995. (604) 540-8883

Contacts

FEMP’s ballast specifications are available from the FEMP Help Desk at (800) DOE-EREC.

EPA Green Lights Customer Service Center has information about ballast disposal. (202) 775-6650

Defense Logistics Agency, Defense Supply Center, Richmond, VA (800) DLA-BULB, or at http://www.dgsc.dla.mil

Occupancy Sensors 3.4.4

Lighting can be controlled automatically by many methods to save energy and lamp replacement costs: energy management and control systems (EMCSs, see section 3.8); daylight sensors that detect available daylight and control fixture outputs accordingly (section 7.2); photocells for exterior use, time-clocks and spring-wound timers (section 3.8); and occupancy sensors which prevent energy waste by turning off lights operating in unoccupied spaces, or by dimming lights according to daylight level within the building. This section covers occupancy sensors.

Action Moment

Installing occupancy sensors is relatively easy, requiring no particular timing for implementation. Facility managers should certainly consider enhanced controls when renovating, constructing new areas, or doing other electrical work. Good candidates for sensors include private offices, restrooms, hallways, lounges, computer rooms, clerical areas, conference rooms, warehouse aisles, storage rooms, copier rooms, classrooms, and loading docks.

Technical information

Occupancy sensors are triggered by infrared detection, ultrasonic emissions, microwaves, or sound. The first two technologies are the most popular, and hybrid infrared/ultrasonic sensors are available to combine the best features of both types. Sensors are either wall-mounted at the switch location or ceiling-mounted with remote control modules and relays.

1 **Infrared sensors** respond to movement of a heat source, such as a person moving in front of its field of view. Small motions, such as typing, may not trigger infrared sensors. These are suitable where there are no obstructions and they are not to be triggered by inanimate moving objects, such as a mobile twisting in an unoccupied classroom.

2 **Ultrasonic sensors** emit high-frequency energy in the 25 to 40 kilohertz range, well above normal human hearing. Objects moving in the space, even outside the direct line of sight, cause a frequency shift in the returning signal. Ultrasonic detectors are very sensitive to small movements, and may be triggered by wind-blown curtains or papers. These are suitable where obstructions such as bathroom partitions are present.

3 **Wall-mounted units** are designed to replace standard wall switches, and are so easy to retrofit that facility managers may choose to use them at any time. The best applications are small rooms, such as private offices, bathrooms, copy rooms, and storage closets.

4 **Ceiling mounted systems** usually control several lighting banks through infrared/ultrasonic occupancy sensors, a remote low-voltage controller, and line-voltage relays.

5 **Coverage area of sensors** depends on the room arrangement, room geometry, presence of partitions, location of sensors, the sensor's sensitivity setting, the type of sensor, and type of motion. Manufacturers' ratings are very rough guidelines. Facility managers should plan to adjust the sensor's sensitivity for specific applications.

Sensors vary widely in their ability to detect a person entering a room and maintain detection of small movements. This is true even within type groupings (ceiling-mounted infrared sensors, wall-mounted ultrasonic sensors). Be sure to consult comparative test reports.

"Automatic-off/manual-on" sensors allow occupants to decide whether lights are turned on, but they always ensure that lights are turned off after occupants leave. This type of sensor can be useful in areas such as break rooms, where quick visits to vending machines do not require lights to be turned on. For extended breaks occupants may want the lights on.

Lamp lumen depreciation sensors are designed to dim a lamp more when it is new and its light output is naturally highest. Light output is normally less at the end of lamp life, and the sensors accommodate by dimming less, or not at all. In this way, lighting designs that are normally overlit at beginning of lamp life and properly lit at end-of-life can save energy in the early years after relamping.

Occupancy sensors guard against custodial staff leaving lights on in unoccupied areas during and after nightly cleanings.

The Electric Power Research Institute estimates that occupancy controls save energy:

Private offices	25%
Open offices	18%
Conference rooms	35%
Restrooms	40%
Hotel Meeting Rooms	65%

Shortened lamp and ballast life may result from using occupancy sensors to control equipment that will turn on and off frequently. Ensure that the sensors are designed and calibrated to the situation.

Occupancy sensors can save 30% to 50% of the energy used for lighting, which comprises a major portion of typical electrical usage in facilities. The reduction in greenhouse gases from reductions in electrical generation needs depends on the individual occupancy sensor installation.

User satisfaction is important, and land users need orientation for a successful outcome. Dissatisfied occupants may sabotage the controls, and negate the savings.

Alcoa Composites in Monrovia, CA enjoys $26,000 annual electricity savings as a result of installing ultrasonic sensors in offices, work areas, and hallways. The installation paid for itself within 1 year.

Contacts

Renssellaer Polytechnic Institute, Lighting Research Center, National Lighting Product Information Program (NLPIP), Troy, NY, offers comparative test reports for purchase. (518) 276-8716 or http://www.lrc.rpi.edu/

Environmental Protection Agency, Green Lights Program at (202) 775-6650 offers general information.

Exterior lighting is used to improve security, enhance safety, and to direct pedestrians and vehicles. It is also used in nighttime work areas, sports facilities, landscapes and cityscapes. A wide selection of new lamps, ballasts, fixtures and controls are available to lighting designers to replace inefficient exterior lighting systems.

Action Moment

Exterior lighting systems using incandescent, fluorescent, or mercury vapor lamps should be evaluated, redesigned, and replaced with new hardware using compact fluorescent, metal halide, or sodium lamps.

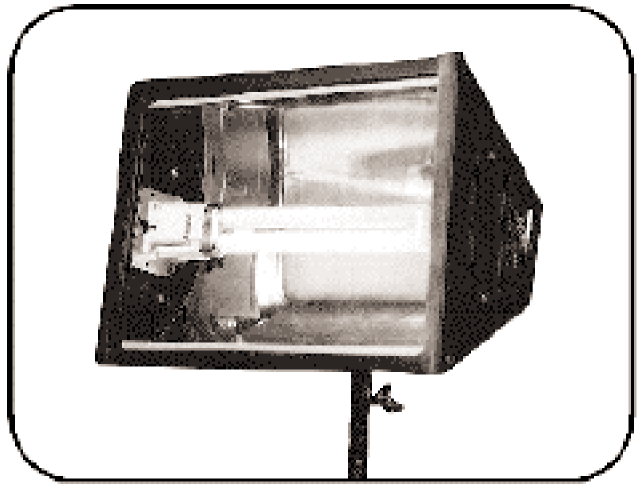
Technical Information

Exterior lighting principles should be considered when implementing any exterior lighting retrofit. These principles assist in achieving energy conservation and also provide superior lighting quality to users.

1 **Minimize glare**. Glare greatly detracts from nighttime visibility. If two parking lots are equally illuminated to 5 footcandles, the installation with the least glare from the fixtures will provide the greatest visibility, safety, and visual comfort. Unfortunately, numerical levels for glare are not included in exterior lighting standards.

2 **Minimize or eliminate light directed upward**. Light emitted at angles of 80^{o} or higher (straight down is 0^{o}) fails to produce useful illumination on horizontal surfaces in open areas such as parking lots. At these high angles light produces significant glare, light pollution, and energy waste. Light above 90^{o} is totally wasted and produces undesirable sky glow.

3 **Direct light only where it is needed**. New fixtures allow designers to control where light falls. By eliminating light spillage into surrounding areas, lower wattage lamps can be used. "Barn lights" that contain 175-watt mercury vapor lamps are good examples of fixtures that should be avoided.



Compact fluorescent floodlights provide high quality light with very low energy.

4 **Avoid over-lighting**. A good rule of thumb is that, "a little light is a lot of light where there isn't any other light."

5 **Consider human usage patterns**. For example, a driver traveling in rural areas will temporarily be blinded by suddenly encountering bright roadway lights. In driveways, place the first few lights at lower levels to counter this problem.

6 **Turn off lights by 11:00 P.M.** unless they are needed for security or safety.

7 **Design systems to accommodate maintenance accessibility;** to have long ballast and lamp lives; and to resist dirt, animal droppings, bird nests, vandalism, and water damage.

Some high intensity discharge (HID) ballasts incorporate control circuits that allow easy attachment of motion sensors or energy management system controls.

Use HID lamps with specific orientations rather than universal position lamps. Lamps that specify burning in the horizontal, base-up, or base-down positions can produce 10% to 20% more light and last up to 60% longer.

Consider photovoltaic (PV) lighting for remotely located sites not presently served by power lines. Locations requiring low levels of light that are as close as 50 ft. from a power source can be good applications for PV lighting. Examples are signs and bus shelter lights (See section 3.10.1).

Low-pressure sodium lights are the most efficient light source, but are generally more difficult to control. The monochromatic yellow light they produce has absolutely no color rendering capability. Three cars—red, blue and black—may all appear identical under these lights. However, if astronomical observatories are nearby, using low-pressure sodium (LPS) will help reduce light pollution because filters for specific wavelengths can be installed on telescopes.

Relamp groups of fixtures at the same time to reduce maintenance costs, lamp stocking, and light depreciation toward the end of lamp life.

Control of exterior lighting may be provided by manual switches, time clocks, photocells, motion sensors, or energy management and control systems. By automating controls, users need not manually switch lights on and off each night. However, where time clocks are used, they should be periodically checked to ensure the time is set correctly and adjusted for changes in time of sunrise and sunset. Where photocells are used, they should be very sensitive to low light levels and placed in open areas, such as on roofs. This will help ensure that lights do not operate unnecessarily at dusk and dawn. See section 3.8 for more information about control systems.

References

Illuminating Engineering Society of North America, *IES Lighting Handbook*, eighth edition, New York, NY, 1993.

Markowitz, Gary, "HID Luminaries: An Overview," *Architectural Lighting*, Oct/Nov 1993.

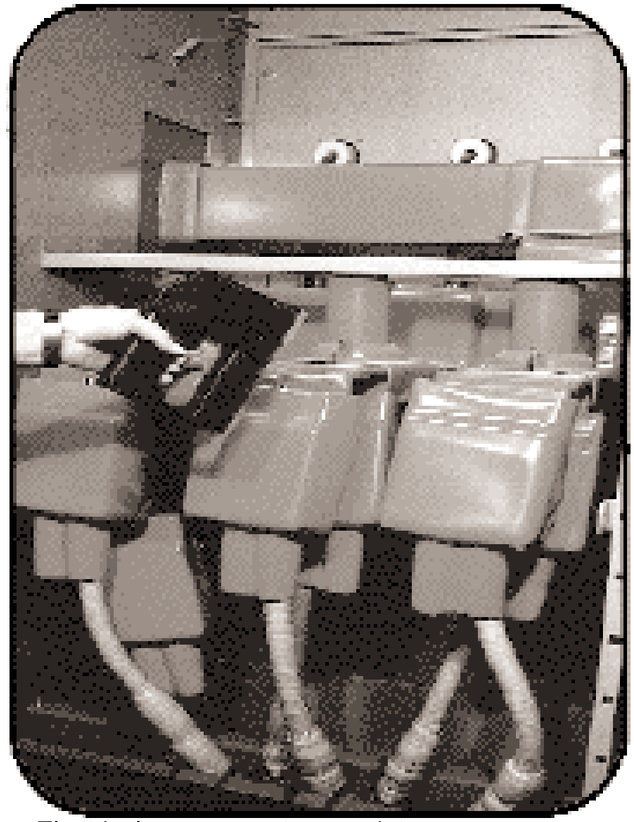
Contacts

International Dark-Sky Association, 3545 N. Stewart Ave., Tuscon, AZ 85716 or at http://www.darksky. org/ offers information on techniques for providing good outdoor lighting without contributing unnecessarily to light pollution.

Electricity is the largest energy source in most facilities. Electric utility bills include both energy charges in kilowatt-hours and power demand charges in kilowatts. Rates may vary by season and time of day. Utilities penalize facilities with low power factors that require the utility to provide power-factor compensations. In the broadest sense, power systems include HVAC equipment, motors, lighting, kitchen appliances, water heaters, and plugloads that deliver power to end-users. The focus of this Section is on distribution components such as transformers, switchgear, wiring, and other power system components. Analysis of power systems is discussed in section 3.5.1 and transformers are addressed in section 3.5.2.

Action Moment

Consider efficiency, reliability and maintenance of power systems whenever installing, renovating, or replacing equipment. Electrical power systems are often thought to be stable, reliable, and to have little potential for saving energy. However, there are opportunities within the facility's distribution system to save energy, increase equipment life, and reduce unscheduled outages.



Electrical power system maintenance programs will increase both efficiency and reliability.

Technical Information

Opportunities for improving efficiencies of electrical power systems include evaluating and correcting voltage imbalances, voltage deviations, poor connections, undersized conductors, poor power factors, insulation leakage, and harmonics. Components to check in a maintenance program include transformers, conductors, switchgear, distribution panels, and connections at loads and elsewhere.

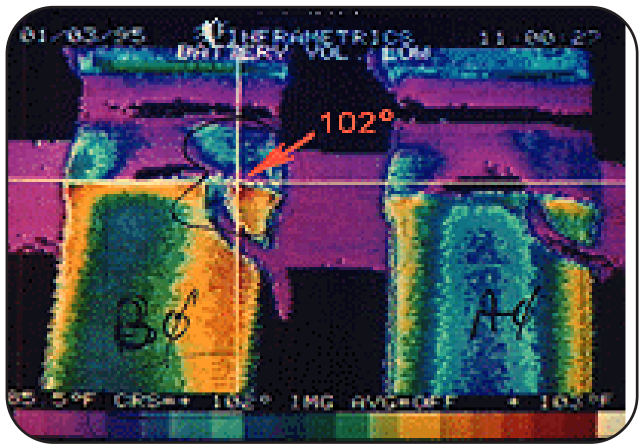
Voltage imbalances are problematic differences between relative voltage levels among the three phases in part or all of a facility. Voltage imbalances result in preventable energy waste, excessive equipment wear, and premature equipment failure. Power demands on all three power phases should be virtually equal in order to maintain equal voltages in all phases. Problems with conductors, connections, and transformer settings may cause imbalances in any facility. However, supplying single-phase needs while maintaining three-phase balance is a challenge.

Before making any major changes to the distribution system, consider the effects on the phase-to-phase balance.

Avoid imbalance in supply circuits by distributing single-phase loads such as lighting, single-phase motors, resistance heating, and plugloads among phases.

Maintenance Type	Philosophy
Reactive maintenance	Repairs are made or components are replaced only upon failure.
Preventive maintenance	Includes inspecting, diagnosing, and servicing electrical systems to minimize future equipment problems or failures.
Predictive maintenance	Uses tests to predict the necessary service interval and targets equipment with the greatest service needs.
Proactive maintenance	Employs failure analysis and predictive analysis as feedback to improve maintenance practices.

The annual cost penalty for operating a 100 hp motor with a 4% voltage imbalance is approximately $830 per year. This cost is due to reduced motor life, energy charges, and electrical demand charges. This assumes continuous operation, utility rates of $0.04 per kWh, and demand charges of $4.00 per kW.



The hot spot on this infrared scan shows a problem with a control wire connection in a large generator breaker.

Match the maintenance sophistication of electrical facilities to the situation and resources. The more critical the equipment, the more maintenance resources should be devoted to it. Maintenance programs for electrical distribution systems may be reactive, preventive, predictive, or proactive. The table on the next page shows the distinguishing features of differing maintenance strategies. With good record-keeping, a manager can develop the tools needed for at least a predictive maintenance program.

References

Washington State Energy Office, *Keeping the Spark in Your Electrical System: An Industrial Electrical Distribution Maintenance Guidebook*, (WSEO 93-15), Olympia, WA, 1995.

An analysis of an electrical power system may uncover energy waste, fire hazards, and impending equipment failure. A well-executed analysis takes planning and lays the foundation for ongoing reliability-based maintenance.

Action Moment

The best time to initiate preventive maintenance on electrical systems is before failures occur. Problems may be hidden until failure occurs, especially if the system is not regularly maintained. In a new facility, maintenance should begin from the outset. For electrical systems, it is never too late to start a regular maintenance program.

Infrared thermography can quickly identify electrical power system problems and should be included in a proactive maintenance program.

Technical Information

"Tune-ups" for electrical power systems yield both direct and indirect efficiency improvements and increase the reliability of equipment. Direct improvements result from correcting leaks to ground and cutting resistive (I^2R) losses in the distribution components. Indirect improvements result from improving efficiency of equipment previously operating with poor quality input power, such as three-phase motors operating with phase-to-phase voltage imbalances.

O/M **Establish a preventative maintenance program with good record keeping**.

1 Document the system component and loads starting with the available drawings and other documentation. Update them to "as-built" and keep them current.

2 Inspect components noting discoloration, deformation, damage or hot odors, noise, or vibration.

3 Manually operate all switches and disconnects on a monthly schedule to help eliminate any corrosion.

4 Conduct a regime of electrical tests designed to identify actual and potential problems. This may include contact condition assessment with a voltage drop survey, infrared thermography, power factor assessment, or voltage assessment to determine imbalances and deviations from target voltages.

5 Consider a proactive maintenance program with the predictive elements discussed in Section 3.5.

When conducting electrical assessments, be aware of varying conditions. Power quality may change greatly at night or other times because of changes in loads.

$ Facility managers increasingly find that reliability-centered maintenance can save money, energy, and downtime. A lumber/plywood facility in Oregon projected $125,000 in potential savings by instituting an electrical system preventive maintenance program. Estimating true savings is difficult due to the uncertainty about when failures will occur, what equipment will be damaged, and how long problems will last.

System Problem	Common Causes	Possible Effects	Solutions
Voltage imbalances or differences between relative voltage levels among the three phases in all or part of a facility.	Improper transformer tap settings, one single-phase transformer on a polyphase system, single-phase loads not balanced among phases, poor connections, bad conductors, transformer grounds or faults.	Motor vibration, premature motor failure, energy waste. A 5% imbalance causes a 40% increase in motor losses.	Balance loads among phases
Voltage deviations refer to voltages being too low or high.	Improper transformer settings, incorrect selection of motors, e.g., a 230/208 motor (which is actually 230 rated) on a 208 circuit.	Over-voltages in motors reduce efficiency, power factor, and equipment life, and increase temperature.	Check and correct transformer settings, motor ratings and motor input voltages.
Poor connections may be in distribution or at connected loads.	Loose bus bar connections, loose cable connections, corroded connections, poor crimps, loose or worn contactors, corrosion or dirt in disconnects.	Wastes energy, produces heat, causes failure at connection site, leads to voltage drops and voltage imbalances.	Use IR camera to locate hot-spots and correct.
Undersized conductors.	Facilities expanding beyond original designs, poor power factors.	Voltage drop and energy waste.	Reduce the load by conservation insulators.
Insulation leakage.	Degradation over time due to extreme temperatures, abrasion, moisture, chemicals, conductor insulation inappropriate for conditions.	May not cause breaker to trip, and may leak to ground or to another phase. Variable energy waste.	Replace conductors, insulators.
Low Power Factor	Inductive loads such as motors, transformers, and lighting ballasts; non-linear loads, such as most electronic loads.	Reduces current-carrying capacity of wiring voltage regulation effectiveness, and equipment life. May increase utility costs.	Add capacitors to counteract reactive loads.
Harmonics (non-sinusoidal voltage and/or current wave forms)	Office electronics, telephone PBXs, uninterruptable power supplies, variable frequency drives, high` intensity discharge lighting, and electronic and core-coil ballasts.	Over-heating of neutral conductors, motors, transformers, switch gear. Voltage drop, low power factors, reduced capacity.	Take care with equipment selection and isolate sensitive electronics from noisy circuits.

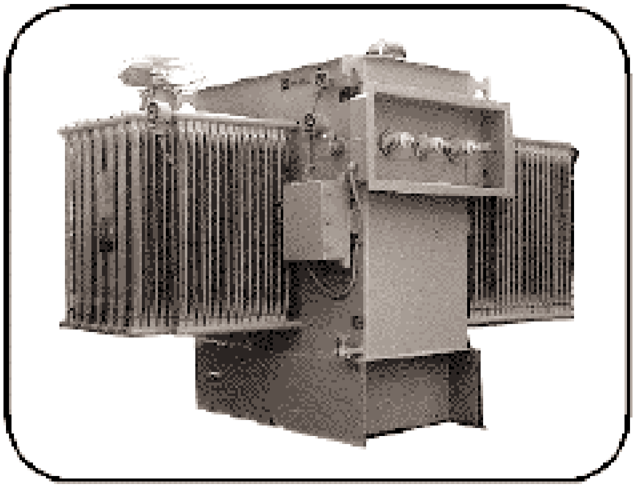
References

IEEE Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems, (ANSI/IEEE Standard 242-1986), Institute of Electrical and Electronics Engineers, 1986.

Washington State Energy Office, *Keeping the Spark in Your Electrical System: An Industrial Electrical Distribution Maintenance Guidebook*, (WSEO 93-15), Olympia, WA, 1995.

Transformers 3.5.2

Customer-owned transformers allow facilities to purchase power at lower costs and at high voltages, and then generate the range of voltages needed for internal applications. Transformers commonly used in large facilities are oil-filled, pole-mounted types for overhead distribution; and oil-filled, pad-mounted models for underground feeds. Dry-type transformers, used for smaller, special applications, are typically located inside buildings away from harsh environments. Transformer failure may be catastrophic and cause power interruptions. Other transformer problems are more subtle and may result in energy waste that goes unchecked for years.



Energy-efficient transformers should be specified when replacing or obtaining equipment.

Action Moment

Purchase energy-efficient transformers and practice good installation techniques whenever replacing or adding new equipment. Commence proactive transformer maintenance along with other electrical maintenance functions.

Technical Information

1 **Efficiencies of most dry-type transformers** range from 93% to 98% with core losses due to magnetizing and coil losses from impedance and resistance. When purchasing transformers, look for those with high efficiency ratings that fit the need. Be sure to obtain all transformer loss information from the manufacturer and match the transformer to the load profile. Manufacturers trade-off coil losses (most significant at full load) and core losses (most significant at low load). Consequently a low temperature rise unit that operates very efficiently at high load may be inefficient at low load.

Each year, according to insurance industry figures, there are more than 100 incidents of electrical and fire damage due to inadequate transformer maintenance, causing $10 million in losses.

2 **Disconnect the primary side of transformers not serving active loads.** Transformers consume power even when loads are switched off or disconnected. Disconnecting the primary side of transformers to save transformer standby losses is safe provided that critical equipment such as clocks, fire alarms, and heating control circuits are not affected.

For three-phase transformers, ensure that each phase balances in voltage with others to within the minimum transformer step. If this fails to yield equal tap settings, redistribution of loads is necessary.

3 **Reduce acoustical noise** from pad-mounted transformers by proper design. In areas where personnel would be affected by the 60 Hz hum of power transformers, use isolators to reduce transmission to the building's structural components. Install isolators between the transformer core and housing, and also between the housing and the building structure.

O/M **Visually inspect transformers** to verify that oil is contained and that connections appear to be sound.

Scan temperatures of transformers using infrared thermography to determine points of energy waste and pending failure. Criteria for assessment include ambient air temperature, rated-rise of similar transformers under the same conditions, and an absolute maximum allowable temperature.

Maintain balanced voltage with polyphase transformers by maintaining equal tap settings. Balance single-phase loads among phases to keep voltages within 1% of the average.

Be careful when connecting single-phase transformers to a three-phase system. If the load is large, a three-phase transformer should be used and the single-phase loads should be balanced.

Cooling oil in old transformers may contain polychlorinated biphenyls (PCBs). PCBs are hazardous, cancer-causing agents that must not be released into the environment. When replacing PCB-containing transformers take care to avoid spillage. Collect oils for recycling, incinerate at high temperature, or landfill in a secure, authorized area. Follow applicable safety and environmental protection standards for handling and disposal.

References

Knisley, Joseph R., "Controlling Building Noise with Good Electrical Designs," *EC&M*, Sept 1995.

Oak Ridge National Laboratory, *The Feasibility of Replacing or Upgrading Utility Distribution Transformers During Routine Maintenance*, (NTIS Order Number DE95002372), Oct 1972.

Wahlstrom, Randy, "Choosing Energy Efficient Transformers," *Energy Engineering*, Vol 92, No 5, pp 6-17.

Washington State Energy Office, *Keeping the Spark in Your Electrical System: An Industrial Electrical Distribution Maintenance Guidebook*, (WSEO 93-15), Olympia, WA, 1995.

There is a wide variety of energy-consuming devices in Federal buildings, some of which are only recently beginning to receive attention due to their power and water consumption. Office equipment, food service equipment, and laundry equipment have excellent potential for reducing energy consumption.

Action Moment

When selecting office, food, or laundry equipment, the facility manager may reduce energy consumption by opting for the high efficiency, high performance equipment described in sections 3.6.1 and 3.6.2.

Office electronics are the most rapidly growing consumer of electrical power in commercial buildings.

Technical Information

1 **Selecting energy-efficient equipment**—PCs, monitors, copiers, printers, and fax machines—and turning off machines when not in use can produce enormous energy savings. A typical PC operating 9 hours a day will use only 38% of the power consumed by a computer operating 24 hours. Power management devices on computers can reduce energy usage even further by turning down the power when the computer is unused. Copiers, laser printers, faxes, and other office equipment can save up to 66% of their 24-hour power consumption by keeping them on only during office hours.

2 **EPA's Energy Star program**, which began in 1992, was reinforced by a 1993 Executive Order that required all Federal agencies to purchase only Energy Star compliant computers. Computers in this program must have the capability of powering down to 30 watts after a user-controlled 15- to 30-minute delay.

3 **High-capacity, multistage dishwashing machines** are designed for medium to large food service operations, including hospitals, colleges, hotels, and restaurants. The multistage dishwashers reuse water from the two-rinse stages to prewash the dishes. In addition to water savings, these devices save considerable detergent and rinse additives. Due to the improved design of the dishwashers, dish breakage has been reduced.

4 **Prior to upgrading a kitchen, consider the following energy-efficient types of equipment:** infrared fryers; convection ovens (to include steamer models); microwave ovens; and specialized equipment, such as a pizza oven. Computerized controls can produce savings since they automatically time the cooking of certain foods. Energy-efficient exhaust hoods can provide significant savings because they use outside air rather than inside conditioned air for ventilation. Side curtains around cooking equipment help restrict the flow of conditioned air to the outside. Exhaust air can be used to pre-heat air for HVAC purposes or to pre-heat water.

5 **Microcomputers on newer model clothes washing machines** permit precise control of water temperature and cycles. Operate washers and dryers at full loads rather than partial loads in order to save energy.

6 **Laundry water temperatures should be reduced** to 71˚C (160°F) unless prohibited by codes. Some soaps and detergents will perform at even lower temperatures, and their use is encouraged. Water temperatures should be checked, with an accurate thermometer, and adjusted as needed.

Contacts

The EPA Home Page at http://www.epa.gov/docs/GCDOAR/es_office.html has information about Energy Star office electronics.

Tiller, D.K. and G.R. Newsham, "Switch Off Your Office Equipment and Save Money," *IEEE Industry Applications Magazine,* 2(4), 1996 pp. 17-24.

Office electronics are the fastest growing use of electricity in commercial buildings in the United States, with over 30 billion kWh of annual consumption valued at more than $2.1 billion. Users now have the option of installing energy-efficient office equipment that can potentially reduce the energy consumption of conventional equipment by 50%, at the same time reducing air conditioning loads, irritating noise from fans and transformers, and electromagnetic field emissions from monitors.

Action Moment

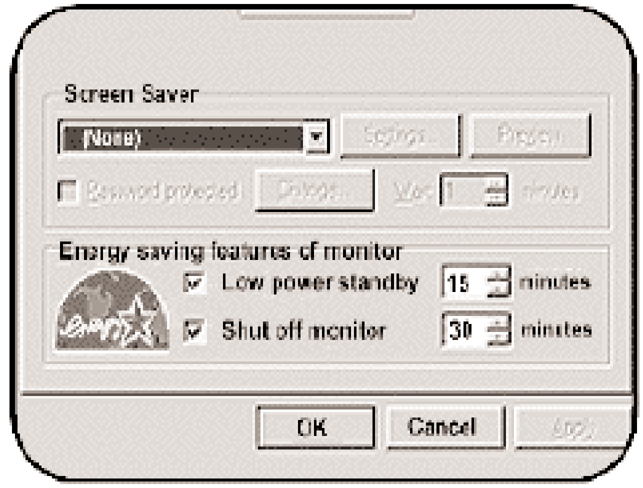
When new office equipment such as computers, monitors, copiers, or fax machines is purchased, be certain they are Energy Star-compliant as required by Executive Order 12845. DOE and EPA recently announced joint support for the Energy Star Programs.

Computers

To save energy used by computers, buy an Energy Star computer and Energy Star monitor, or a laptop. Laptops draw only 15 to 25 watts compared to the 150 watts used by a conventional, non-Energy Star PC/monitor. Buy monitors no larger than required. Energy Star computers save energy, provided the following requirements are met:

1 **The computer's energy management features must be activated**. Some computers are shipped in an activated state. Others require the user to enable the power management features.

2 **The computer and its network card must be compatible with the network**. The manufacturer must have tested it with the specific network type to which it is attached, or it may not work.



Energy Star monitors allow the user to set low power and power-off timing via software.

3 **The monitors must be capable of entering a low power state.** Monitors must be capable of being shut off by a Display Power Monitoring Signal (DPMS) signaling protocol, by a software utility, or by a special plug connected to the PC.

4 **"Universal" monitors** can both accept a DPMS from a PC, and run power management from a non-DPMS PC.

5 **The computer must be able to operate commercial software** both before and after recovery from a low power state. The manufacturer should supply information verifying this capability.

Turn computers off at night, on weekends, and during the day when they are not in use.

A 150-watt PC/monitor will cost $105 per year to operate if left on continually. Turning it off at night and on weekends will save $80 per year in energy costs. Turning it off when not in use during the day can save another $15 per year.

Printers/Facsimile Machines

1. **Rather than buying one printer per worker**, use a network or printer-sharing switch to allow laser printer sharing.

2. **To reduce printer use**, implement paper reduction strategies and use e-mail.

3. **Although older Energy Star printers required a delay time to return to print mode**, newer models return to operating mode immediately from low power mode.

4. **Fax machines now have Energy Star ratings** which, through their lower standby energy use, reduce power consumption by 50%.

5. **Use plain-paper fax machines to save money**. Also, thermal fax paper is not acceptable in typical paper recycling programs.

6. **Use e-mail or direct computer faxing** instead of paper-faxes whenever possible.

DOE-EPA's Energy Star Printer, Fax and Printer/Fax Combination Requirements.

Printer/Fax Speed (pages/minute, ppm)	Average Watts in Low Power Mode	Printer Default Time (min)	Fax Default Time (min)
0<ppm<7	15	15	5
7<ppm<14	30	30	5
ppm>14 and high end color	45	60	15

Copiers

1. **Copiers use more energy** than any other piece of office equipment. Be sure to buy an Energy Star copier and be sure it is sized correctly for the job.

2. **Again, use e-mail,** web sites, and "paperless faxing" where possible.

3. **Double-sided copying** is an important energy- and paper-saving feature. Try to use paper with a high recycled content.

4. **Copying in batches** significantly reduces energy consumption because the printer spends far less time in high-power mode.

DOE-EPA's Energy Star Photocopier Program (Tier 2) — Effective 1997

Copier Speed copies per minute (cpm)	Low Power Mode (watts)	Recovery TIme (30 seconds)	Off Mode (watts)	Off Mode Default Time	Automatic Duplex Mode
0<cpm<20	none	no	<5	<30 min	no
20<cpm<44	3.85 x cpm + 5	yes	<10	<60 min	optional
cmp>44	3.85 x cpm + 5	recommended	<15	<90 min	default

References

Tiller, D.K. and G.R. Newsham, "Switch Off Your Office Equipment and Save Money," *IEEE Industry Applications Magazine*, 2(4), 1996, pp 17-24.

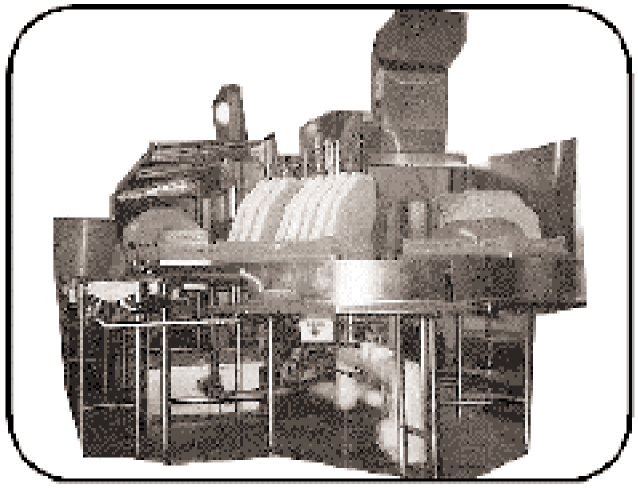
Contacts

The EPA Home Page at http://www.epa.gov/docs/GCDOAR/es_office.html has information about Energy Star office electronics.

Food service and laundry equipment can be among the heaviest consumers of energy and water. New types of high-capacity, multistage dishwashing machines, high-efficiency refrigerators, and other equipment provide significant opportunities to save resources and money. In each case, heat recovery systems can be used to capture waste energy from appliances and use it to pre-heat air for HVAC purposes or to pre-heat water.

Action Moment

When replacing food service and laundry equipment, choose energy-efficient models and units that incorporate waste heat recovery.



New commercial dishwashers reduce water, energy, and labor requirements

Dishwashers

New high-capacity, multistage dishwashing machines are designed for medium to large food-service operations including hospitals, colleges, hotels, and restaurants. In addition to reducing water usage and load requirements, manpower requirements are reduced by 50%.

1 **Multistage dishwashers** reuse water from the two rinse stages to prewash dishes. In addition to water, these devices save considerable detergent and rinse additives. Due to their improved design, breakage is also significantly reduced.

2 **Some dishwasher models** are available with an optional power scraper that removes caked-on, dried food. This can be particularly useful when there is a significant time lag between use and washing.

3 **Typical throughput** of dishes in a high-capacity, multistage washing machine is 3,500 to 3,700 dishes per hour, with a conveyor speed of 5 to 6 feet per minute.

$ **A recent DOD cafeteria installation** of the new multistage dishwashing equipment cost $57,800. The result was a water reduction of 500,000 gallons per year, saving $2,000 per year. Manpower savings were $19,000 per year. The payback time for this installation was 2.7 years and it will save almost $500,000 over its 25-year projected life.

Refrigerators and Freezers

In commissaries, up to 50% of energy consumption can be due to refrigerators and freezers.

1 **Refrigerators and freezers** are divided into medium-temperature (MT) systems (down to 20˚F) and low- temperature (LT) systems (down to -25˚F).

2 **New equipment is available** with EERs of 7 to 9 for MT systems and 5 to 6 for LT systems. Replace old, inefficient systems with high-efficiency, new systems to obtain significant savings immediately.

Relying on refrigerator cases to cool the interior of a space is not very useful, as HVAC systems typically have EERs of 10 to 12 versus the 5 to 9 for refrigeration equipment. This translates to a difference of 40% in energy use. Air spillage from the refrigeration equipment to the space should be minimized.

Product literature is clearly very important to insure proper operation of refrigerators and freezers. Some of the causes of excessive energy use by these devices are: controls set too low; doors that do not close properly; and worn/torn gaskets. An accurate thermometer is needed to check existing temperature conditions. Cleaning condenser heat transfer surfaces to remove dirt and scale is very important for proper and efficient operation. Overloading the unit may result in over- or under-cooling the stored product.

Cooking Equipment

The key ways to save energy when using cooking equipment are: (1) turn equipment off when not in use; (2) use a temperature no higher than necessary; (3) match the equipment to the job; and (4) cook as efficiently as possible. This latter step includes adjusting flames on ranges to just touch the bottom of cookware, avoiding unnecessary oven door openings; cooking foods with the same requirements simultaneously, and cooking in volume.

When upgrading a kitchen, consider the following energy-efficient types of equipment: infrared fryers, convection ovens (including steamer models), microwave ovens, and specialized equipment. Specialized equipment, such as pizza ovens, are designed to cook specific foods very efficiently. Computerized controls can also produce savings, since they automatically time the cooking of certain foods.

Energy-efficient exhaust hoods can provide significant savings because they use outside air rather than inside conditioned air for ventilation. Side curtains around cooking equipment can help restrict the flow of conditioned air to the outside. Exhaust air also can be used to pre-heat air for HVAC purposes or to pre-heat water.

Laundry Equipment

Microcomputers on newer-model laundry equipment permit precise control of water temperature and cycles.

Using equipment efficiently means ensuring that washing machines and dryers are operated at full loads rather than partial loads.

Laundry water temperatures should be reduced to 160^{O}F, unless prohibited by code. Some soaps and detergents perform at lower temperatures and should be used where appropriate. Temperatures should be checked with an accurate thermometer and adjusted as needed.

To reduce energy use of clothes washers and dishwashers: repair leaks; insulate storage tanks and distribution piping; clean sediment out of equipment; and test/tune up water-heating components.

Horizontal-axis washing machines, very popular in Europe, are extremely energy and water efficient. Only recently have American manufacturers begun to produce this type of equipment. Investigate procuring this type of machine when in the market for clothes washing equipment.

References

American Council for an Energy Efficient Economy (ACEEE), *The Most Energy-Efficient Appliances —1996 Edition,* Washington, DC.

Hot water is used in Federal facilities for hand washing, showering, janitorial cleaning, cooking, dishwashing, and laundering. Facilities often have significant hot water needs in one or more locations, and many smaller needs scattered throughout the facility. Methods for reducing the energy used to generate hot water include: maintaining equipment and insulation; reducing hot water use and water temperatures; reducing heat losses from the system; and utilizing waste heat sources and appropriate technologies, including solar water heating.

Solar thermal water heating can meet hot water demand at very low operating cost. Flat plate collectors are in the middle of the photo. Also shown are PV panels on the flat portion of the roof.

Action Moment

Reduce demand first through efficiency measures and by matching the water temperatures to the task. Then, consider heat source and new equipment to lower operating costs further. Installing higher-cost, new water-heating technologies, such as waste heat recovery, is often done in conjunction with air conditioning equipment changes. Plan ahead and select a technology for use in the event the existing system fails.

Water Heating Technologies

Several water-heating technologies are listed below.

1 **Solar thermal water heating** captures the energy from the sun for heating water. Direct systems circulate domestic water directly into the panels. Indirect solar systems use heat exchangers and food-grade antifreeze solutions to eliminate freeze damage and hard water scaling of the panels.

2 **Standard electric water heaters** store electrically heated water in insulated storage tanks. Many older tanks have poor insulation compared to today's standards and should be replaced or jacketed externally with additional insulation.

3 **Tankless electric or on-demand electric heaters** eliminate standby losses by heating water only during use. They are located at the point of use, and are convenient for remote areas having only occasional use. However, they can increase electrical power demand charges if hot water is used during peak periods of the month.

4 **Steam-fired water heaters** utilize centrally produced steam for heating water. These units are popular in commercial kitchens where steam is also used for cookers. Where boilers must be kept operating during summer months to supply small amounts of steam for kitchen purposes, changing to alternative water heating would be extremely cost effective.

5 **Standard gas-fired water heaters** use natural gas or propane burners located beneath storage tanks. Standby losses tend to be high because internal flues are uninsulated heat-exchange surfaces.

6 **Condensing gas water heaters** are extremely efficient gas units that capture the latent heat of vaporization from the combustion gases. Flue gases are cool enough to permit venting with special PVC pipe.

7 **Tankless gas water heaters** are installed at the point of use. These on-demand heaters may be good options for remote sites where there is adequate gas piping, pressure, and venting.

8 **Air-source heat pump water heaters** are specialized vapor-compression machines that transfer heat from the air into domestic water. Commercial kitchens and laundries are excellent opportunities because both indoor air temperatures and hot water needs are high. In the process of capturing heat, the air is both cooled and dehumidified, making space conditions more comfortable. Air-source heat pumps are only recommended if the air source is warm with waste heat.

9 **Water-source heat pump water heaters** are dedicated heat pumps that heat domestic water from energy captured from a water source. The heat source may be groundwater that is used for its stable year-round temperature, or a low-grade waste heat source at a temperature lower than the desired domestic water temperature.

10 **Waste heat water heaters**, also known as desuperheaters, are connected to air conditioners, heat pumps, or refrigeration compressors. Hot refrigerant gas from the compressor is routed to the gas side of the unit's heat exchanger. Water is essentially heated for free whenever the air conditioner, heat pump, or refrigerator compressor is operating. When a waste heat water heater is connected to a heat pump that is operating in heating mode, some of the heat pump's capacity is devoted to water heating.

Insulate tanks and hot water lines that are warm to the touch. Only recently have manufacturers installed adequate amounts of insulation on water tanks. Hot water lines should be continuously insulated from the heater to the end use. Cold water lines also should be insulated near the tank to minimize convective losses.

Limit operating hours of circulating pumps. Large facilities often circulate domestic hot water to speed its delivery upon demand. Both the cost of operating the pump and heat losses through pipe walls will be reduced.

Install heat traps. Heat traps are plumbing fittings that cut convective heat losses from water storage tanks.

Install hot water heaters near the points of most *frequent* use to minimize heat losses in hot water pipes. This location will not necessarily be where the most hot water is used.

Eliminate hot water leaks. Delays in repairing dripping faucets often lead to more expensive repairs. Failure to replace faucet washers promptly will cause metal-to-metal contact between the valve stem and valve seat.

Repair hidden waste from failed shower diverter valves that cause a portion of the water to be dumped at a user's feet. This leakage is usually not reported to maintenance teams.

Reduce hot water temperature. Temperatures can be reduced to 60°C (140°F) for cleaning and laundering.

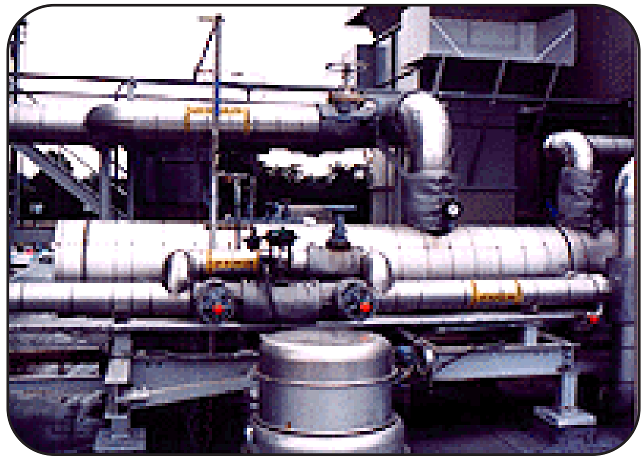
Low-flow fixtures. Some low-flow showerheads and faucets atomize water into tiny droplets, making warm water feel cold. Only purchase, quality low-flow heads that fully drain when off. These types have high user acceptance.

Water tank. Turning down the hot water temperature below 120°F (49°C) for conservation may cause indoor air quality problems by allowing Legionella to grow inside domestic water tanks.

Contacts

The FEMP Help Desk at (800) DOE-EREC can provide many publications about energy-efficient water heating.

Heat recovery is the capture of energy contained in fluids or gases that would otherwise be lost from a facility. Heat sources may include heat pumps, chillers, and steam condensate lines, and even hot air associated with kitchen and laundry facilities. Heating water for domestic use offers the best waste heat recovery opportunities under the following conditions: (1) hot water demand must be high enough to justify equipment and maintenance costs; and, (2) waste heat must be of high enough temperature to act as the heat source.



Heat recovery captures heat that would otherwise be lost to the environment.

Action Moment

Large facilities such as hospitals and military bases often have the perfect mix of waste heat and demand for hot water to justify using waste heat recovery systems for water heating. Consider waste heat recovery whenever adding or replacing large heating or air conditioning equipment. For example, double-bundle chillers can easily provide for the recovery of heat normally lost to a cooling tower.

Technical Information

Opportunities for capturing waste heat depend upon the temperature of the waste heat source. Where a water temperature of 60˚C to 82˚C (140°F to 180°F) is required for domestic applications, waste heat sources with higher temperatures should be used. Lower-temperature sources such as hot kitchen air or drain water may require mechanical systems to concentrate the heat. Otherwise the waste heat may be used to pre-heat the water before another fuel is used to elevate the temperature to the desired level.

1 **Hot gas heat exchangers**. The refrigeration cycle of air conditioners and heat pumps provides an opportunity to capture heat for heating domestic water. HVAC compressors concentrate heat by compressing a gaseous refrigerant. The resultant superheated gas is normally pumped to a condenser for heat rejection. However, a hot gas-to-water heat exchanger may be placed into the refrigerant line between the compressor and condenser coils to capture a portion of the rejected heat. In this system, water is looped between the water storage tank and the heat exchanger when the HVAC system is on. Heat pumps operating in the heating mode do not have waste heat because the hot gas is used for space heating. However, the heat pump system can still heat water more efficiently compared to electric resistance heating.

2 **Double-bundle condensers**. Some chillers have condensers that make water heating with waste heat recovery possible. Double-bundle condensers contain two sets of water tubes bundled within the condenser shell. Heat is rejected from the system by releasing superheated gas into the shell and removing heat as the refrigerant condenses by one of two methods. During the heating season, water pumped through the “winter bundle” absorbs heat where it is used for heating domestic water or heating the perimeter of the building. During the cooling season, water pumped through the “summer bundle” rejects heat to the cooling tower after hot water needs are met.

3 **Heat from engines.** Heat exchangers can be placed on exhausts of reciprocating engines and gas turbines to capture heat for water heating or steam generation. Water jackets may also be placed on engines in order to capture heat from the engine and exhaust in series. Some equipment also acts as a silencer to replace or supplement noise reduction equipment needed to meet noise requirements. Systems for domestic heating are unpressurized, but temperatures above 99°C (210°F) are possible with pressurized systems. Designers must be careful that the pressure drop is less than the back pressure allowed by the engine manufacturer.

4 **Heat from boiler flues**. Hot flue gases from boilers can provide a source of waste heat for a variety of uses. The most common use is for pre-heating boiler feed water. Heat exchangers used in flues must be constructed to withstand the highly corrosive nature of cooled flue gases.

5 **Hot drain heat exchangers**. Energy required to heat domestic water may be reduced by pre-heating with drain water. Kitchens and laundries offer the greatest opportunities for this type of heat recovery since water temperatures are fairly high and schedules are predictable. These systems must be designed to filter out waste materials and ensure the heat exchange are not fouled by the dirty waste water.

6 **Steam condensate heat exchangers**. Buildings with steam systems for space heating or kitchen facilities may recover some of the heat contained in hot condensate. Condensate is continuously formed in steam systems when steam loses heat in the distribution lines or when it performs work. A condensate receiver reduces steam to atmospheric pressure to allow reintroduction into the boiler. A heat exchanger located in the condensate return before the receiver can capture condensate heat for heating water.

7 **Heat pump water heaters**. Rooms containing laundries and food preparation facilities are often extremely hot and uncomfortable for staff. Heat from the air can be captured for heating water by using a dedicated heat pump that mechanically concentrates the diffuse heat contained in the air. These systems are discussed in section 3.7.

8 **Refrigeration equipment**. Commercial refrigerators and freezers may be installed with condensing units at one location. This will enhance the economic feasibility of capturing heat from hot refrigerant gases for water heating.

References

Center for the Analysis and Dissemination of Demonstrated Energy Technologies, "Heat Exchangers in Aggressive Environments," Analysis Series # 16, 1995.

Heating water using the sun's energy is a renewable technology that is practical in almost any climate. In many parts of the United States, solar systems can meet the total hot water demand during summer months. In the winter and other times when collection rates are lower than hot water demand, alternative heat sources supplement solar heating.

Action Moment

Solar water heating should be considered to replace electric water heating when water demand is both high enough to justify initial costs and fairly constant throughout the week. Good candidates are laundries, hospitals, dormitories, gymnasiums, prisons, and other regularly-used shower facilities. Swimming pools are good summer season applications for solar water heating systems.

Solar water heating is a proven technology that directly substitutes renewable energy for conventional water heating. This array of parabolic trough collectors was paid for through an Energy Savings Performance Contract (ESPC).

Technical Information

Solar thermal water heating systems come in various configurations suited for different climatic zones and applications. The two basic components are collectors, usually mounted on the roof or ground, and an insulated storage tank. Active systems contain mechanical pumps for circulating the collection fluid which is either plain water, or water containing antifreeze. Passive systems do not have pumps. There are three basic configurations:

1 **Passive systems** do not use pumps or other mechanical devices, have relatively inexpensive maintenance requirements, and can be used in sun belt areas where freeze protection is a modest concern. Circulation relies on the buoyancy of warm water rising from the collector to the tank, which is always located above the collector. Heat pipes—sealed tubing systems containing refrigerant— can also be used for heat transfer from panel to tank. The storage tank may be located remotely from the collector (thermosyphon systems) or as part of the panel (integral collector/storage—ICS). With ICS systems, roof structures must be strong enough to support the weight of water-filled collector tanks.

2 **Direct or "open loop" systems** are simple, very efficient, and suitable for mild and moderate climates with good water quality. In direct systems, water ultimately consumed by the end users is heated directly in the collector. Some systems make clever use of photovoltaic-(PV) powered direct-current pumps sized to adjust the flow of circulating fluid to sunlight conditions. Damage to collectors is a concern if water is hard or corrosive. Also, direct systems must be protected from freeze damage. Direct Systems are especially applicable to swimming pool water heating.

3 **Indirect or "closed loop" systems** are dependable and suitable for all climates. Indirect systems circulate nontoxic antifreeze through the closed "solar loop" consisting of the collector, piping, and heat exchanger located at the storage tank. Antifreeze in the collector and exposed piping ensures protection from freeze damage, corrosion, and scaling in the collector. Like direct systems, indirect systems may use PV-powered pumps.

Freeze protection strategies should be provided in all but tropical climates, there are four basic strategies:

1. In **Drainback Systems**, water from collectors and exposed piping drains into a reservoir whenever the circulating pump is turned off. This provides reliable freeze protection even when electrical power fails.

2. **Draindown Systems** dump water from a collector onto the ground or into a drain when triggered by near-freezing temperatures. They also may be manually drained in case of power failure during freezing. Draindown systems historically have been the least reliable.

3. **Recirculation Systems** utilize warm water from the storage tank to circulate into the collectors during freezing weather. They should be considered only in mild climates.

4. **Indirect Systems containing antifreeze** are reliable for use in any climate and are very effective at avoiding freeze damage.

Collectors for domestic water heating are available in three basic types:

1. **Flat plate collectors** are the most common and consist of insulated rectangular frames containing fluid-filled tubes mounted on dark-colored absorber surfaces. Highly transmissive tempered glass covers the absorber.

2. **Evacuated tube** collectors utilize a tube-within-a-tube design similar to a thermos bottle. A vacuum between the fluid-filled inner tube and glass outer tube allows maximum heat gain, minimum heat loss, and very high temperature potential.

3. **Parabolic-trough collectors** are efficient but can be expensive. Their most cost-effective use is in large systems such as those found in prisons where their cost is less than the cost of flat plate collectors. Long, parabolic-shaped mirrors track the sun and focus its light onto centrally located fluid-filled tubes. Because the sunlight is focused, diffuse light cannot be used, making this a poor choice for humid climates.

Solar systems should be tested and certified by independent groups such as the Solar Rating and Certification Corporation (SRCC) or the Florida Solar Energy Center (FSEC).

Colder climatic zones require the use of more collector area and the use of indirect systems having superior freeze-protection capabilities.

Removing trees to accommodate sunlight access for solar collectors may be a net energy loser if there is substantially more heat gain though exposed windows when air conditioning.

At times of the year when collectors harvest sunlight very efficiently, water temperatures may be above 60˚C (140˚F). Ensure that mixing valves are installed to keep users from being scalded.

On direct systems, collectors may require periodic treatment with a nontoxic solution, such as diluted vinegar, to remove scaling buildup that inhibits heat transfer and efficiency.

The economics of installing solar water heating depend on the cost of alternative fuels such as electricity. Hot water demand, patterns of usage, and availability of solar energy are also key considerations. Retrofitting solar water heating into existing buildings is complicated by the need to provide access for running pipes and space in mechanical rooms for larger storage tanks. Solar water heaters can provide 40% to 80% of the annual hot water needs.

References

Department of Energy, Federal Energy Management Program, "Solar Water Heating," *Federal Technology Alert,* Washington, DC, Sept. 1995.

Contacts

The FEMP Help Desk at (800) DOE-EREC or at http://eren.doe.gov/femp can provide technical assistance and information about financing via Energy Savings Performance Contracting.

Appropriate control systems allow facility managers to automate functions that would be impractical or impossible to control manually. Automatic systems are useful with lighting, air distribution systems, chillers, boilers, heat pumps, pumping systems, compressed air systems, water heating, and other major energy-consuming equipment. Controls may be simple and inexpensive, or complex and costly. Simple controls, including time clocks, occupancy sensors, photocells, and programmable thermostats are discussed in this section. More sophisticated computer-based energy management systems (EMS), that monitor hundreds or thousands of "points" throughout a facility, are discussed in section 3.8.1. Some control systems designed to reduce peak electrical demand and lower utility bills are presented in section 3.8.2.

Action Moment

Facility managers should consider automatic controls and sensing technology when equipment can be turned on, shut off, or modulated based on schedules, temperatures, pressures, light levels, or the presence of occupants. HVAC and lighting are prime candidates for automatic controls.

Technical Information

The following is general information about some of the common controls available to help reduce energy consumption.

1 **Time clocks** are electrical or electromechanical devices that can turn equipment on and off according to a schedule. Small loads can be switched directly and large loads can be controlled indirectly through the use of relays. Many time clocks are 24-hour devices that repeat programs every day. Some have weekly and even annual wheels that allow more complex programming patterns. Although it will minimize wiring costs, locating time clocks near the circuits they control is not necessary.

2 **Occupancy sensors** detect the presence of people by sensing heat (infrared), motion (ultrasonic), or sound. Some systems directly control small lighting loads at line voltage and directly replace wall switches. Others are part of systems that may include several sensors, control logic, and interface to the load. These types of sensors are discussed in section 3.4.4 of this guide. Facilities with EMSs may use occupancy sensors to control lights and HVAC operations that have complex programming involving many functions.

3 **Programmable electronic thermostats** allow facility managers to reset heating and cooling setpoints for different operating modes. Daytime, nighttime, and weekends typically have different target temperatures in order to allow the building temperature to drift appropriately when unoccupied.

4 **Spring-wound timers** are simple devices that automatically turn off loads after a predetermined number of minutes or hours. They can be used to control bathroom exhaust fans allowing them to remove moist air after showering, and preventing continuous operation.

5 **Photocells** are devices that open and close switches in response to light levels. Some photocells are not very sensitive to low light at dusk and dawn. They may switch lights on in the evening before they are needed. This wastes energy, and in some cases, demand charges will also be higher.

Power outages disrupt schedules of electromechanical time clocks because the time setting is lost. Daylight savings time shifts also require resetting the time. Consider solid-state time clocks with rechargeable batteries.

Standard time clocks usually do a poor job of controlling exterior lights because they lose the current time when time changes or power fails. Simple time clocks do not account for daily changes in sunset and sunrise.

EMS systems can be prone to problems with electrical power quality, particularly during power outages.

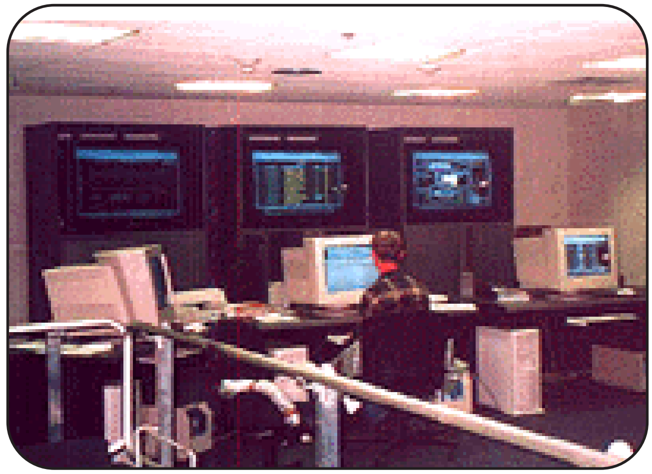
To avoid injury, signs indicating the control mechanism and disconnect switches should be placed near equipment under automatic control.

When purchasing programmable thermostats made for use with heat pumps, ensure they have "ramped recovery" features for heating. Ramped recovery slowly brings the building up to the target temperature without engaging the supplementary electric strip heating.

Facility managers should document all the automatic controls in their facilities. They should record: the locations of the controls; the equipment they control; and the need for resetting the time or program as seasons change, as time changes for daylight savings, or after power outages.

Electrically combining time clocks and photocells may provide a good way to program the needed exterior lighting logic, such as "on at sunset, off at 10:00 P.M." Facilities with EMSs should be able to implement this type of software logic.

Energy management systems (EMSs) improve efficiency by monitoring conditions and controlling energy-consuming equipment. An EMS is typically applied to the largest electrical loads, including HVAC equipment, cooling towers, pumps, water heaters and lighting. Control functions may include basic stop/start functions or more complex chiller optimization routines. An EMS can be used on new or existing facilities and can interface with existing controls, such as pneumatic damper actuators. EMSs typically reduce the cost of doing business by reducing labor costs. EMSs can have very favorable paybacks, especially where existing control systems are lacking or have problems. By tracking system operation using an EMS, a facility manager can perform diagnostics and optimize system performance.



Energy Management and Control Systems can monitor and control equipment throughout a facility from a single location.

Action Moment

Facility managers should consider installing an EMS system in any facility expansion. EMS retrofits are often justified in existing buildings, and can involve improving chiller or boiler controls, adding economizer cycles, controlling lighting loads, and limiting electrical demand. An EMS can be particularly reliable for very large or widely dispersed facilities.

Technical Information

An EMS can perform various functions, from simple single-point control to multifunction systems with complex decision logic. Fully functional EMSs provide the greatest potential for maximum energy and cost savings.

1 **Hardware varies in complexity.** Simple systems include actuators that switch or change loads according to signals from local controllers that contain control logic. More sophisticated systems add sensors or monitoring points, field termination panels for minimizing control wiring, modems, communication links, and central computers. Software often includes user interfaces that graphically depict equipment, sensors, and controls.

2 **Distributed or networked systems** combine the reliability of local controllers with the advantages of facility-wide monitoring. Centralized control provides facility engineers an immediate interface with remote equipment, and allows quick diagnosis of problems and quick response to complaints.

Functional Capabilities

Many scheduling, optimizing, and reporting functions are available on EMSs:

1 **Start/stop controls** will limit operating hours of equipment according to predetermined schedules.

2 **Optimum start/stop** controls delay bringing equipment on-line until the latest possible time. This is particularly useful in limiting HVAC operation.

3 **Temperature setback/setup** saves energy by allowing building conditions to drift within limits during unoccupied periods.

4 **Economizer controls** turn off chillers during mild weather and allow outside air to provide space conditioning.

5 **Enthalpy control** provides more sophisticated economizer control that is based on both temperature and humidity.

6 **Supply temperature reset** modulates circulating water temperature based on load sensors and program logic.

7 **Boiler optimization** balances fuel and combustion air with heating load variations.

8 **Duty cycling** can help reduce utility peak demand charges by turning off equipment a predetermined percentage of the time.

9 **Demand limiters** shed nonessential equipment such as water heaters to reduce peak power demand to a preset level.

10 **Alarm functions** alert operators to conditions outside pre-established ranges.

11 **Monitoring** provides the capability to track: (1) equipment run-time and other parameters for proactive maintenance; and, (2) energy use for cost containment.

12 **Load management controls** stage the start-up of large equipment to avoid power peaks.

Train key employees to use the EMS once it is installed.

Have a qualified engineering firm design specifications before bidding any EMS.

Require the vendor to fully demonstrate the system and all software before delivery. Videotape the demonstration and training for use during refresher training.

Design expansions of EMSs to utilize a single user interface system in order to avoid confusing the operators.

New EMS systems will not necessarily interface properly with existing controllers and other components intended to remain in place.

Be careful with "custom built" systems. Purchase proven systems and software with a good track record. Request systems with open protocols to improve compatibility with future systems.

Reliance solely on the EMS console can lead to misdiagnosis. For example, a temperature alarm would prompt the operator to check position of the VAV damper for that zone. If the sensor indicated that the damper was full open and yet the zone was too hot, the operator might reset the chilled water temperature. However, the combination of a stuck damper (cutting off airflow) and a loose damper shaft (allowing the control system to believe the damper is operating normally) might be the real problem. This situation could easily fool both the control system and the operator.

Use in-house staff for day-to-day service requirements, provided staff is adequate and well trained. Service contracts can be very expensive and should be used only when absolutely necessary.

Sensors should be checked and calibrated on a regular maintenance schedule. Failed sensors and false readings can waste considerable energy.

References

Electric Power Research Institute, "Energy Management Systems," (Technical Brief TB.EMU.121.4.87), Palo Alto, CA (510) 934-4212

Peak Shaving 3.8.2

Utility bills for large facilities include demand charges that can amount to one-third of monthly electricity costs. Demand is measured in kilowatts and is the average electrical load over a small period of time, usually 15 or 30 minutes. Facilities are billed for the largest peak demand during the billing period. Electrical demand peaks can be lowered in several ways: shedding unneeded loads, rescheduling loads, staging equipment start-up, generating power on site, or switching to another fuel.

Action Moment

Facilities with low load factors or steep load-duration curves are the best candidates for cost-effective peak shedding. Facilities already using energy management systems (EMSs) may have most of the hardware and software needed to institute a load shedding program.

Technical Information

Utility tariffs usually encourage demand control and load shifting. Facility managers should understand how their facilities are charged for power and energy. Three elements to examine are as follows:

1 **Demand charges** are based on the highest monthly power peak, measured in kilowatts (kW). All but the smallest facilities will be billed for demand. This charge reflects the electric utility's infrastructure cost of power generation and transmission and the more expensive fuels used in peaking units. Summer-peaking utilities tend to have higher summer demand changes, and winter-peaking utilities have higher demand charges during winter months.

2 **"Demand ratchets"** are minimum demand bills based on some percentage of the highest peak power metered over the preceding year. Thus, one month's high demand can impact monthly charges for an entire year.

3 **Time-of-Use (TOU) tariffs** offer discounted rates for power used at times the utility establishes as off-peak. The difference in energy charges (kWh) between on-peak and off-peak power can be a factor of two to four.

Thermal storage on HVAC systems is effective at cutting peak electrical demand.

Demand shedding or peak shaving strategies include: purchasing smaller, efficient equipment; altering the on-times of existing equipment; switching fuels at peak times; and generating power on-site. Some popular strategies are listed below:

1 **Duty cycling** strategies attempt to limit the operation of equipment to certain times within a utility's demand period. Duty cycling has limited application because of stresses on frequently cycled equipment, and the effect on the building or its systems. For instance, duty cycling of cooling tower motors would allow the chilled water temperature to rise. Cycling a ventilation fan might compromise indoor air quality or adversely affect building pressures.

2 **Demand limiters** shed loads in a pre-established order when demand targets are about to be exceeded. There are two main algorithms used: simple, and predictive or slope-sensitive. Simple demand limiters can result in undesirably high load-shedding frequencies and cannot control demand closely.

3 **Generators** can be used to keep equipment operating while off grid. If the same generators provide emergency backup power, precautions must be taken to ensure emergency power availability even during peak periods. If critical loads also contribute to facility peaks, consider shifting these loads to generator power during peak periods.

4 **Dual-fuel heating and cooling** equipment can provide nonelectric means of meeting space-conditioning needs during times when using electricity would be expensive. For example, hybrid cooling systems, fueled by either natural gas or electricity, can dramatically lower electricity demand by using natural gas at peak hours.

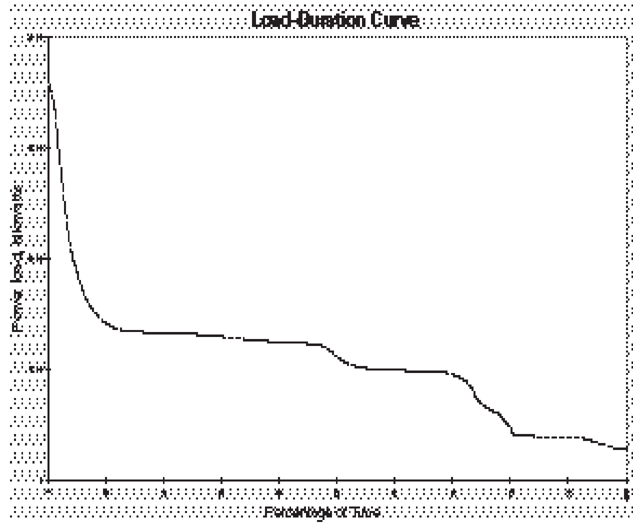
5 **Battery storage** may not yet be cost-effective for peak reduction in most situations unless batteries are in place for other purposes. One example of where battery storage may make sense is for off-peak charging of forklifts used during daylight hours.

6 **Thermal storage** involves storing thermal capacity generated off-peak for on-peak use. During the peak periods of the day, circulating water is cooled by ice baths or chilled water tanks instead of chillers to provide space or process cooling. Heat storage is not as common as ice storage because of the extra volumes needed to store thermal energy without phase changes.

7 **Dispatchable load shedding** is a direct load-control technique, where the utility controls when a customer's equipment is shed under a prearranged agreement. Such arrangements can benefit both parties and justify on-site generation or alternative fuels.

8 **Cogeneration** of electricity and steam from gas turbines may be cost-effective for large facilities.

Facilities with steep load-duration curves are well suited for application of peak-shaving technologies. Load-duration curves, such as the one shown, are generated by sorting electrical loads recorded for each hour of the year. Data may be available from the electrical utility or from the facility's energy management system.



High Loads, occurring only a small percentage of the time, can lead to very large demand charges.

With the use of dimmable lighting ballasts, both lighting and subsequent chiller loads can be reduced. Allowing the HVAC to drift slightly is another effective strategy. According to ASHRAE, one-hour excursions out of the standard comfort envelope will be unnoticeable to most occupants.

Track load factors each month to check the utility's demand charges. The formula to calculate load factor (LF) is shown below. Load factors greater than 100% are impossible and indicate metering or billing problems. Load factors that suddenly deviate from historical values also indicate problems. If problems are found, recheck the billing information and contact the utility.

$$\frac{\text{Monthly kWh}}{\text{Monthly peak kW} \times 24 \times \text{\# days in billing period}}$$

If the facility has a high minimum-demand billing, check if the utility has a "ratchet release" provision to reset the minimum demand to a lower level based on measures implemented by the facility.

The building shell can be considered the primary component of any facility since it is the protective skin that allows both a controlled environment and protection for the building occupants. Consisting of the building's skin, roof, windows, and doors, the shell controls the flow of energy between the interior and exterior of the building. Facility managers have limited ability to change most of these components on a routine basis. However windows and insulation are two factors that can be readily upgraded as a strategy in routine building improvements. Reducing outside air infiltration into the building by improving building tightness should be one of the strategies used to conserve energy.

Action Moment

When reroofing or renovating spaces, be sure to determine if there is an opportunity to upgrade windows, doors, or insulation. Reducing infiltration may be possible during routine maintenance or when remodeling occurs.

Properly placed automatic doors and vestibules can reduce unwanted air leakage in buildings. Ensure the outdoor areas where people congregate, such as smoking areas, are not within electronic "view" of the automatic controls.

Windows

1 **Glazing systems present** an excellent opportunity for energy savings. The strategy will vary greatly as a function of the location of the facility. In hot climates, the primary strategy is to control thermal radiation by keeping solar energy from entering the interior space while allowing visible light through for daylighting. Solar screens that intercept solar radiation, or films that prevent infrared transmission while allowing good visibility, are useful for hot climates.

2 **In colder climates,** the focus shifts from keeping solar energy from entering the space to reducing the interior conduction of energy from the warm to a very cold exterior. Windows with two or three glazing layers that utilize low-emissivity coatings will minimize conductive energy transmission. Filling the spaces between the glazing layers with an inert low-conductivity gas, such as argon, will further reduce heat flow.

3 **Fenestration can be a source of discomfort** when solar gain and glare impact at the work station or other occupant zones. Daylighting benefits will be negated if other factors force occupants to use blinds, for example, to control unpleasant impacts.

4 **Facility managers should choose appropriate window technology** that is cost-effective for the climatic conditions. For example, double-glazing may be inappropriate in South Florida where solar films are the technology of choice. However, double-glazing is cost effective for the middle and northern latitudes of the United States.

5 **In cold climates** make sure that the frame is designed to prevent condensation. Both the frame and sash should have thermal breaks.

Walls and Roofs

For buildings with a primary cooling load, exterior finishes that have high reflectiveness and wall-shading devices reduce the solar radiation load, and consequently the HVAC load. Reflective finishes for the roof will help reduce loads because the roof is exposed to sun loads for the entire operating day. Metal, concrete tile, concrete shingle, aluminum shingles, and single-ply roofing systems are all available in reflective colors at no additional cost.

1 **Wall shading** can significantly reduce thermal loads on the envelope through roof overhangs, sun shades, or a canopy of mature trees.

2 **Light-colored roofs** have a beneficial effect in areas where cooling is the predominant air-conditioning requirement.

3 **In new construction**, a well-designed building envelope can significantly reduce the need for space conditioning, resulting in both initial and operating cost savings for the HVAC sys-

Insulation

1 **Insulation for most commercial buildings** is difficult to upgrade without expensive building modifications. Exterior finish insulation systems (EFISs) (insulation and exterior finish) can be added externally to some buildings to both increase the thermal resistance of the building shell and to improve the building's appearance.

2 **In cooling latitudes**, the addition of insulation has positive impacts on air conditioning to a point, and diminishing returns thereafter. Roofs and attics should receive priority attention for the addition of insulation, particularly during roof replacement.

Insulation is a guideline item under RCRA §6002 and should be purchased with recycled content.

Windows allow for daylight, winter solar gain, natural ventilation, and views. Glazing units are often the weakest point in the building envelope, thermally as well as acoustically. Types of glazing include clear, tinted, reflective, spectrally-selective, low-emissivity (low-e), Heat Mirror ®, electrochro-mic, photochromic, thermochromic, photovoltaic, and transparent insulating. Window units with air, gases, and films within multiple panes are also available. Glazing units can be vertical, sloped, roof monitors, and skylights. High quality windows provide important comfort benefits in addition to energy savings.

Action Moment

Renovations afford opportunities for replacing older, clear, and single-glazed windows. A window retrofit always can be considered independently of other building changes. Improving the energy efficiency of windows without replacing the window units can be done at any time by adding shading devices and storm windows on the exterior, or by adding window treatments such as shades, shutters, window films, and drapes on the interior.

Technical Information

A window is defined by its solar heat gain coefficient (SHGC), U-value, air-leakage rate, visible light transmittance, and materials of construction. The materials and quality of construction will determine its environmental impact, maintenance, durability, and ability to be disassembled for reuse or recycling at the end of its life.

1 **Issues to be considered in the selection of windows** involve the glazing system, the framing system materials, window operation, the joints between the glazing unit and window frame and between window frame and wall. Windows allow heat movement through conduction across the glazing and the frame, infiltration and exfiltration at the frame gaps and between the frame and wall, and solar radiation through the glazing. Window thermal performance should be compared by using the whole-window U-value. This includes the glazing, the frame, and any insulating glass spacers in multiple-glazing units. The lower the U-value (Btu / hr x ft^2 x ^0F), the better the performance. The U-value of single clear glazing is 1.1, or an R-value of 0.9.

2 **Multiple glazing makes use of the insulation created by a gas-filled gap** between the panes, which reduces conductive heat loss or gain. Typical gases are air, sulfur hexafluoride, carbon dioxide, argon, krypton, and xenon. These gases have lower thermal conductivity, thereby creating lower U-values within a smaller gap.

3 **Spectrally selective glazings should be considered for windows** in climates where solar gain in the summer creates large cooling loads, and where daylight also is preferred. These glazings have chemical coatings that allow specific portions of the energy spectrum to be transmitted.

4 **In renovations—particularly of historic buildings—** aluminum, metal and vinyl panning and receptor systems provide a weathertight, finished covering for placement over existing wood frames. This simplifies installation of new units and eliminates the removal of old frames.

Wood frames may be a better material from an environmental standpoint. However, they have greater life-cycle costs because of their shorter life, and higher maintenance costs compared to metal and plastic windows. The emphasis when selecting frame materials should be on thermal performance and maintenance, rather than the initial environmental impact of the material.

1 **Select windows for the best** combination of solar heat gain prevention, low SHGC (SHGC < 0.4) and high visible light transmittance (Vt > 0.6) for exposures other than south. An excellent choice for the combination of reducing solar gain and maximizing daylight gain is the use of double-glazed air-filled clear glass, with or without low-e coating, and external shading devices.

2 **The best methods for increasing the acoustical performance of windows** are to ensure that windows are airtight, and to increase the thickness of the glass. Increasing the thickness of a single pane from 12 mm to 25 mm will increase sound reduction by 10 decibels.

3 **The use of many types of inert gases,** air, and carbon dioxide in multiple-glazing units must be considered in the context of the environmental costs of producing these windows and the net benefit received from reduction of energy use. Air fill in a double-glazed window with a single low-e coating requires no energy for extraction, and can provide a greater net reduction of CO_2 production over the 20-year life of the window than the use of argon, krypton, or xenon.

4 **The choice of either fixed glazing units or operable units** should always be based on site-specific and climate-specific opportunities and constraints. Casement, pivoting, and awning windows offer the greatest opening area for natural ventilation and utilize compression seals that provide the best method of sealing the joint between sash and frame. Fixed windows provide the best thermal performance because of fixed seals, and can be designed to satisfy acoustical and security concerns as well.

Glazing that insulates poorly and highly conductive frames will have a colder interior surface than the inside of exterior wall surfaces in wintertime. Warmer, humid, interior air can condense on the inside of the glass and frames. This damages window frames, sills, wallboard, paint, and wallcoverings. A more thermally efficient window and a nonconductive frame with thermal breaks is less likely to cause condensation. Avoid metal frames that lack thermal breaks.

Facility managers should be aware of the advantages and disadvantages of using custom or stock windows for replacements. While custom windows will have a greater unit cost, they do not require additional adaptation devices and labor to modify the window unit or the framed opening that stock windows can require. The most economical materials for custom windows are aluminum, vinyl, fiberglass, and steel.

References

Arasten, D., “Advances in Window Technology,” Lawrence Berkeley National Laboratory, Report 36891, February 1996.

Carmody, J., S. Selcowitz, and L. Heshong, *Residential Windows*, W.M. Norton and Co., 1996.

Contacts

The FEMP Help Desk at (800) DOE-EREC can provide window evaluation software developed by Lawrence Berkeley National Laboratory.

The National Fenestration Rating Council (NFRC) (301) 589-NFRC or at http://eande.lbl.gov/BTP/NFRC can provide information on the window rating labels that they developed.

Insulation provides resistance to the conductive flow of heat from either the exterior to the interior, or vice versa. The thermal resistance is measured in R-value: (ft^2 x hr x $^{\circ}F$)/Btu. The primary forms of building envelope insulation are loose fill, batt, rigid board, and foamed-in-place. Insulation, together with moisture barriers and vapor barriers, provides the means to control the passage of sensible and latent heat and prevent condensation at the building envelope. Because insulation represents a small portion of building costs and has a major impact on operating cost, it offers one of the most economical and effective measures a facility managers can take to reduce the environmental impacts of their buildings.

Action Moment

The ability to make improvements in insulation is highly dependent upon the type of insulation used and its location in the building envelope. Improvements to cavity insulation will be disruptive to building operations and require blown-in or foamed-in-place insulation. Methods such as exterior insulation and finish systems (EIFSs) can be used over existing exterior wall finishes independently of other changes. Exterior built-up roof insulation can be removed and reapplied in conjunction with reroofing on low-slope roofs. Gasketing and caulking are an integral part of insulating envelopes for energy efficiency and can be done independently, or in conjunction with insulation upgrades. Insulation must be purchased with recycled content according to RCRA §6002. Re-roofing and renovation are good opportunities to consider insulation upgrades.

Technical Issues

1 **Critical selection issues for insulation** are high R-value over time, minimal environmental impacts in their manufacture, long life, minimal replacement and landfill waste—including waste generated during installation—and minimal health hazards to producers, installers and building occupants.

2 **Two of the most critical environmental impacts of insulation** are the use of CFCs for blowing agents, and the health concerns generated by fibrous materials such as asbestos and fiberglass.

3 **When specifying insulation**, a facility manager can ascertain the blowing agents that are used for board and foam insulation and look for alternative blowing agents such as steam, carbon dioxide, and pentane.

4 **Moisture in the exterior wall cavity** occurs when water is trapped in the wall cavity by impermeable surfaces and by condensation if the dew point temperature occurs at the exterior side of the wallboard. Eliminating moisture barriers and placing additional rigid insulation behind the interior wallboard of a stud wall will allow moisture to permeate from the wall cavity and reduce the temperature extremes between the warm back-side of the interior wallboard and the wall cavity.

5 **Vapor barriers go on the "warm side"** of building insulation. This means that in climates where cooling predominates, vapor barriers go on the outside of insulation. In climates where heating predominates, vapor barriers go on the inside of the insulation. Vapor barriers should be used instead of moisture barriers in warm-humid climates to prevent moisture buildup at the wall cavity. In warm climates, beware of interior wall treatments that act as vapor barriers.

Choose insulation based on its life-span. This solves several issues at the same time:minimal maintenance and replacement, avoidance of landfill waste, more efficient use of nonrenewable resources, and higher return on investments over the life of the building. The insulation selected should have a minimum service life of 30 to50 years.

There are many choices for insulation materials with excellent R-values and low environmental impact. Some of these include cellulose insulation made from recycled paper and boric acid, cotton insulation made from textile mill waste, and cementitious, isocyanurate, and urethane foamed-in-place insulation.

Encapsulated fiberglass batt insulation is available as a substitute for typical batt blankets in order to contain the dispersal of fiberglass fibers in installation. Fiberglass is also available without formaldehyde as a binder in limited parts of the country.

Consider the insulation that best suits the cavity type and ease of access. Foamed-in-place and blown insulations will best suit renovations where interior sheathing is to remain as undamaged as possible.

The economic return on greater insulation thickness does not follow a linear relationship between savings and increased thickness. Facility managers should be aware of diminishing returns depending on the geographic location of the facility and the limitations of the type of insulation.

Settling, dust, and moisture accumulation reduce the R-value of loose fill and batt insulation, especially in vertical wall cavities. Appropriate installation with spacers or foamed-in-place insulation in cavity walls can avoid this problem.

Be aware of the potential health hazards associated with fibrous insulation. Asbestos is a proven carcinogen and is prohibited in all buildings. The debate on the hazards of fiberglass and mineral wool is ongoing. Caution suggests that existing asbestos, fiberglass, and mineral wool insulation should be left in place and encapsulated with the addition of insulation, when conditions permit. When removal is required, all relevant regulations and methods for removal, transportation and disposal should be followed.

Thermal bypasses in the building can significantly reduce insulation effectiveness. Thermal interfaces and gaps need to be sealed.

The Audubon Society's Audubon House in New York is a renovation of an existing building. Cementitious foamed-in-place insulation was used to fill cavity walls and increase the airtightness of the envelope, as well as to ensure excellent indoor environmental quality.

Passive solar design measures minimize use of mechanical systems and nonrenewable fuels. Passive solar design is a design approach that takes maximum advantage of nature and integrates building components—walls, windows, materials, lighting, mechanical systems—to reduce energy costs and fuel use. Passive solar strategies include daylighting; energy-efficient glazing; proper building form and orientation to the sun; natural cooling using ventilation and shading for most larger non-residential buildings; and passive solar heating of smaller buildings (less than 20,000 sq. ft.) in cold climates. The passive features are designed to integrate and interact optimally with the building envelope, HVAC, and lighting systems.

This passive solar building incorporates trombe walls, daylighting, and awnings.

Action Moment

Any renovation or addition to a building envelope offers opportunities for integration of passive methods. The best time to incorporate passive solar is early in the design process, or when the addition or building is first conceived. Ideally, an energy budget is included in the building design specifications, and the Requests for Proposal require the design team to demonstrate their commitment to whole building performance and their ability to respond to the energy targets. The commitment is emphasized during programming and throughout the design and construction process.

For retrofit projects, consider daylighting strategies, such as making atriums out of courtyards, or adding clerestories; heat control techniques such as adding exterior shades; and redoing HVAC systems and lighting systems, perhaps down-sizing if the passive strategies reduce energy loads sufficiently.

Many buildings in the Federal inventory have passive features because they were built before modern lighting and HVAC technologies were available. When renovating older buildings, determine whether passive features that have been disabled can be revitalized.

Technical Information

1 **Highlight passive solar as a project goal.** Many agencies, including the GSA and the DOD , already have agency document language encouraging the use of passive solar design and renewables in all new construction and major renovation wherever feasible. An example of a good general project goal is “to produce a beautiful, sustainable, cost-effective building that meets its program, enhances productivity, and consumes as little non-renewable energy as possible through the use of passive solar design, energy efficiency, and the use of other renewable resources.”

2 **Incorporating energy performance goals into the programming documents** conveys the seriousness of energy consumption and the use of passive solar as a design issue. For small offices, warehouses, and other smaller (10,000 sq ft or less) projects, facility managers or their contractors can develop energy budgets themselves easily using energy software such as ENERGY-10. For larger multi-zone projects (for example, laboratories or high-rise office buildings), national average

energy consumption data by building type can be cited as targets to be exceeded, or more complex analyses can be run by consultants.

Thirty percent to fifty percent energy cost reductions below national averages are economically realistic in new office design if an optimum mix of energy conservation and passive solar design strategies is applied to the building design. Annual savings of $0.45 to $0.75 per sq ft are a reasonable estimate of maximum possible cost savings.

Passive solar design considers the synergy among all the building systems. For example:

- Can natural light reduce the need for electric light?
- If less electric light creates less heat, will there be a lower cooling load?
- If the cooling load is lower, can the fans be smaller?
- Will natural ventilation allow these fans to be turned off at times?

Don't look for generic design solutions or rules-of-thumb because there are so many possible combinations and system interactions. Some of the variables involved include: climate (sun, wind, air temperature, and humidity); building orientation (glazing and room layout); building use type (occupancy schedules and use profiles); lighting and daylighting (electric and natural light sources); building envelope (geometry, insulation, fenestration, air leakage, ventilation, shading, thermal mass, color); internal heat gains (from lighting, office equipment, machinery, and people); HVAC (plant, systems and controls); and energy price (fuel source, demand charges, conversion efficiency).

The integrated interaction of at least 16 energy-efficient strategies are considered in passive solar design. They are: daylighting; glazing; shading; energy-efficient lighting; lighting controls; insulation; air-leakage control; thermal mass; passive solar heating; natural ventilation; economizer cycle; exhaust air heat recovery; high-efficiency HVAC; HVAC controls; evaporative cooling; and solar water heating.

Passive solar design is an integrated design approach that optimizes total building performance rather than a single building system. This is the key to "green building" design.

Buildings designed using passive design technologies are generally more comfortable for the occupants, resulting in productivity benefits that are great relative to the building cost.

Cost analysis is conducted at the same time as technical analysis in a passive solar design in order to optimize investments for maximum energy cost savings.

References

Olgyay, Victor, *Design with Climate: Bioclimatic Approach to Architectural Regionalism*, Princeton University Press, Princeton, NJ, 1963.

Watson, Donald, *Climatic Design: Energy-Efficient Building Principles and Practices*, McGraw-Hill, New York, NY, 1983.

Contacts

FEMP offers a course on passive solar design, *Designing Low Energy Buildings.* Call (800) DOE-EREC for course information.

Passive Solar Industries Council (PSIC), 1511 K St. NW, Suite 600, Washington, DC 20005 (202) 628-7400 or at http://www.psic.org has developed a software package called "ENERGY-10" to evaluate passive measures in smaller industrial buildings.

Renewable and Alternative Energy Systems 3.10

As the rate of fossil fuel resource depletion accelerates due to pressures from emerging economies worldwide, prices are likely to rise. Conversely, technology and manufacturing advances have brought the cost of renewable energy use, such as solar and wind, down significantly. In the near future, power generated from renewable resources and by alternative methods of power generation will have significant cost advantages over conventional hydrocarbon systems. In the near term, there are niche applications, such as remote photovoltaics and solar swimming pool heating where renewables have a definite cost advantage. Because they are pollution-free, renewables have huge advantages when environmental impacts are considered. Wind power has already broken through the cost barrier that historically prevented the large-scale introduction of sustainable energy systems. Over 3,500 MW of wind energy generating capacity have been installed worldwide. Photovoltaics and fuel cells also are beginning to emerge as strong competitors for conventional power systems, with over 500 MW installed worldwide.

This solar-hydrogen fuel cell at the Telonicher Marine Lab in Trinidad, California, serves as a research and demonstration project.

Action Moment

When adding power generation capacity for a site or large facility, be sure to investigate the potential for renewable and alternative energy systems. In addition to their low environmental impacts, they will become more cost advantageous each year as the costs of conventional fuels rise. On-site power generation from renewable energy resources provides the added potential of reducing peak power demand with significant savings per peak kWh. Life-cycle costing comparisons between renewable energy systems and conventional power generation should include forecasted demand reduction as a cost component in favor of renewable energy.

Technical Information

1 **Photovoltaic power systems** are rapidly becoming competitive with conventional power systems, especially where the cost of infrastructure to deliver power to a site is relatively high. Photovoltaics should be given serious consideration for isolated or remote applications and structures because of the high cost of power line installation. Photovoltaics are competitive with diesel or propane generators. Hybrid photovoltaic/generator systems combine the low operating cost of photovoltaic with the availability of generator power. Additional information on photovoltaic technology is provided in section 3.10.1.

2 **Wind energy systems**, covered in section 3.10.2, can generate electrical power more cheaply than fossil fuel systems, with rates as low as \$0.039/kWh. The wide range of mechanical and electrical components required for wind power generation creates demand for many sophisticated components, thereby keeping expenditures for energy in the domestic economy. Because winds on the order of 13 miles per hour average are required, not every region is suitable for economically generating energy from wind. Wind turbines may not be suitable in populated areas, and local topography can either accentuate or attenuate wind patterns. However, much of the United States and many overseas lo-cations are excellent places for wind energy systems, and their many advantages warrant their serious consideration.

3 **Fuel cells** are electrochemical engines that convert the chemical energy of a fuel and an oxidant directly into electricity. The principal components are catalytically activated electrodes for the fuel (anode) and the oxidant (cathode) and an electrolyte to conduct ions between the two electrodes. Because the operating conditions of the fuel cell are largely determined by the electrolyte type, fuel cells are classified by the type of electrolyte. They have high power generation efficiency, and perhaps most importantly, they pave the way for the transition to what many consider to be the replacement for hydrocarbon fuels: hydrogen. DOE has several active programs that can assist the facility manager in acquiring fuel cells for their location. Section 3.10.3 contains information and points of contact for these programs.

4 **Federal Renewable Energy Screening Assistant (FRESA**) is a software tool used to identify retrofit opportunities that are most likely to use renewable energy cost-effectively. This allows users to better focus on analytical resources. FRESA screens for 15 renewable energy, conservation, and power generation options, including active solar heating and cooling, solar water heating, daylighting, solar thermal electric, wind, small hydro, electricity from biomass and waste, and load avoidance by building envelope improvements. The reports FRESA generates are consistent with the DOE/FEMP SAVEnergyAudit format.

When performing a life-cycle costing of renewable or alternative energy systems, forecasting fuel price changes over a system's lifetime is, of course, very difficult. NIST provides several publications that can assist the facility manager with this type of information.

References

National Institute of Standards and Technology, *DISCOUNT: A Program for Discounting Computations in Life-Cycle Cost Analyses,* (NISTIR 4513). A program for computing discount factors. Be sure to ask for the latest version.

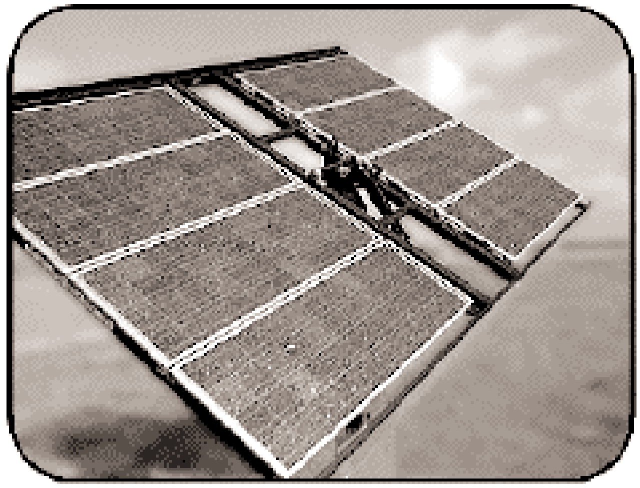
National Institute of Standards and Technology, *Present Worth Factors for Life-Cycle Cost Studies in the Department of Defense*, (NISTIR 4842-2). A separate version of the report listed above, for DOD analyses.

See section 2.2 for more information on life-cycle cost analysis.

Contacts

The FEMP Help Desk at (800) DOE-EREC has information on the latest developments in wind energy, photovoltaics, fuel cells, and other "green" energy technologies, as well as the FRESA software.

Photovoltaics (PV) or photovoltaic cells are devices that convert light into electricity. Although there are several photovoltaic technologies, the typical cell is a thin rectangular or circular wafer made of boron-doped silicon sandwiched with a wafer of phosphorous-doped silicon. The wafers are wired together in modules. Thin-film technologies deposit the PV material directly onto glass, plastic, or metal substrate. Especially exciting are products that integrate PV directly into building materials such as glass, flexible shingles, and raised-seam metal roofing.



Photovoltaic panels are frequently mounted on devices that track the sun.

Action Moment

The present trend in pricing is rapidly making PV competitive with conventional power systems, especially where the cost of infrastructure to deliver power to a site is relatively expensive, such as extending a new power line or operation of a generator at a remote site. Give PV serious consideration for isolated or remote applications and structures because the cost of power line installation is very expensive. Consider replacing diesel generators with PV in environmentally sensitive areas where fuel spills are a special problem.

Technical Information

There are two basic PV system types for any given application. The first are stand-alone systems with battery storage, hybrid PV/generator systems with a diesel or propane generator as back-up. The second are utility-interactive (grid-connected) systems with PV as the primary power source and the utility grid as the backup.

Manufacturers use several types of semiconductor materials in photovoltaic cells: single crystal silicon, polycrystalline silicon, hydrogenated thin-film amorphous silicon, cadmium telluride, copper indium diselenide, gallium arsenide, and others.

1 ***Thick-cell photovoltaics*** are on the order of 4 to 17 mils thick and are comprised of single-crystal or polycrystalline silicon. *Thin-cell photovoltaics* are less than 5 microns thick, require far less material, and are extremely lightweight.

2 ***Thin-film* photovoltaic cells** are typically 6% efficient in converting light to electricity. *Thick-film* cells have efficiencies on the order of 16%.

Stand-alone systems can be set up to function in several ways:

1 **A direct-coupled system** is the simplest version and consists of photovoltaic cells driving a DC load with no battery storage. Loads such as water pumps, ventilation fans, and special DC refrigerators are good applications.

2 **Battery storage systems** to drive DC loads. These systems store the energy until it is needed, for example, in powering navigational aids at night. The simplest version drives DC loads only, and may require a battery system with charge control if the loads are variable.

3 **Battery storage systems to drive DC or AC loads.** These systems have an inverter and charge controller to drive connected AC loads. A hybrid version has one or more energy sources such as a wind or motor generator set to supplement battery charging.

Some good stand-alone applications: Backup power and emergency communications; irrigation systems for agriculture; microwave repeaters; cathodic protection for bridges, pipelines, towers, and wellheads; navigational aids; security systems; environmental sensors such as radiation monitors; meteorological stations; noise monitors; and area and signboard lighting.

Utility-interactive systems or grid-connected systems require an interface to operate with the grid. The PV power is delivered first to the load. Any excess power is fed back into the grid. These systems require synchronous inverters that not only convert DC into AC power, but also match the output power to the phase and frequency of the grid. Some considerations for these systems:

1 **Public Utilities Regulatory Policy Act** (PURPA) requires utilities to interconnect to any qualified facility. However, the facility must pay for the interconnection.

2 **The technical and operating issues** that must be coordinated with the utility are: metering, safety, equipment protection, service reliability, and power quality.

3 **When planning a utility-interactive system**, be sure to check into metering options, buy and sell rates for power, outdoor disconnect requirements, insurance requirements, and interconnection costs.

4 **Selecting a PV array** is an important element in creating the PV system. The following basic information is required to select and procure a PV array:

Selection criteria: voltage-current characteristics; long term reliability; power output density; dimensions and weight; manufacturer's reputation; cost and warranty; framing materials; suitability for high-temperature operation and self-regulation.

Procurement specifications should contain: module manufacturer and model number; module dimensions; wiring arrangement; junction box configuration; module max power; max current; short circuit current; open circuit voltage and other rating conditions; module framing and fastening systems; grounding arrangements; instrumentation and provisions for diagnostics; array circuit disconnect arrangement; array bypass diode arrangement.

In 1970 photovoltaic cells cost over $1,000 per peak watt of power and were used solely for exotic applications such as spacecraft power systems. Prices today are under $5 per peak watt, and power stations of the multiple megawatt range are under development.

Storage systems for PV arrays provide the owner the capability of using the captured energy at night or at other off-peak times. The typical storage system is a set of batteries sized to accommodate the PV input as well as the load demand. Additional benefits of a battery storage system are: (1) power is supplied at stable voltages and the transient peaks from the PV system are smoothed out; and, (2) transient peak loads coming on and off line can be supplied the necessary electrical power at the exact time it is needed.

When selecting a battery system, the designer needs to consider size and weight, cost, warranty, availability, reputation of the manufacturer, maintenance requirements, cyclic and calendar life, daily depth of discharge, temperature and environmental conditions, off-gassing characteristics, and terminal configuration.

References

Department of Energy, National Renewable Energy Laboratory, *Photovoltaic Fundamentals*, (DOE/CH10093-117, Revised Feb 1996).

Florida Solar Energy Center, *Photovoltaic System Design Manual*, (FSC-GP-31-86, Revised April 1996), Cape Canaveral, FL

Solar Energy Industries Association, 122 C St, N.W., Washington, D.C. 20001 (202) 383-2600.

Contacts

Contact the FEMP Help Desk at (800) DOE-EREC, or the FEMP Home Page at http://www.eren.doe/femp.

Wind power is perhaps the biggest success story in the arena of alternative or renewable energy systems. At present, power generation by wind turbines is competitive with fossil fuel and nuclear power. A new National Wind Technology Center was recently opened by NREL in a collaborative effort among industry, utilities, environmental groups, and others. Over 3,500 MW of windpower generating capacity have been installed worldwide.

Action Moment

Wind power is an excellent choice for providing power for large sites with high electricity prices and where the prevailing winds exceed 21 kilometers (13 miles) per hour for 90% of the year. Wind electric turbines that generate power at under 5¢/kWh are available in sizes from 1 to 500 kW. If necessary they can be grouped together in farms to supply larger requirements.

Technical Information

The grid-connected capacity of wind energy systems in the United States was 1,717 MW in 1994, almost half of the world's total installed wind capacity. However, at present, the rest of the world is installing wind energy capacity at 10 times the U.S. rate. For example, India is expected to add up to 1,200 MW of wind energy systems in the period 1994 to 2000.

1 **Wind energy systems help the U.S. economy** by creating demand for a wide range of components, including: wind electric turbine blades, gearboxes, generators, electronic controls, and towers.

2 **There are two basic wind electric turbine designs:** vertical axis machines that look like "egg beaters" and horizontal machines that look like propellers. The latter comprise 95% of the installed utility-scale (larger than 250 kW) turbines.

3 **Hybrid wind/diesel systems** are available that utilize wind energy generation to the maximum extent possible, while still providing reliable and economical power.

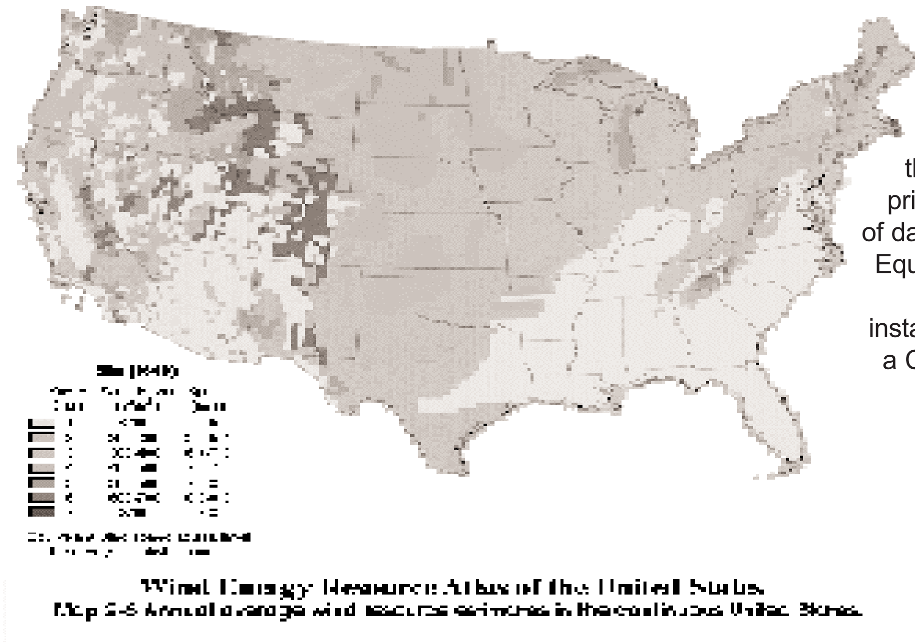
Wind power systems now produce electricity cheaper than fossil fuel plants and are the major success story in renewable energy.

4 **Wind electric turbine systems for small-scale rural electrification** have been in use since the 1930s and require an annual average wind speed in excess of 13 kilometers per hour (8 mph) to be economical.

5 **Wind energy systems** also are available for roles other than generating electricity for the grid. Water pumping systems are available that lift water directly through mechanical means, or that generate electricity for electric pumps.

6 **Wind energy developers** are now bidding utility-scale projects as low as 3.9¢/kWh, an almost 80% reduction from the costs of the first wind energy projects that were installed at a cost of 30¢/kWh in 1981. Many people are forecasting that in the next 10 to 15 years, wind energy will be the cheapest energy available from any source.

7 **Although some noise is generated** by wind turbine plants, a 300 kW wind turbine creates only 45 dB of noise at a 200 meter distance.



To obtain accurate information on wind speeds in a given location or to increase the confidence level in wind data prior to executing a project, a year of data collection may be necessary. Equipment to accomplish this costs $1,500 to $3,000 and can be installed in one day. FEMP also has a CDROM containing wind speeds throughout the United States.

8 **The power available from wind is proportional to the cube of its speed**. By doubling wind speed, the power generated increases by a factor of 8. A generator operating in 19 kilometer per hour (12 mph) winds will generate 29% more electricity than one operating in a 18 kilometer per hour (11 mph) wind.

9 **Approximately 20 hectares (50 acres) of land are required per MW of installed capacity.** However much of the land is actually unoccupied and can be used for farming, ranching, and other activities. Systems range from 24 to 37 meters (80 to 120 feet) in height to avoid ground turbulence and to increase performance due to higher wind velocities at altitude.

The downsides of wind-turbine-generated electricity are the potential visual impacts and bird collisions. Efforts are being made to mitigate both of these effects. Using turbines of the same size and uniform spacing, plus the use of computer simulation to analyze the visual impacts can greatly improve the appearance of a wind farm. The National Audubon Society and others are working with the American Wind Energy Association to minimize bird impacts.

Wind energy carries a "production tax credit" for any wind turbines installed after December 31, 1993 and before July 1, 1999. The tax credit is 1.5¢/kWh generated and applies for the first ten years of the turbine's operation. The Energy Policy Act of 1992 contained these provisions for stimulating the development of wind power.

References

American Wind Energy Association, *Small Wind Energy Systems Application Guide*, Washington, DC, 1993.

American Wind Energy Association, *Wind/Diesel Systems Architecture Guidebook*, AWEA Standard 10.1-1991, Washington, DC, 1991.

American Wind Energy Association, *Wind Energy for Sustainable Development*, Washington, DC, 1992.

Contacts

For a CDROM of windspeeds from around the United States, contact FEMP at (800) DOE-EREC.

American Wind Energy Association, 122 C Street, NW, Washington, DC, 20001 (202) 383-2500

National Renewable Energy Laboratory, National Wind Technology Center, 1617 Cole Blvd., Golden, CO, 80401 (303) 384-6900

National Wind Technology Center, NREL, 1617 Cole Blvd., Golden, CO, 80401 (303) 384-6900.

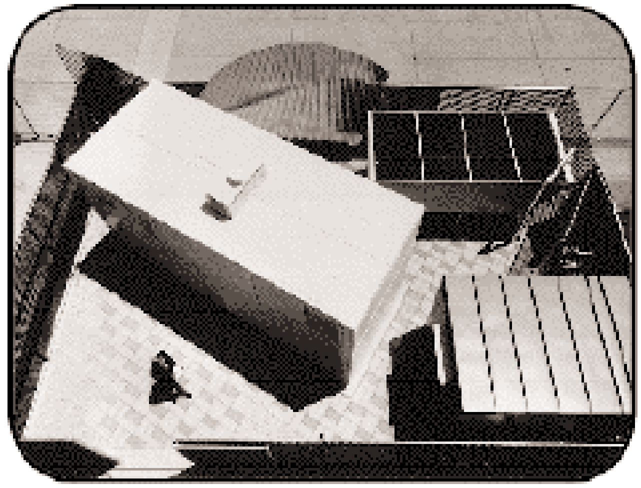
Fuel cells generate electricity by converting chemical energy into electrical power with no moving parts. Power generation via fuel cells is a rapidly emerging technology that provides electricity with high efficiency and low noise. Fuel cells provide the opportunity to transition from fossil fuels, such as natural gas, methane, and liquid hydrocarbons, to what many consider to be the fuel of the future: hydrogen. The oxygen used in the fuel cell is atmospheric oxygen and the hydrogen is either elemental hydrogen or hydrogen extracted from hydrocarbon fuels using a device called a *reformer*. Fuel cell power plants that produce up to 11,000 kW have been built from multiple 200 kW units.

Action Moment

The Department of Energy and the Department of Defense have several programs to subsidize the purchase of fuel cells for use in a variety of applications. These programs are intended to create a "push" effect to accelerate the development of this technology. In a recent program, DOE earmarked $15 million for grants to prospective buyers with priority being given to DOD installations. DOE is offering to pay $1,000 per kW for Federal projects between 100 and 3,000 kW, not to exceed one-third of project costs. Contact the DOE's Business Information Center about this program. (http://www.metc.doe.gov/business/solicita.html)

Technical Information

Fuel cells are electrochemical engines that convert the chemical energy of a fuel and an oxidant directly into electricity. The principal components are catalytically activated electrodes for the fuel (anode), the oxidant (cathode), and an electrolyte to conduct ions between the two electrodes. Because the operating conditions of the fuel cell are largely determined by the electrolyte, fuel cells are classified by the type of electrolyte.



This fuel cell powers some of the electrical systems at the Pittsburgh International Airport.

There are several fuel cell technologies being developed at present:

1. **Phosphoric acid** fuel cells (PAFC) have an acid electrolyte and are the most highly developed fuel cells. These have relatively low-temperature operation, around 200˚C (400˚F), produce on the order of 200 kW, and are commercially available.

2. Fuel cells using a **molten carbonate** (MCFC) electrolyte are relatively high-temperature units, operating in excess of 600˚C (1100˚F). MCFCs are being designed for larger-scale applications on the order of 50 to 100 MW. The high-temperature exhaust gases can be used in a combined cycle system, creating an overall efficiency on the order of 80%.

3. **Solid oxide** (SOFC) electrolyte fuel cells are also high-temperature devices, operating at 600 to 1000˚C (1100 to 1800˚F). At these temperatures a natural gas-powered fuel cell does not require a reformer. The solid construction of the SOFC fuel cell prevents some of the corrosion problems of liquid electrolyte fuel cells. A variety of 20 to 25 kW SOFC units have been tested, and units up to 150 kW are planned.

Proton exchange membrane (PEM) fuel cells are well-suited to mobile applications requiring relatively compact power systems. The electrochemistry of PEM fuel cells is similar to that of phosphoric acid fuel cells. They operate in the same pressure range, but at a much lower temperature, about 80˚C (175˚F). PEM cells are being used to power buses and automobiles. Their very low thermal and noise signatures may make them especially useful for replacing military generator sets.

Efficiencies as high as 70% have been observed for fuel cells in laboratory settings. Actual efficiencies of commercially available fuel cells range from 50% to 60%. In automotive applications the expected efficiency range is 36% to 50%, compared to 20% for current internal combustion systems.

Fuel cells are inherently less polluting than conventional fossil-fuel technologies and are more efficient in producing electricity. They produce almost no harmful air or water emissions. The principal by-product is water.

Fuel cell-powered vehicles are projected to save 2 billion to 4 billion barrels of oil per day by the year 2030. Total economic benefits are forecast to range from $26 billion for methane-powered fuel cell vehicles to $116 billion for hydrogen-powered vehicles.

The footprint of a 200 kW PAFC unit is about 20 m^2 (200 ft^2), while the footprint of a 2.85 MW MCFC plant is about 450 m^2 (4,500 ft^2).

Many types of fuel cell power plants must have their stack and fuel processor units replaced every 5 to 10 years, requiring a shutdown of several days for the replacement.

The U.S. Army Corps of Engineers Construction and Research Laboratory (CERL) plans to complete the distribution of eleven 200 kW PEM fuel cells to Department of Defense installations by the end of 1996.

Four parallel 15 kW fuel cells provide all the power required by the Space Shuttle once it is in orbit.

References

Department of Energy, Federal Energy Management Program, "Natural Gas Fuel Cells," F*ederal Technology Alert,* Washington, DC. Available from the FEMP Help Desk at (800) DOE-EREC.

Contacts

Department of Energy, Morgantown Energy Technology Center, 3610 Collins Ferry Road, Morgantown, WV 26505, (304) 285-4086

Department of Energy, Office of Propulsion Systems, 1000 Independence Avenue SW, Washington, DC 20585, (202) 586-8055

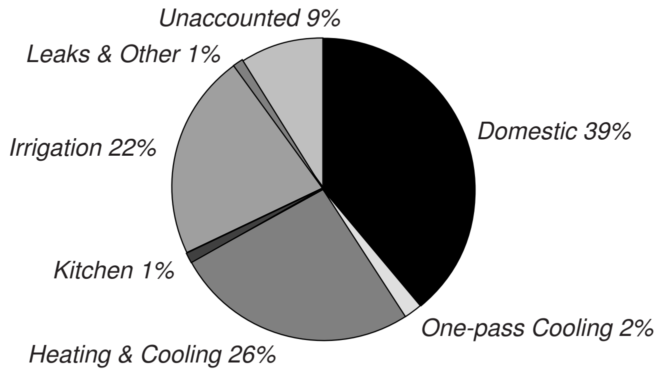
Department of Energy, Argonne National Laboratory, Electrochemical Technology Program, 9700 Cass Avenue, Argonne, IL 60439-4837, (708) 252-7563

Department of Energy, National Renewable Energy Laboratory, 1617 Cole Blvd., Golden, CO 80401 (303) 231-7681

Department of Energy, Pacific Northwest National Laboratory, PO Box 999, MSIN-K5-08, Richland, WA 99352. Ask for Steven Parker. (509) 375-6366

Facility managers should conduct comprehensive audits of the water use of all buildings under their supervision. Not only is this an excellent idea, it is mandated by Executive Order 12902, "Energy Efficiency and Water Conservation at Federal Facilities." The water audit should be accompanied by an examination of available water management techniques and the implementation and monitoring of appropriate measures.

Water Use in Commercial Buildings



Action Moment

Water management techniques can and should be implemented in all Federal facilities. These techniques fall into three major categories: (1) reducing losses by repairing leaky faucets and pipes; (2) reducing the overall amount of used water (by, for example, using low-flush toilets); and, (3) reusing water (for example, using graywater for irrigation).

Technical Information

Water use in the United States has doubled from about 910 billion liters (200 billion gallons) a day in 1950 to over 1.8 trillion liters (400 billion gallons) a day in 1990. Federal agencies collectively spend more than $500 million dollars annually on water and sewer costs.

Replacing a leaky faucet can save 160 liters (36 gallons) a day. Replacing the same faucet with an automatic shutoff control that delivers a limited amount of water per use can save 23,000 liters (5,000 gallons) of water a year. The standards established for water consumption by the Energy Policy Act restrict showerheads to 11 liters per minute (2.5 gpm), and urinals to 4.5 liters (1 gallon) per flush. In 1997, toilets for commercial buildings will be required to use no more than 7 liters per flush (1.6 gpf) at (552 kPa) 80 psi and faucets shall use no more than 10 liters per minute (2.2 gpm) at (414 kPa) 60 psi.

Water management measures that are cost-effective—that is, with a payback of 10 years or less—can be immediately implemented. Note that the true cost of water must include costs to heat, cool, pump, and treat or dispose of wastewater. Dollar savings from reduced water and energy use as a result of water conservation projects are substantial.

A successful water management program begins with the development of a comprehensive water management plan that depends on a complete understanding of how the facility and its occupants use and dispose of water.

The Nuclear Regulatory Commission's (NRC) Phillips Building reduced annual water consumption by more than 6.4 million liters (1.4 million gallons) in one year (1992) compared to the previous year. Many plumbing fixtures over 30 years old were replaced with modern counterparts. The total cost of replacing 100 faucet seats and washers was about $1,000. Monthly inspections insure the continuation of this very successful program. How did it get started? It began with a water management plan similar to the one outlined on the next page.

Eight Steps to a Successful Water Management Plan

1 **Gather information.** Start with the facility floor plan, operating schedules, number of employees and visitors, and maintenance/janitorial schedules. List all fixtures together with the manufacturer's data on rated flow rates. Determine outdoor water applications, quantity, and schedule. Obtain utility name and water/sewer bills for the past 2 years from the utility. Check meter calibration results to adjust quantities if necessary.

2 **Conduct a comprehensive facility survey.** Assemble a team with members from management, the physical plant, the maintenance department, water management specialists, plumbing/mechanical/landscape contractors, and the utility. Compare fixture counts on floor plans to actual fixtures. Determine: schedules of use of fixtures (verify by checking at various times of the day); the amount of water used per fixture by measuring flow rates and time per use; and, water use by other water-consuming equipment, such as cooling towers and cafeteria equipment. Total the facility water-use through water meter and sub-meter readings. Evaluate cooling tower water for: water quality, chemical content, pH, total dissolved solids, and conductivity. Include irrigation water use, often the area of greatest waste.

3 **Explore and evaluate water management options.** Explore all equipment and devices against the factors influencing the facility's water use. Determine if maintenance procedures need to be upgraded. For example, constantly running toilets can use 23,000 liters (6,000 gallons) a day.

4 **Conduct life-cycle cost analyses and explore financing options.** Total water cost must include water purchased from utilities, pumping energy, pretreating, water heating and cooling, chemical treatments (e.g. cooling towers), and sewer costs. Use the NIST BLCC program to compare alternative plans. Where appropriate, consider the GSA Federal Buildings Fund if there are energy savings involved. Check into utility programs or Energy Savings Performance Contracts (ESPC) with private firms.

5 **Develop a water management plan and work schedule.** Prioritize the changes to be made based on current water use, occupant needs, and life-cycle cost analysis. Determine the schedule of implementation and associated funding.

6 **Inform building occupants about water management.** Send a letter to everyone telling them about the plan. Post signs near equipment to make occupants aware of water savings initiatives. Set up a "Hotline" to report leaks or other wastes of water. Start a water information section in the newsletter detailing water savings.

7 **Implement the water management plan.** Check with contractors to ensure that work is going as planned. Check bills to verify consumption reductions as the program evolves. Repair problems for users immediately.

8 **Monitor the water management plan.** Carefully check to ensure that savings are occurring. Make regular contact with the operating and maintenance staff to insure their active participation.

References

General Services Administration, *Water Management: A Comprehensive Approach for Facility Managers*, Washington, DC, 1995.

American Water Works Association, *Water Audit and Leak Detection*, Denver, CO, 1990.

Contacts

Water management training courses are offered by FEMP. For information, call the FEMP Help Desk at (800) DOE-EREC. See FEMP Focus, June 1995 issue.

WATERGY, A Water and Energy Conservation Model for Federal Facilities is available from the FEMP Help Desk for water conservation audits.

American Water Works Association, Denver, CO, (703) 684-2492.

There are three common varieties of toilets found in facilities: gravity flow, flush valve, and pressurized tank systems. Similarly there are four common varieties of urinals: the siphonic jet urinal, washout/wash-down urinals, blowout urinals, and waterless urinals.

Action Moment

The vast majority of toilets and urinals in existing facilities were designed and installed at a time when there was little or no regard for using water efficiently. Consequently, there are ample opportunities to make significant savings in water usage. Complete replacement is the desired option. Retrofit is a second choice, but is sometimes necessary due to budgetary constraints. Retrofit reduces the amount of water used per flush but the fixtures were not designed to use the reduced amount of water. Only complete replacement of porcelain fixtures ensures that the reduced water quantity can perform efficiently and effectively.

Technical Information

Toilets account for almost one-half of a typical building's water consumption. Americans flush about 22 billion liters (4.8 billion gallons) of water down toilets each year.

According to the Plumbing Foundation, replacing all existing toilets with 7 liters per flush (1.6 gpf) ultra-low-flow (ULF) models would save almost 25,000 liters (5,500 gallons) of water per person each year.

Many retrofit options are available for toilets: displacement devices, toilet dams, early closure devices, dual-flush adapters, insert or valve replacement devices, electronic sensors, flushometer modifications, and timers. However, none of these modifications will achieve the maximum 6 liter requirement for toilets manufactured after January 1, 1994. These retrofits will merely allow the fixture to operate using less water until it is replaced.

The table on the next page shows the difference in water consumption for conventional, retrofitted, and modern toilets and urinals.

1 Gravity Toilets

Adjust the flush valve to reduce the water used per flush without impeding waste removal or violating the manufacturer's requirements.

Check for leaks every 6 months and periodically replace valves and ballcocks. Use toilet cleaners that are not highly corrosive to flapper valves.

Toilet dams are flexible devices that keep up to 4.5 liters (1 gallon) per flush out of the flush cycle.

Early closure devices can be used to save 4.5 to 9 liters (1 to 2 gallons) per flush. These devices cause the same force to be exerted with each flush but with half the water.

Dual-flush adapters adjust the system to use two types of flushes, saving up to 5.5 liters per flush (1.2 gallons). One flush is standard and removes solids while the second is smaller and removes paper and liquids.

2 Flush Valve Toilets

Adjust the flush valve to use as little water as possible per flush.

Early closure devices can replace or amend the existing valve to save 4.5 to 9 liters (1 to 2 gallons) per flush.

Dual flush adapters (see the previous section on gravity toilets above) can save 2.7 to 5.5 liters (0.6 to 1.2 gallons) per flush.

Consider ultrasonic or infrared sensors, the most costly but most effective retrofit because they virtually eliminate double flushing.

Toilet and Urinal Water Consumption by Model

Option	*Pre-1970 Models, Water Usage (gallons)*	*Traditional Model Retrofits*	*Modern Model Water Usage (gallons)*
Toilets			
Gravity flow	5 - 7	Save up to 2 gpf	1.6
Flush valve	5	Save up to 3.4 gpf	1.6
Pressurized tank	1.6	—	1.6
Urinals			
Siphonic jet	continuous flow	—	1.0
Blowout	2 - 3	—	1.0
Washout	2 - 3	—	1.0
Waterless	—	—	0

3 Pressurized Tank System Toilets

Use these toilets to replace gravity toilets. They are designed to use 7 liters (1.6 gallons) per flush released with a force 500 times greater than conventional 23 liters (5 gallons) toilets.

To insure the effectiveness of these toilets, check regularly for leaks.

4 Urinals

For siphonic jet urinals, retrofit with infrared or ultrasound sensors to eliminate double flushing, or replace 6.8 to 14 liter (1.5 to 3 gallon) models with 4.5 liter per flush (1 gpf) models.

Blowout urinals, which discharge at intervals as the water tank reaches a given level, can be modified to function with sensors only when the building is occupied.

Displacement devices such as bags or bottles—to reduce the water use of 23 liters per flush (5 gpf) toilets to 16 liters per flush (3.5 gpf)—are not recommended because they can cause plumbing problems.

The Prince Kuhio Federal Building and Post Office in Honolulu is a 10-story building housing 1,400 employees. A complete toilet and urinal replacement program is saving 40 million liters (8.8 million gallons) of water annually. With the total cost of replacement estimated to be about $235,000, annual cost savings in sewer and water bills are about $31,000.

References

Department of Energy, Federal Energy Management Program, “Water Saving Restroom Fixtures,” 1995. Available from the FEMP Help Desk at (800) DOE-EREC.

A software program called “WATERGY” will quickly screen facility water consumption. Available from the FEMP Help Desk at (800) DOE-EREC.

According to the Plumbing Products Efficiency Act that became effective on January 1, 1994, new showerheads and faucets must now have 11 liters per minute flow rates at 552 kPa (2.5 gpm flow rates at 80 psi). A variety of new products is available (with widely varying prices) to help achieve this reduced flow rate. Although drinking fountains are not regulated by the government, they should be included in water management programs.

Action Moment

It is becoming common for showers to be installed in office buildings, paralleling a trend toward more healthy life-styles, commuting by bicycle or foot, and exercise programs. Many Federal facilities are dorms and barracks that do, in fact, contain large numbers of showers and faucets. A wide variety of shower retrofit options can help achieve the 11 liters per minute (2.5 gpm) requirement with rapid payback.

Technical Information

1 **A conventional showerhead is rated** to use 14 to 32 liters per minute (3 to 7 gpm) at normal water pressure, about 552 kPa (80 psi). A 5-minute shower with a conventional showerhead typically consumes 110 to 160 liters (25 to 35 gallons) of water.

2 **Replacement options that maintain** shower quality and achieve the 11 liters per minute (2.5 gpm) requirement vary in price from $3 to $95. They have a narrower spray area and a greater mix of air and water than conventional showerheads, enabling them to decrease water flow and provide what feels like a full-volume shower.

3 **Older faucets with flow rates** of 14 to 23 liters per minute (3 to 5 gpm) waste large quantities of water every day. A single leaky faucet (one drip per second) will waste 165 liters (36 gallons) of water a day. Federal guidelines mandate that all lavatory and kitchen faucets and replacement aerators manufactured after January 1, 1994, consume no more than 11 liters per minute at 552 kPa (2.5 gpm at 80 psi). Metered valve faucets are restricted to a 1.1 liter (0.25 gallon) per cycle discharge after this date.

4 **The American National Standards Institute** (ANSI) is developing a new faucet standard. It will lower the limit to 10 liters (2.2 gpm) per minute and will automatically become a part of the Energy Policy Act requirements.

5 **Variations in water pressure are clearly** problematic for water management programs. Pressure-compensating faucets can be used to automatically maintain 11 liters per minute at 138 kPa (2.5 gpm at 20 psi) as well as at 552 kPa (80 psi). Adding a pressure-compensating aerator can reduce the flow below 11 liters (2.5 gpm) per minute.

Showers

1 **Modern, low-flow showerheads** that deliver 9 to 14 liters per minute (2 to 3 gpm) can save many gallons per shower when used to replace more consumptive showerheads. Pulsater types vary the spray patterns in one of two ways. They either pause the flow between spurts, or vary the flow between a strong flow and a light mist. Temporary cutoff valves attached or incorporated into the showerhead stop the water flow when the individual is soaping or shampooing. When the water flow is reactivated, it emerges at the same temperature, eliminating the need to remix the hot and cold water.

2 **Atomizer and aerator showerheads** deliver water in fine droplets and save water. However, the cooling effect is so great that users tend to use more hot water to compensate.

3 **Flow restrictors are washer-like disks** that fit inside showerheads and provide tempting retrofits. However, flow restrictors provide poor water pressure in most showerheads. Permanent water savings are better provided through the installation of well-engineered showerheads costing approximately $10 per unit.

Faucets

Be sure to institute a regular program of faucet maintenance to insure that leaky faucets are immediately repaired.

1 **For manual-valve faucets,** one of the following conservation options are available:

- **Flow restrictors** limit the flow of water to 2 to 11 liters per minute (0.5 to 2.5 gpm) by means of a washer-like disk installed in the faucet head.
- **Aerators** placed on the faucet add air to the water stream, increasing the effectiveness of the flow and reducing water use.

2 **Metered Valve Faucets** deliver a preset amount of water and then shut off. For water management purposes, the preset amount of water can be reduced by adjusting the flow valve. The American Disability Act requires a 10-second minimum on-cycle time.

3 **Electronic Faucet Controls** are discussed in section 4.4.

Drinking Fountains

1 **Self-Contained Units** have an internal refrigeration unit. Adjust the exit water temperature to 21˚C (70˚F) versus the nominal 18˚C (65˚F) of most units. Insulate the piping, chiller, and storage tank to save energy. If appropriate, add an automatic timer to shut off the unit during evenings and weekends.

2 **Remote Chillers or Central Systems** serve and supply cold drinking water to several locations. To conserve energy, the temperature can be raised from 18˚C to 21˚C (65˚F to 70˚F); piping should be well-insulated; and a timer can be used to turn off the unit when the building is unoccupied.

Metering faucets have manufacturer list prices of $100 to $150. Sensor-operated metering faucets are priced at $260 to $310. Sensor faucets require electrical wiring for connection of AC power.

In addition to the tremendous water-saving potential of the new generation of “no-hands, no-touch” controls for faucets, toilets, and urinals, these devices help address occupant concerns about disease transmission via contact with bathroom surfaces and fixtures.

Action Moment

Electronic controls can be retrofitted or installed with new fixtures to produce tremendous water savings. Some facilities report a 70% water savings. This type of on-demand system also produces proportional savings in water, heating, water treatment, and sewage. When retrofitting or remodeling, consider the use of electronic controls to make a major impact on water consumption.

Technical Information

The operation of an electronic fixture depends on an infrared (IR) signal whose continuous beam is interrupted by the approach of a person. In the case of a faucet with IR, the individual’s hands enter a detection zone, the beam is broken, and a solenoid valve actuates to deliver the stream of tempered water. The reverse process occurs when the hands are removed. Toilets and urinals employing this technology actuate when the user steps away.

1 **Some brands of no-hands faucets** are equipped with timers to defeat attempts to alter their operation.

2 **A 10-second handwash typical of an electronic faucet** will consume only 0.6 liter (1 pint) of water. A 10-second cycle is required as a minimum by the American Disability Act.

3 **Electronic controls can also be used** for other purposes in order to reduce resource consumption in restrooms, creating an “electronic restroom.” Sensor-operated hand dryers are very hygienic and save energy by automatically shutting off when the user steps away. Soap dispensers can be electronically controlled. Electronic door openers can be employed to further reduce contact with bathroom surfaces.

4 **Electronic fixtures are particularly useful for handicapped installations** and hospitals, greatly reducing the need to manipulate awkward fixture handles and removing the possibility of scalding due to improper water control.

5 **No-touch faucets are available** with (1) the sensor mounted in the wall behind the sink; (2) the sensor integral to the faucet; and, (3) the sensor mounted in an existing hot- or cold-water handle hole and the faucet body in the center hole. For new installations, (1) is the best choice, while (2) and (3) are better for retrofit or renovation.

6 **At sports facilities** where there is heavy use of urinals, the entire restroom can be set up and treated as if it were a single fixture. Traffic can be detected and the urinals flushed periodically based on traffic rather than per person. This greatly reduces water flow.

7 **Computer controls can be used** to coordinate water usage to divert water for fire protection when necessary.

Thermostatic valves can be used with the electronic faucets to deliver water at a preset temperature

1 **A 24-volt transformer** operating off a 120-volt power supply is typically utilized. The transformer should be UL-listed. For security, the transformer and the solenoid valve can be remotely located in a chase. Some versions are available with a 5-year-life lithium battery.

2 **Solenoid valves** should be industrial-grade with long service life.

3 **A dual-beam IR sensor**, or a variety with color recognition, should be specified because they function better for dark skin.

4 **For hospitals or other medical facilities**, electronic fixtures should be used to the maximum extent possible because they can help the health care professionals meet the OSHA protocols for handwashing after patient contact. These devices can control soap dispensing, the soaping and rinsing time, and the use of paper towels for drying.

5 **No-hands faucets utilizing electronic controls** make cleaning much easier since there are no handles in the way. The industrial-grade solenoid valves used in these devices are far more durable than their mechanical counterparts and are virtually unaffected by chemicals and other constituents of the water supply.

6 **Some manufacturers estimate a payback period** of less than 6 months when changing a conventional for an electronic fixture. This includes cost savings in water, energy, and maintenance of electronic fixtures.

References

Marsch, Donald R. "Getting a Hand on No-Hands Fixtures," *The Construction Specifier,* August 1990, pp 61- 66.

Reclaimed water is one of several forms of water reuse. Specifically it is water from a wastewater treatment plant (WWTP) that is diverted into another use such as landscape irrigation or fire protection. In some areas of the United States, reclaimed water may be referred to as Irrigation Quality or "IQ" water.

Since the beginning of the century, per capita water use in the United States has quadrupled. Americans typically consume between 270 to 450 liters (60 and 100 gallons) per capita each day.

The use of wastewater for non-potable uses can greatly reduce the demand on potable water sources and its use is encouraged by diverse organizations such as FEMP, EPA, and the American Water Works Association (AWWA).

Action Moment

Facility managers with buildings in an area with chronic water shortages should check with their local wastewater utility and inquire if they have a program to provide reclaimed water to the building's location. Reclaimed water programs are particularly popular in California, Florida, and Texas. If the government facility or base owns a WWTP, it may be a good idea to determine the feasibility of modifying it to provide reclaimed water for applications that do not require potable water. There are a whole host of potential applications for reclaimed water: landscaping, golf course, or agricultural irrigation; decorative features such as fountains; cooling tower makeup; boiler feed; once-through cooling; concrete mixing; and fire main water. Note that the use of reclaimed water may be restricted by code.

Technical Information

1 **For a successful reclaimed water project** one or more of the following ingredients is required: (1) high- cost water or lack of a high quality freshwater supply; (2) local public policy encouraging or mandating water conservation; (3) availability of high quality effluent from a WWTP; and, (4) reuse must be the most cost-effective means of wastewater effluent disposal.

2 **Piping and valves used in reclaimed water** systems must be color coded with purple tags or tape in accordance with AWWA standards. This minimizes piping identification problems and cross-connection problems when installing systems. The AWWA also recommends the liberal use of warning signs at all meters, valves, and fixtures. Note that potable water mains are usually color-coded blue, while sanitary sewers are green.

Reclaimed water should be maintained at 69 kPa (10 psi) lower pressure than potable water mains to prevent backflow and siphonage in the event of accidental cross-connection. Although it is feasible to use backflow prevention devices for safety, it is a far better practice never to connect reclaimed and potable water piping directly. One additional precaution is to run reclaimed water mains at least 30 centimeters (12 inches) lower (in elevation) than potable water mains, and separate them from potable or sewer mains by a minimum of 1.5 meters (5 feet) horizontally.

The quality of the reclaimed water must be reviewed in order to assure there will be no adverse effects from long-term use such as landscape damage due to salt buildup.

In St. Petersburg, Florida, perhaps the major municipal innovator in reclaimed water use, over 2,200 hectares (5,500 acres) of greenspace are irrigated by reclaimed water. In addition, over 7,300 customers are served with reclaimed water, creating a daily mean demand of 90 million liters (20 million gallons) a day. The water is supplied to commercial and residential customers via a "third" main consisting of over 130 Km (80 miles) of piping that ranges in size from 5 to 122 centimeters (2 to 48 inches) in diameter. The system also serves 289 fire hydrants and numerous building fire protection systems. The William C. Cramer Federal Building, operated by the GSA, is connected to this system. It saved 6.4 million liters (1.4 million gallons) of fresh water in 1992. Built in 1967 and housing 900 employees, it has more than 1,400 square meters (15,000 square feet) of turf, 17 trees, and hundreds of shrubs. The success of using reclaimed water for irrigation has prompted the GSA Field Office Manager, John F. Bennett, to plan the use of reclaimed water for cooling tower makeup water.

Although water prices vary greatly around the country, reclaimed water costs significantly less than potable water. For example, in Jupiter, Florida, the price of potable water is now $0.37/1000 liters ($1.70/1000 gallons) versus $0.06/1000 liters ($0.26/1000 gallons) for reclaimed water. Similar pricing differences occur wherever reclaimed water is available.

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Water Environment Federation, 601 Wythe Street, Alexandria, VA 22314-1994. (703) 684-2400.

American Water Works Association, 6666 West Quincy Avenue, Denver, CO 80235. (303) 794-7711

Water is a critical resource in many regions and relatively extreme measures for the optimal use of water are sometimes necessary. A significant amount of potable water can be readily reused for various non-potable purposes. *Graywater* is water from showers, baths, bathroom sinks, and drinking fountains. It contains a minimum amount of contamination and, with minimal processing, can be used again for non-potable applications. *Blackwater* is heavily soiled water from toilets, urinals, and from kitchen sinks. Blackwater—laden with fat, oil, and grease— is difficult to process and reuse compared to graywater. Both graywater and blackwater contain pathogens, and must be treated prior to any reuse. Humans should avoid contact with either before treatment. *Rainwater* is another excellent source of water. It can be collected in cisterns for use in a wide variety of non-potable uses with little or no treatment. A rainwater cistern can also serve as an emergency supply of drinking water if appropriately treated prior to use.

Action Moment

Installation of graywater and rainwater harvesting systems requires significant modifications to existing building plumbing and other elements. Both are appropriate for significant building renovations requiring extensive retrofit or remodeling of an existing structure. Buildings with crawl spaces are far more amenable to plumbing system retrofits than those with slab-on-grade construction, where runs under the slab.

Technical Information

1 The basic steps in graywater recycling are: (1) collect the water from sinks, showers, washers, baths, and other sources of non-fecal, non-food laden water; (2) pipe the water to a treatment unit for physical, biological, and chemical treatment; and, (3) store the water and pump it to its ultimate end use.

Graywater can be used for irrigation, for toilet or urinal flush water, for ornamental ponds, and for cooling tower water makeup.

2 The National Sanitation Foundation's Standard 41, which regulates the minimum water quality for recycled wastewater, is shown in the table below.

Component	Maximum Limits
BOD	5 mg/l
Suspended solids	5 mg/l
Total coliform	2.2 counts/100 ml
Turbidity	1 mg/l
Nitrogen removal	85 - 95%

For sites not served by public sewer, a *combined wastewater treatment/recycling system* may be considered. These differ from graywater systems in that all the water, both graywater and blackwater, is collected and treated. In addition to its use in toilet/urinal flushing and landscape irrigation, water from combined systems can be used as the supply water for ornamental ponds.

Prices for combined wastewater treatment/recycling systems range from $70,000 for a unit serving 100 people to $450,000 for a unit serving 2,500 people. The relatively high cost of this equipment results in it being leased far more often than being purchased.

When sizing graywater or other water conservation systems, keep in mind the following assumptions on toilet use: (1) half of the occupants are men and half are women; (2) men use a toilet 24% of the time and a urinal the remaining 76%; (3) women use a toilet 100% of the time; (4) each occupant uses the sanitary facilities three times per day over an 8-hour period; (5) sink use consumes

1.1 liter (0.25 gallons) of water per use; and, (6) the additional contribution from urine to flow volume is assumed to be 0.32 liters (0.07 gallons) per fixture use.

Recycled water can be stored only up to 48 hours before use or discharge to the municipal sewer. The size and storage capacity of the recycled water system must take this into account.

Recycled water such as graywater must not come into contact with people. Any use in irrigation should be via subsurface trickle irrigation systems.

A maintenance program for graywater systems should include: (1) inspecting the system for leaks and blockages; (2) cleaning and replacing the filter bimonthly; (3) replacing the disinfectant; (4) ensuring that controls function properly; and, (5) periodically flushing the entire system.

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Stormwater is precipitation that does not soak into the ground or evaporate, but flows along the surface of the ground as runoff. The management of stormwater involves a combination of treatment technologies and strategies to reduce both the runoff itself and the amount of pollutants that enter the runoff.

Action Moment

If chronic stormwater problems occur, conduct a comprehensive, in-depth engineering analysis of the facility or installation.

Technical Information

A stormwater analysis will include: soil analysis, topography mapping, peak flow calculations, runoff characteristics. It will also quantify the vehicular pollutants that reach the runoff stream, such as, oil, gas, detergents, and cleaners. Fertilizers, pesticides, herbicides, and other landscaping treatments also contaminate stormwater and their quantity must be measured in the analysis.

The locations around the facility that are typical sources of stormwater contamination are: parking lots, maintenance shops, car-washing areas, and landscape zones that receive treatments of chemical fungicides, pesticides and fertilizers. Construction operations that involve soil movement can also cause significant stormwater pollution.

There are numerous techniques for storing and treating stormwater runoff. Best Management Practices (BMP) define appropriate designs for permanent stormwater treatment facilities. However, before these costly facilities are built, all simple techniques should be examined for applicability. Natural stormwater runoff and ponding systems also can be attractive water features.

Stormwater Management Practices

1 **Reduce stormwater production** by minimizing land disturbance.

2 **Minimize impervious surfaces.** Preserve original topography, vegetation and landforms as much as possible. Separate impervious surfaces with turf, gravel, or vegetation to increase infiltration. Use porous paving and avoid curbs where possible. Curbs increase the concentration of pollutants. When there are no curbs, rainwater runs directly off driveways, sidewalks, and roads, into the ground.

3 **Reduce pollutants in stormwater.** Minimize use of road salt, sweep streets regularly, reduce animal waste, and reduce car use. Reducing reliance on cars can be achieved through emphasis on public transportation, bicycle and pedestrian paths, and car-pooling. Avoid the use of pesticides and fertilizers in the landscape. Significant sources of pollution such as refueling areas, gas stations, and high- use parking lots should have specialized runoff collection and pretreatment facilities. Discourage dumping of motor oil, antifreeze, and other hazardous wastes into storm drains. Be sure to post warnings on drains.

4 **Manage stormwater runoff at construction sites**. Construction activities can cause high stormwater runoff, erosion, and pollutants discharged into streams and rivers. Ensure that heavy equipment is reliable and well-maintained and does not leak hydraulic fluid, oil, and fuel. Avoid soil compaction because heavily compacted soil absorbs water less efficiently. Regrade and plant disturbed areas as soon as possible. Minimize slope modifications by designing landscaping to consider the original topography of the site. Erect temporary barriers such as straw bales to capture sediment in runoff.

On-Site Stormwater Management

1 **Dry Retention Ponds.** Most dry retention ponds, designed to temporarily hold water and release it gradually through an outlet channel, are fully drained between storms. They are not very effective in removing pollutants because pollutants do not have a chance to settle and break down.

2 **Retention Ponds**. Retention ponds hold water at all times with excess volume for handling water from storms. Shallow ponds are most effective, with the entire depth totally mixed, creating an anaerobic condition that assists pollutant breakdown.

3 **Constructed Wetlands.** Although similar to retention ponds, constructed wetlands are created as shallow marshes with an appropriate variety of plants.

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Contacts

Center for Watershed Protection, 8737 Colesville Road, Silver Spring, MD 20910.

Florida Department of Environmental Regulation, Stormwater/Nonpoint Source Management, 2600 Blair Stone Road, Tallahassee, FL 32399-2300.

Northeast Illinois Planning Commission, 222 S. Riverside Plaza, Suite 1800, Chicago, IL 60606. Tel: (312) 454-400; (312)454-0411 fax.

Almost 70% of the total energy invested in a building's construction is embodied in the materials themselves. Embodied energy is the energy required to extract, transport, process, install, and dispose of, or recycle the materials that make up the building. Critical resource depletion and pollution resulting from excessive use of virgin materials requires facility managers to consider alternative choices. The goal is to make the building more environmentally friendly while maintaining or improving its functional and energy performance.

Action Moment

Any renovation or addition presents facility managers with the opportunity to make environmentally sound materials choices.

Technical Information

1 **Environmentally sound alternatives** to traditional materials can be chosen by looking at the net impacts of the material use on the environment and humans. This impact will be realized through the direct effects of the material itself or the impact that the material has on other resources, such as fossil fuels used for to generate energy. Alternatives to traditional materials in construction and renovation are at the low end of the materials processing stream, requiring minimal energy to transform them from raw materials to finished building products.

2 **"Guidelines for Procurement of Products That Contain Recycled Materials,"** mandates that federal agencies and construction projects that receive federal funds should buy environmentally preferable materials when more than $10,000 is spent on a particular material. The use of recycled-content materials generates many direct environmental benefits, as well as the indirect benefits of supporting U.S. businesses that manufacture recycled materials.

Embodied Energy of Building Materials

Material	Energy Intensity
(MJ/kg)	
Cement products	
Concrete	1.2 - 2
Mortar	1.4 - 2.2
Cement	4.9 - 7.4
Wood	
Lumber	4 - 7
Particleboard	14 - 20
Plywood	18
Nonmetallic minerals	
Brick	2.8 - 5.8
Gypsum	1.4 - 7.4
Glass wool	14.0 - 23.4
Glass (sheet)	10.2 - 21.6
Plastics	
Paint (water based-dry)	76.0 - 77.7
Polyethylene	49.3 - 87.0
Polystyrene	105.0 - 122.8
Metals	
Steel	25.7 - 39.0
Zinc	43.2 - 68.4
Nickel	58.0 - 168.3
Aluminum	145.0 - 261.7

Source: Cole & Rousseau, 1992.
Note: Energy intensities in extracting, processing, and manufacturing selected materials are in mega-joules per kilogram (MJ/kg). This table does not include energy for transporting, installing, and disposing of the materials.

3 **The most commonly accepted measures** of the environmental impacts of building materials are embodied energy, CO_2 emissions, and air pollution as measured by Air Emissions Indices.

4 **Materials that are highly refined or toxic** in their original state should be avoided. This is the case in spite of the ability to process some of this toxicity out of the product.

Materials Selection Plan. The selection of materials involves a decision-making process that takes many factors into account. The analysis involves planning and evaluation and should include the following actions.

1 **Assess the material** for its suitability for the planned use.

2 **Examine the first cost** of the materials. This includes the cost of the materials themselves and the cost of installation.

3 **Examine life-cycle costs,** considering the following: operational cost (high R-value insulation will lower operation costs); replacement cost (wear-resistant materials reduce replacement frequency); maintenance cost (non-fibrous materials require less maintenance); residual value (metals are easily recyclable); and resale, salvage or disposal costs or benefits (high-quality and handcrafted materials will acquire value over time).

4 **Locate an environmentally-sound** alternative to the planned use.

5 **Research code acceptance.** If code approval for environmental alternatives is problematic, the demand for materials will encourage producers to invest in testing to obtain code acceptance.

6 **Determine the availability** of the material from local sources and weigh the trade-offs from obtaining materials that are not locally available but have good environmental attributes.

7 **Examine producer's qualification/criteria** including the Material Safety Data Sheet (MSDS), certification of environmental qualities, especially third-party certifications, and test data. Specify materials options based on low-toxicity criteria such as water based products, non-laminated products, and mechanical fastening systems.

Third party eco-labeling and certification programs can be useful tools for selecting material. There are several certification programs for sustainably harvested wood, as well as programs for certifying specific environmental claims made by manufacturers for specific products.

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Center for Resourceful Building Technology, PO Box 100, Missoula, MT 59806. (406) 549-7678

Center for Maximum Potential Building Systems Inc., 8604 FM 969, Austin, TX 78724. (512) 928-4786 or at http://www2.maxpot.com/maxpot

Cross Creek Initiative, 117 NW 16th Ave., Gainesville, FL 32601 (352) 371-3718.

Floor coverings include carpet, cementitious materials, stone, marble, ceramic and clay tile, wood, and sheets or tiles made from vinyl, linoleum, rubber, and cork. The conventional criteria for floor covering material selection include: wear resistance, slip resistance, and aesthetics. Environmental considerations for floor coverings include the resource efficiency of the source materials, the additives used to install and finish them, their potential to create indoor air quality problems, and their disposal/recycling at the end of their useful life. Floor coverings can be integral to the building floor structure, mechanically fastened, or chemically bonded.

Action Moment

Depending upon the ease of removal, durability, amount of traffic, and changes in space usage, opportunities for replacing existing floor coverings can occur relatively often during the life cycle of a building.

Technical Information

The composition and units of floor covering material determine the flexibility of repair and replacement, and the ability to disassemble and separate the components for recycling. The factors to be considered are: the use of composite materials; modularity; and attachment methods, either chemical bonding or mechanical fastening.

1 **Carpet is the most common floor covering in office settings** and also a major source of indoor air contamination. The styrene butadiene latex rubber used to adhere face fibers to backing materials and the adhesives used to install carpets generate volatile organic compounds (VOCs) including 4-PC, a known carcinogen. Carpets that cover large surfaces within an interior environment also provide "sinks" for the absorption of VOCs from other sources.

2 **Cementitious materials** provide opportunities for integrating the floor finish with the building structure. They provide durability and low maintenance, and provide the opportunity for using recycled materials, as in terrazzo-type finishes.

3 **Stone and marble** are low-embodied-energy materials, low maintenance and durable, and regional sources can save transportation costs. Cementitious mortars and grouts reduce the presence of VOCs associated with other types of flooring. Ceramic and clay tile utilize plentiful, low-embodied-energy materials. Glazes are typically energy-intensive and produce pollutants in their manufacture. Durable materials and tough finishes provide a long floor life. However, they also make separation of the base materials for recycling more difficult.

4 **Wood floors provide optimal environmental benefits** by the use of a renewable and long-lasting material and the ability to disassemble and reuse or recycle the flooring at the end of its useful life.

5 **Sheet goods include vinyl, linoleum, rubber, and cork**. These are available in rolls or tiles and require the use of adhesives for installation. They are typically made as composites with several layers: facing, body and backing. Vinyl and linoleum are low cost, durable, and low maintenance. They also are extremely difficult to recycle. Rubber flooring is available with a high recycled content. Cork is an excellent sound-absorbing material and is recyclable.

Facility managers can make cost-effective qualitative improvements in the interior environment of their buildings by using high-quality and environmentally sound materials in appropriate locations depending on visibility, function, and traffic volume.

1 **The EPA's recommended guideline for recycled carpet content** is 100% recycled polyethylene terepthalate (PET) from recycled plastic soda bottles. Several major U.S. carpet companies produce commercial carpets with 100% recycled PET face fibers. Several companies make carpet cushion materials that utilize recycled and natural materials such as recycled post-industrial fibers, recycled polyurethane, and jute and hair.

2 **Alternatives to commercial carpets** installed in rolls with adhesives containing VOCs include carpet tiles with backings, and "tackless" installation. Carpet tiles allow for the replacement of individual tiles when they are soiled or damaged. Fusion-bonded carpets use heat instead of adhesives to bond the face fiber to the primary backing, thereby reducing VOCs that are introduced into the building by the carpet.

3 **Wool carpet is naturally flame resistant**, durable, and provides excellent indoor environmental quality. Linoleum is made from renewable and nontoxic materials. Ceramic tile is available that is made from recycled glass or recycled mine tailings.

4 **Installing carpets** in strict accordance with the Carpet and Rug Institute guidelines as well as additional measures such as requiring suppliers to unroll and air-out carpets in the warehouse before bringing them into the building will minimize the risks of indoor air quality problems resulting from carpet.

5 **"Ever Green" lease** is a new idea in floor covering whereby carpet manufacturers take complete responsibility for the carpet and maintain the carpet for the life of the facility for a monthly charge. Leased carpet will have the lowest first cost and the carpet is typically recycled at the end of its lease period.

Carpets should never be installed near entrance doors or areas where moisture and organic matter can contaminate them. Carpet fibers are an excellent medium for dust mites and microbial agents, especially if the carpet becomes wet and cannot be properly dried.

The use of sealers and varnishes causes high levels of VOCs during installation. Their release into the interior environment and subsequent absorption by other sink materials, such as drywall, allows for their re-release into the space over time.

Because floor coverings are a large source of VOC contamination and a medium for agents that affect IAQ, facility managers should consider the many recent lawsuits involving public buildings with IAQ problems. High-aesthetic and environmental-quality floor covering may be the most expensive choice. This may require facility managers to make choices that do not have quantifiable dollar paybacks.

References

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Contacts

The Carpet and Rug Institute, PO Box 2048, Dalton, GA 20722. (706) 278-3176

Wall coverings include the use of sheathing materials and coatings that provide fire proofing, acoustical absorption, impact and moisture resistance, light reflectivity, and aesthetic qualities. Gypsum board is a sheathing material made from gypsum, paper facing, and binders. Typical gypsum board uses 100% recycled paper content in the facing. Other types of wall sheathing include recycled paper products, composites of paper and gypsum, and other fiber-based materials such as cork and wood. Paint and wall coverings are a common source of volatile organic compounds (VOCs) that can affect Indoor Air Quality (IAQ). Environmental concerns with the use of wall coverings are: the source materials, the additives used to install and finish them, their potential to create indoor air quality problems, durability, and disposal/recycling at the end of their useful life.

Action Moment

Apart from interior fixtures such as furniture, the most flexible components of a building are interior fixtures, the interior space partitions, and finishes. Any change in space usage will require the alteration of fixtures, interior partitions, and finishes and be an opportunity to use more environmentally sensitive products.

Technical Information

1 **Paints, stains and varnishes are liquid surface coatings** composed of four main parts: carriers, binders, solids, and the pigments that give them their color. Paints and varnishes provide moisture and wear resistance for surfaces, which in turn increases their life span. Water-based substitutes are available for most solvent-based coatings to reduce the presence of volatile organic compounds (VOCs). Light-colored paints typically have the lowest concentration of VOCs due to the absence of coloring pigments. Low-VOC paints contain less than 250 grams/liter of VOCs, excluding the water in the paint.

2 **Vinyl wall coverings provide moisture resistance** for "wet" areas such as restrooms and food preparation areas. Vinyl is produced from vinyl chloride, which results in the production of vinyl chloride monomer, a known carcinogen. Vinyl wall coverings also can be sources of VOC emissions. They also act as vapor barriers on exterior walls, creating the potential for moisture buildup in the wall cavity and subsequent microbial growth.

3 **Wallpaper application systems** can be water-based or solvent-based, strippable or non-strippable. Strippable wallpapers allow for the removal of wall papers without energy-intensive stripping processes. Water-based adhesives contain lower VOC levels than solvent-based adhesives, but are potentially lower performance. Therefore, they require more attention to the weight of the paper, location, and quality of installation for their successful use.

4 **Wall coverings can be a significant sink for VOCs**, depending on their area, porosity, and texture. These same qualities also provide acoustical absorption. The integration of low-maintenance and durable wall coverings with acoustical performance requires consideration of the wall geometry, height, and location.

5 **Light-colored wall coverings** can bounce daylight from perimeter windows or interior skylights throughout interior spaces.

There are many environmentally sound alternative wall coverings available on the market. Examples include: water-based low-VOC paints, natural fabric wallpapers, recycled-content papers and recycled-content synthetic fibers. Composite laminates and veneers are also available with recycled content and low-toxicity binders.

1 **Facility managers should ensure scheduling of drying times** for wet-applied finishing materials, such as paints and adhesives, to avoid

the accumulation of VOCs in the interior environment and protect installers from high levels of exposure.

2 **Renovations that occur adjacent to occupied spaces** have the potential for allowing the infiltration of VOCs from work areas to occupied spaces. Facility managers can ensure that precautions are taken to seal off work spaces from occupied space and to isolate entrances and storage areas from occupied spaces. Additional ventilation may be required during construction to remove VOCs.

3 **Non-urea-formaldehyde-based laminates** can provide an extremely durable and low-maintenance wall finish and act as encapsulation material for gypsum board, joint compounds, and primers that combine to form the interior wall sheathing. Joint compounds typically contain high levels of VOCs. Water-based wallboard joint compounds are commercially available.

Water-based paints and sealers can have lower covering performance than solvent-based paints, negating some of their environmental benefits. Low-VOC water-based paints are also limited to shades of white.

Vinyl wall covering should be avoided at all costs on exterior walls, particularly where cool inside temperatures will cause condensation of warm, moist air on the wall cavity side of the interior vinyl wallpaper. They should be used where the generation of high humidity will allow moisture to accumulate on wall surfaces, and where resistance to stains and chemicals is necessary.

Natural fibers are renewable and biodegradable, but typically must be imported into the United States. Other drawbacks can be poor durability, and the presence of chemical treatments for insect, fungi, and stain.

Wall coverings are available in a wide palette of environmentally sound alternatives, and many of these products can have beneficial impacts on occupant comfort and productivity. At the same time, cost and functional constraints will always require selectivity to ensure improvement in the quality of the indoor environment.

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Buildings provide services through the distribution of resources. These resources include energy, water, food, office supplies, packaging, and maintenance. By-products from using these resources include graywater; blackwater; waste heat; food waste; paper; cardboard; plastic; metals; glass; and various other liquid, solid mineral, and chemical wastes. The three R's of resource conservation, "Reduce, Reuse, Recycle," provide a hierarchy for decision-making to cost-effectively minimize waste.

Recycling helps keep reusable materials out of landfills, and may provide an income stream for agencies.

Action Moment

The generation of waste in any building provides opportunities for reduction and recycling. The ability to reduce and recycle is enhanced by good operational planning and by minor facility alterations to provide for the collection and storage of building-generated wastes.

Technical Information

Issues related to recycling some basic materials are outlined below:

1 **Metals.** Steel, copper, aluminum, brass, mercury, and zinc from appliances, light fixtures, cladding, flashings, plumbing, wiring and structural materials are the most valuable recyclable materials. Metals are also easily recovered and can be reconstituted back into new metal products of the same quality.

2 **Cardboard and paper.** Cardboard and paper comprise the single largest component of municipal landfill waste, but are also easily recycled. They can be relatively high-value because of timber supply fluctuations in the Northwest United States and the sheer volume of paper products used in this country. Cellulose insulation, made from recycled newspaper and telephone books, is gaining in popularity. Dry and clean cardboard is preferable for recycling operations. Fluctuations in the price of wood can cause oversupply of recyclable cellulose material. White office paper compromises only 2% of the municipal solid-waste stream. However, the cost to the economy of using this paper is over $40 billion annually—greater than the entire cost of landfill, incineration, and recycling.

3 **Plastics.** Plastics are problematic for recycling because they are often combined with other materials in composite assemblies. It is necessary to separate monopolymer plastic from copolymer plastics or materials that contain several types of plastics. Plastics such as polystyrene and polyethylene can be recycled. PVC has been problematic for recycling but advances are being made to increase its recyclability.

4 **Glass.** The color of the glass is the main consideration for recycling glass. Clear glass is recyclable for more purposes than colored glass. Glass can be recycled into a variety of other products, including new glass (given uniformity of color); fiberglass insulation (major manufacturers of fiberglass batt insulation use at least 20% recycled glass and can use as high as 40% recycled content); asphalt shingles; concrete aggregate; brick; ceramic tile; and siding. Glass aggregate has also been used for drainage fill.

5 **Rubber.** Tires and other rubber products can be recycled into flooring materials, low-grade industrial uses, road surfacing amendments, and car and boat bumpers.

Recycling opportunities are material- and location-specific, depending upon the recycling programs and businesses that are established within economically-viable distances from the facility. The feasibility of recycling depends on the consistent supply and quality of the recovered resources to support businesses that deal in recycling. Large-scale operations can form partnerships with local recycling businesses in symbiotic relationships.

1 **Promoting recycling** promotes value-adding within the community and community resource self-sufficiency. All of the jobs and processes that add value to recycled materials generate economic benefits that remain within the local community.

2 **A comprehensive building waste reduction and recycling program** can address opportunities for resource conservation. Programs typically: (1) address the purchasing practices used in the facility; (2) inform occupants of the actions they can take for reducing and recycling; and, (3) establish goals and monitoring to achieve the maximum feasible degree of materials use efficiency and recycling.

3 **Plan for waste collection areas** for recyclables, including several vertical chutes in multistory buildings, each designated for a major waste category, such as metals, papers, and plastics.

4 **Fluorescent light tubes**, computers, and other types of office equipment can be reused and recycled, including replaceable components such as toner cartridges. Oils and ethylene glycol from vehicles can be recycled. The generation of paper and polystyrene wastes can be reduced by double-sided printing and copying, and the use of washable units.

5 **Composting** is the highest level of waste resource use after recycling, and can provide high-grade soil amendments for landscaping and food production. Facilities with large amounts of food, paper, and yard wastes provide excellent opportunities for producing compost for landscaping and gardens.

References

National Audubon Society and Croxton Collaborative Architects, *Audubon House: Building the Environmentally Responsible, Energy-Efficient Office*, John Wiley & Son, Inc., New York, NY, 1994.

The amount of waste from construction projects can be as high as 15% of all materials used in the project. The percentage of construction and demolition (C&D) waste volume in a typical municipal landfill in the United States is estimated to exceed 25%. Increasing tipping fees and diminishing landfill space are direct consequences of C&D waste production. Wastes that contain nondegradable substances create long-term hazards to both human health and the health of the ecosystem. Reducing waste lowers disposal costs and lowers the amount of new materials required by 10% to 15%. It offers opportunities for recovering costs from the sale of recyclable and salvaged materials. Waste reduction occurs through design and planning of construction operations, including building renovation.

Action Moment

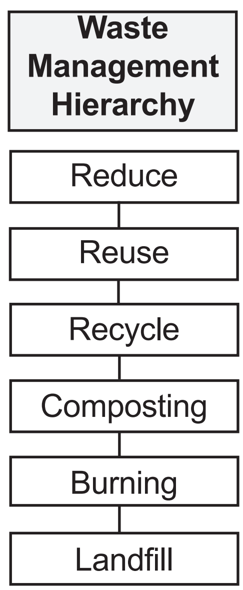
Opportunities to reduce, reuse, and recycle materials occur at all stages of the building process, from design through demolition, for all material components of the building.

Technical Information

1 **Pre-construction meetings to set up** a Waste Management Plan with subcontractors and contractors will both inform the facility manager of the feasibility of job-site waste reduction and recycling, and inform the subcontractors and contractors of the intentions of the facility manager.

2 **Where feasible, "reverse distribution"** to manufacturers of construction and demolition waste can be a significant aspect of the waste management program. Reverse distribution entails returning unused, waste, and salvaged materials to the original manufacturer. This process requires cooperation among builder, owner, material distributor and manufacturer, as well economical distances between the job site and the factory.

3 **There are several issues** regarding buildings and materials that aid in reducing resource consumption. For example, adaptive reuse of existing buildings reduces materials needs and the waste of existing resources. Prefabricated units are built to better tolerances, reducing construction waste.



The simplest measure a facility manager can take to prevent job-site waste is to minimize packaging waste by requiring suppliers to keep packaging materials.

The three R's of resource conservation that apply to construction operations are Reduce, Reuse, and Recycle. Both unused and recovered materials can be used in new construction on the job-site. Recycling can occur on-site, for example, by using waste wood for mulch, and waste concrete for non-structural fill. Recycling can occur off-site at materials recovery facilities (MRF). Some businesses reclaim materials for re-manufacture into new products.

Construction Waste Management Plan. Specifications should include the following requirements for waste management:

1. **Assign individuals** on the contractor's staff to facilitate waste reduction and management.

2. **Perform a waste audit** on each job to determine which materials can be recycled in the local area.

3. **Establish contacts** with local recycling companies to set up the lines of responsibility: who is responsible for which materials, pickup schedules, and standards of quality for recycled materials.

4. **In retrofit or renovation projects,** arrange for the location of recycling bins, assign responsibility, and determine what organization will claim the "waste." Valuable recyclable materials, especially architectural ornaments and high-value metals or heartwood, can be sold, reducing overall costs.

5. **Site-separate all waste for recycling,** and store in separate secure containers. Containers can be set aside for wood, plastics, cardboard, metals, glass, drywall, and non-recyclable waste. Ensure that the bins are not contaminated by other waste materials.

6. **Educate employees and subcontractors** about recycling and have pre-construction meetings to inform each trade that they are responsible for their own waste recycling. The best method is to make recycling a requirement in all contracts because the contract is enforceable.

7. **Establish a defined area for the operations of each trade**, especially wood cutting, so that off-cuts will be kept in one area and can be sorted by dimension for future reuse.

If waste management is not specified in contract documents, it will not be covered in bids. It either will not be done or there will be additional charges in the form of a change order.

Typical Composition of Building C & D Wastes in the United States

Material Type	Percent (%) by Mass	by Volume, Yd^3
Steel and iron	2.73	0.05
Copper	0.02	negligible
Lead	0.06	negligible
Aluminum	negligible	na
Concrete	53.75	0.90
Brick	21.21	0.35
Wood	22.01	1.10
Glass	0.22	negligible
Plastic	negligible	na
Total	100%	2.40

Source: Lund, 1993.

Waste management also includes disposal in the most environmentally benign way when all other resource-efficiency measures have been utilized. The most environmentally benign disposal method is biodegradation. Hazardous wastes must be disposed of separately from other disposable waste.

There are often several options for on-site disposal of waste building materials. An example is the practice of placing gypsum wall board off-cuts into stud cavities or grinding it up for use as a soil amendment. Both of these practices are convenient for drywall subcontractors but should be examined for their true environmental benefits and costs.

References

Lund, H.F., ed., *The McGraw-Hill Recycling Handbook*, McGraw-Hill, NY, 1993.

Contacts

For information about waste management, recycling, and recycled content building materials, contact Portland Metro, 600 NE Grand Avenue, Portland, OR 97232. (503) 797-1650.

Center for Construction and Environment, University of Florida, Gainesville, FL 32611. (352) 392-7502

Site Selection and Building Orientation 6.1

Site selection has a major impact on the immediate natural community and the future occupants of the building. Thoughtful placement of the building on the site promotes energy conservation by taking advantage of natural site features such as breezes, sunlight, shade, and topography. Minimal site-clearing reduces costs, and undisturbed plant materials may provide a low-maintenance landscape that avoids supplemental irrigation and fertilizer. Mature stands of native vegetation often provide the desired energy-saving shade and wind control that would otherwise require years to develop from expensive new plantings. Distinguish between deciduous and evergreen trees. Evergreens provide year-round sun and wind protection; deciduous trees protect in the summer and expose in the winter—which can be good or bad, depending on climate.

Action Moment

Building orientation is an action step permitting passive design features and non-mechanical measures to conserve energy, utilize solar energy for thermal gain, and direct prevailing winds for natural ventilation and cooling. Natural conditions should be utilized to full potential to reduce the use of more expensive mechanical systems. For example, in the snowbelt, proper building orientation can use the sun and wind to help clear driveways and parking lots naturally.

Technical Information

1 **Site inventory surveys** should be thorough and objective, and consist of foundation, vegetation, and wildlife habitat surveys. A foundation survey includes all structures and physical construction on the site, including topography, soils, and hydrology. Vegetation surveys show the location and character of all important plants. Wildlife habitat surveys recognize unique and dynamic site aspects.

2 **Proximity of trees to structures** and constructed features should take into account growth rate, life span, and ultimate canopy shape. This includes the balance of desirable qualities of shade with loss of future solar access. When existing tree populations are too dense, selective thinning and lifting the canopy will improve air movement, enhance ground- level vistas, and allow remaining trees better development potential. Special care should be used in construction near trees. Important plant areas and trees to be retained should be effectively barricaded to prevent trespass toward the tree closer than the outer perimeter of branches. Tunnel for utility lines instead of trenching near trees. When cutting roots and limbs, cut cleanly. Water well before major cutting to invigorate the tree. When major roots are cut, light canopy pruning will reduce transpiration stresses.

3 **Soil surveys guide plant selection** and irrigation system design. Soil analysis based on random sampling should report soil type, soil pH, total soluble salts, and infiltration rate. Soil texture, percentage of organic matter, and water holding capacity should also be determined. County Agricultural Extension Offices can perform these analyses for a modest fee.

4 **Preserve high-quality habitat** in areas as large and circular as possible and connected by wildlife corridors. High-quality habitat supports a relatively greater diversity of plants and animal life than other nearby habitats. Size of habitat and corridor requirements vary widely by species. Endangered species and species of special concern vary widely by region. For details of habitat protection and corridor design, contact the local office of the state's Department of Natural Resources; or the regional offices of the U.S. Department of the Interior or U.S. Environmental Protection Agency.

5 **Channel development** into areas that are already disturbed. Existing infrastructure, facilities, and cleared areas may be used with resultant savings. Restore and enhance ecological functions damaged by prior site activities that are obsolete. Revegetation, waterway restoration, and habitat reconstruction are immediate opportunities.

6 **Temporary storage** of materials, vehicle parking, and other disruptive construction activities should be limited to areas of the building site that will be permanently altered.

7 **Significant wetlands** and significant uplands should be protected by design. These designations are variously interpreted by region, state, or district. This variability does not diminish the importance of protecting and enhancing these natural features.

8 **Retained wetlands** and natural water bodies should be insulated from construction activities and post-construction site functions by effective upland buffers.

9 **Natural drainage systems** should be used wherever possible. During construction, take all precautions necessary to prevent erosion and siltation of these natural features. Ensure, by design and specification, that water moving off-site from extreme storm events after construction will not cause environmental damage.

10 **Transplant preservable vegetation** from the construction footprint to the landscape site. Ideally done during plant dormancy, with pre-dig invigoration by watering and light feeding, and with incremental digging of rootball, transplanting can occur nearly year-round. When possible, gather seeds prior to disturbing the site for redistribution after construction or for growing under nursery conditions.

11 **Driveways and parking** should be located on the east or north side of buildings in southern climates. This reduces heat buildup during hot afternoons. Existing or installed shade trees can cool these surfaces.

12 **A "wind rose" is a diagram** of annual wind directions and velocity for a particular region. It is useful for plotting information on winds in order to provide natural shielding from adverse winds and utilize favorable winds for passive cooling measures. Wind rose information is available from the nearest airport, reference librarian, or County Agricultural Extension Office.

Existing irrigation systems can be retrofitted with more water-efficient devices. Depending on water source, in-line filters may be needed. Pressure-reducing devices will generally be required to support low-volume watering. Downsizing from high-volume devices to mist, micro-spray, drip emitters, porous pipe, and similar technologies are well understood by professional irrigation specialists. Digitally programmable, multi-zone timers with soil-moisture limiting switches should be used. With low-volume irrigation, many multi-zone systems can be reduced to fewer zones because of water volume reduction per unit time.

Rectangular buildings should be oriented with the long axis running east-west in regions where solar heat gain is a major annual energy burden. Short-length walls receive less direct sun and the total heat load of building is reduced.

Good general landscaping practices allow facility managers to combine immediate action plans with the long-term benefits of incremental improvements in grounds maintenance. The objective is to create landscapes that have positive environmental impacts and reduce energy use.

Good landscaping practices reduce the use of harmful pesticides, minimize use of potable water, and decrease stormwater runoff.Good practices include choosing appropriate plants, irrigating efficiently (if at all), and considering reclaimed waste water or harvested rainwater for irrigation.Other benefits of good landscape include: complementing natural elements of local ecosystems; preserving the inherent beauty and functionality of the site; maintaining and enhancing local eco-structures and functions to increase diversity and vitality; promoting operational integration of natural processes and social processes; and limiting soil compaction.

Trees planted around buildings create a pleasant environment and can cut energy bills.

Technical Information

All landscapes change, grow, and evolve in a process of succession. By sensitively working with these natural dynamics, good landscaping can provide economy, efficiency, and satisfaction for the workforce.

Good general landscape principles consider site functions for humans and wildlife and anticipate cycles of use throughout the day, week, and year. They foresee extremes of climate, annual solar angles with patterns of light and shade, annual direction and intensity of breezes, seasonal color of flower and leaf, and create a dynamic of vista.

1 **Appropriate plant selection** means "using the right plant in the right place." This refers to using native or other plants well-adapted to planting conditions and consistent with the intent of the landscape design. Plant growth rate; mature size; life span; brittleness; and light, water, and soil pH requirements are important factors in selecting vegetation. By matching plant requirements with site realities, and by correctly placing appropriate plants, expensive and time-consuming problems can be avoided. Thoughtful selection and siting of trees, shrubs, and groundcover can cut air conditioning energy use 5% to 20%.

2 **Efficient irrigation** is accomplished by grouping plants with similar water needs. Design irrigation systems to avoid over-watering by using ultra-low volume distribution devices. Irrigate after on-site inspection or electronic sensing of moisture need, rather than by schedule. Water requirements vary greatly by season. As the landscape matures, less irrigation is required—especially when native or well-adapted plants and thick mulch are used. Automatic irrigation controllers should have rain switches that override the on-signal when sufficient rain has fallen or soils are moist.

3 **Reclaimed waste water**, sometimes called Irrigation Quality or IQ water, is another possible source of water for irrigation. It is often available at attractive rates from a nearby utility. It must be scrupulously isolated from potable water distribution, and all IQ hose bibs must be clearly marked as "non-potable." Section 4.3 discusses possible uses of reclaimed waste water.

Rainwater harvesting in specially designed above- or below-ground cisterns can reduce the use of potable water in landscapes. Careful planning is needed that considers anticipated water needs, rainfall patterns, space requirements, engineering design, construction cost, maintaining water quality, and means of actually distributing stored water. Cisterns may have a collateral use as thermal reservoirs for heating/cooling systems. Section 4.4 discusses rainwater harvesting in more detail.

To pave surfaces in landscaped areas, use loose-set masonry units, flagstones, gravel, turf block, "geo-webs" (flexible or rigid synthetic grid structures), crushed shell, mosaics of reused concrete slab, and forestry-derived materials. A bedding of crushed, recycled concrete improves drainage and may serve as a useful application for an otherwise difficult-to-dispose-of material. Poured-in-place pervious concrete may be suitable for some applications. Large expanses of black, unshaded pavement will increase the energy consumption of nearby buildings.

Mulches hold soil moisture; reduce weed growth; slow erosion; build soil texture; increase root density by keeping soil cooler in summer and warmer in winter; and, feed important soil microorganisms, which, in turn, buffer soil pH. Mulches add color, texture, contrast, and definition. Mulches can consist of leaves; grass clippings; shredded wood from site clearing, utility, or commercial sources; pine bark; pine straw; nut hulls; or saw dust. Under deciduous trees, leaf litter eventually becomes mulch if left undisturbed.

Turf grass should be limited to recreational areas rather than used in mass planting. This allows major reductions in water, chemicals, maintenance energy, pollution, noise, and labor. Where turf is used, selection should consider the local climate and growing conditions. Alternatives include various combinations of low-growing ground covers, ornamental grasses, wildflower meadows, and decorative mulches. Turf can be expected to decline as tree canopy density increases. As this happens, a transition to mulch, leaf litter, and/or shade-tolerant plants is recommended.

Graywater from hand-washing sinks may be used directly for hydrating plants—but only in a drip-mode, not sprayed.

Cypress mulch should not be used because its harvest depletes an important tree population.

Crushed stone and pebbles are durable but do not contribute to organic content of soil. They hold and reflect heat, which may increase water needs of nearby plants. Crushed shell also may raise soil pH.

References

Executive Memorandum on *Environmentally and Economically Beneficial Practices on Federally Landscaped Grounds*, April 26, 1994.

Georgia Cooperative Extension Service, *Xeriscape—A Guide to Developing a Water-Wise Landscape*, Atlanta, GA, 1992.

Contacts

For local consulting on landscape and soils issues, contact your local County Cooperative Extension Service or the National Resources Conservation Service.

American Society of Landscape Architects, 4401 Connecticut Avenue, N.W., 5th Floor, Washington, DC 20008 (202) 686-2752 or at Home Page http: //www.asla.org/asla/

Enviroscaping involves landscape modifications using plants to increase or decrease the impact of sun and air movement on the local environment and microclimate. These actions can complement and amplify structural modifications of buildings that are intended to conserve or utilize natural and mechanical energy. Plants provide economical means of modifying microclimate and are an investment in future energy savings. Plants create cooler temperatures by evaporating water from their leaves and, depending on humidity, can lower outdoor air temperature several degrees. A surface covered by plants will produce less glare and make the natural light more pleasant and usable. Energy and water efficiency does not mean wild, ragged, or arid landscapes. A well-designed enviroscape can cut air conditioning use 5% to 20%.

Action Moment

Water-balance the site by retaining stormwater with earth shaping, pervious surfaces, detention, retention, and rainwater harvesting. Swales, berm, and other earth shaping can be attractive design elements. They create hydro-zones for plants with similar water requirements, and can add attractive water features to landscapes. This simplifies irrigation design and reduces the cost of installation and maintenance. Man-made water bodies and earth shapes should be designed for maximum habitat value as well as engineering objectives. Landscape maintenance cannot be avoided, but it can be minimized through good design, planning, and intentions to work with, rather than against, natural processes. Landscapes do not require a severe, clipped, geometric regularity.

Technical Information

1 **Soil humus** is built by incorporating leaf litter and lawn clippings as well as other organic mulches. Plants need nutrients but these are largely created by photosynthesis. They do not need artificial, synthetic, chemical food. Native or adapted plants, suited to site conditions, will thrive with minimum effort and resources. Chipping locally derived wood waste for mulch can be less expensive than disposal and purchase. Apply mulch initially about 3 inches deep—except at trunks of trees, because over-moist conditions can harm bark. Top-dress organic mulches annually as they are metabolized into the soil's food chain.

2 **Weed management** is best achieved by prevention and non-chemical means. Mulch will prevent most weed seeds in the soil from germinating. Weed seeds will still arrive and hand removal before seeds are released is most effective. Weed control in lawns is aided by less frequent mowing, because increasing shade will reduce weed germination. Taller grass will have more photosynthetic surface and cool the soil, grow more vigorous roots and need less irrigation. Hand weeding is less expensive, less dangerous, less noisy, and is healthier for workers and the environment.

3 **Integrated pest management** requires periodic scouting for evidence of disease, pest insects, or other symptoms of deterioration. Simple, manual, nontoxic measures are sufficient if taken early. Recognize beneficial insects. They generally follow pest populations. Understand the useful roles of insect predators like birds, toads, lizards, spiders, and bats. These allies need habitat, shelter, food, water, and freedom from harassment. For environmental, economic, and human health reasons, toxic chemicals should not be used, except on a spot basis when all less toxic controls fail.

4 **Arbors and trellises** over walkways and outdoor activity areas can provide attractive and functional shade. Such shade can benefit nearby walls and windows. Deciduous plants will allow winter sun to provide warmth and light.

5 **Trees are valuable assets** for passively enhancing the interior comfort of small and medium-sized buildings especially in warmer climates.

Once established, most trees require little maintenance. Shade and air movement modification depend on height, growth rate, seasonal leaf persistence, canopy shape and density, seasonal solar angles, wind velocity, proximity, and height of structure. Generally, trunks of trees that grow to less than 40 feet tall can be 10 feet from walls. Trunks of trees growing over 40 feet should be no closer than 20 feet from walls. To allow air movement, lower branches near buildings should be removed as the tree grows.

6 **Shrubs can be wind buffers and guides**. Evergreen shrubs planted closely together and somewhat near a building wall can create a "dead-air" space of thermal insulation to reduce secondary heat loss in winter. In summer, these same shrubs can provide cooling by evaporation and by shading early and late sun from walls. However, maintaining a 2-foot clear-zone between shrubs and wall allows for maintenance access and reduces mildew on exterior surfaces. Where operable windows allow natural ventilation, proper pruning of shrubs will not block air flows or views.

7 **Simple, flowing designs usually require less maintenance**. When choosing and placing plants, an expectation of their mature size and form aids in site selection. The number of plant species is easily limited by creating well-defined areas for planting and by arranging plants in groups to create mass effects. Planting beds around tree groups can simplify trimming, reduce mower damage to tree trunks, and increase mowing speed. Structural edging of planting beds creates a clean line and reduces the need for mechanical edging.

8 **There are many effective, commercially-available, biological controls** that harness pest-specific growth-limiting hormones, predatory bacteria, microorganisms, and other complimentary creatures. If native or hardy adapted plants are used, pest and disease problems generally will never get out of hand. Plants not stressed by over-feeding, over-watering, or extreme cutting will be naturally resilient to predation and disease.

9 **Solid outdoor surfaces** such as concrete and asphalt reflect and retain a great deal of heat and should be kept to a minimum unless these qualities can be made seasonally useful by design.

Invasive, non-native plants vary by region. Because of their potential to invade and disrupt native plant communities and create other environmental burdens, such plants should not be installed and should be removed if already present. While some such plants are merely discouraged, others may be strictly prohibited. Contact the nearest Department of Agriculture for details.

References

Department of Energy, *Cooling Our Cities*, DOE/CH10093-211, Washington, DC, November 1993.

Environmental Protection Agency, *Cooling our Communities: A Guidebook on Tree Planting and Light-Colored Surfaces*, Washington, DC, January 1992.

Arizona Energy Office, *Shading and Landscaping for Energy Efficiency*, Phoenix, AZ 85012 Tel: (602) 280-1402.

Contacts

County Agricultural Extension Office can provide planting information for enviroscapes.

EPA has determined that the average U.S. citizen today spends 90% of the time indoors, and indoor air pollution levels can be up to 96 times greater than outdoor pollution levels. This makes Indoor Air Quality (IAQ) one of the greatest health concerns in this country. Poor air quality can have a significant impact on worker health and productivity.

IAQ Impacts on Health

Category	Sources	Symptoms
Irritation	Formaldehyde, VOCs, combustion gases, particulates, manmade fibers, pesticides	Irritation of skin uppwer airway, eye, nose and throat, headache, erytherma
Pulmonary	Asbestos, combustion gases, formaldehyde, ozone, particulates	Rapid breathing, fatigue, increased infections, pulmonary edema, asthma, allergies, flue-like symptoms
Cardiovas-cular	Carbon monoxide, particulates	Headache, fatigue, dizziness, aggravation of existing pulmonary conditions, heart damage
Nervous System	Carbon dioxide, carbon monoxide, formaldehyde, VOCs	Headache, blurred vision, fatigue, malaise nausea, impaired judgment
Reproduct-ive	Formaldehyde, VOCs	Menstrual irregularity, birth defects
Cancer	Asbestos, radon, combustion gases, VOCs, particulates	Cancer of the lung, stomach, colon

Action Moment

Facility managers should not wait to address known problems of IAQ. Become proactive in identifying and solving problems with indoor air quality. Involve workers in the solution and take their complaints about IAQ seriously. Consider IAQ when renovating spaces, maintaining HVAC and other equipment, or contracting for janitorial services.

Technical Information

Three concepts are used to describe the typical IAQ problem: sick building syndrome, building related illness, and multiple chemical sensitivity.

1 **Sick building syndrome** (SBS) is the condition in which at least 20% of the building occupants display symptoms of illness for more than two weeks, and the source of these illnesses cannot be positively identified.

2 **Building related illness** (BRI) refers to symptoms of a diagnosable illness that can be attributed directly to a defined indoor air quality pollution source.

3 **Multiple chemical sensitivity** (MCS) is a condition in which a person is sensitive to a number of chemicals, all at very low concentrations.

Noise and poor lighting often exacerbate symptoms related to IAQ problems.

Volatile Organic Compounds (VOCs), a major source of IAQ problems, are carbon-based chemicals that evaporate easily and emit vapors. Common sources are paints and carpeting, especially carpet backings and adhesives. VOCs are inhaled and easily transported into the bloodstream. VOC source strengths are more important in determining IAQ than the interior ventilation rate. Emission rates from VOCs can vary by a factor or 100 to 1,000, while the greatest variation in ventilation rates may be a factor of 20, illustrating the relative importances of these two factors in IAQ.

Combustion by-products can create hazardous conditions if allowed to accumulate inside a building. Improper ventilation, inoperative or undersized exhaust fans, and improper pressurization of the building can all lead to buildup of combustion by-products.

Bioaerosol contaminants can occur over time from HVAC maintenance problems and air infiltration. Relative humidity that consistently exceeds 60% can result from operating deficiencies in removing interior moisture. Common causes of bacterial and fungal growth are moisture in walls, wet carpet that does not dry properly, and standing water in air-conditioning condensate drain pans. Other sources of moisture for microbial growth are chronic water spills, leaky plumbing fixtures, and one-time water disasters.

The best strategy in dealing with indoor air pollutants is to eliminate the four main sources of indoor air pollution: (1) VOCs, particularly formaldehyde, in building materials, cleaning products and pesticides; (2) bioaerosols from both indoor and outdoor sources; (3) combustion gases from appliances and automobiles; and (4) particulates from fibrous materials and combustion gases. Poor ventilation can be a major cause of IAQ problems and properly balanced and maintained ventilation systems that provide adequate outdoor air quantities are necessary.

1 **Air handlers** should be easy to clean and tightly sealed, have a minimum of joints and other dust catchers, and have effective filters.

2 **Inspection of air handlers** should be facilitated by good access doors and light- or white-colored surfaces inside the air handlers to accommodate ongoing inspections.

3 **Condensate pans** inside air handlers should drain fully, and any debris should be removed from the pans.

4 **Fresh air intakes** should be inspected to ensure that poor quality air is not drawn into the building from "short circuits" between exhaust and air intakes, or site-specific conditions such as wind patterns. Look for standing water on the roof, bird feces or nests, and proximity to cooling towers, parking areas, waste stacks, exhaust vents, loading docks or other adjacent sources of contamination.

5 **Floor drains** should be refilled periodically to prevent sewer gas from entering the building through dry traps.

6 **Wall-to-wall carpeting** should be minimized, and the use of carpet adhesives eliminated.

7 **Paints and adhesives** should contain no or very low VOCs. Interior painting should be done during unoccupied time, such as weekends. Adequate "airing out" should be done to remove the majority of the VOCs from the air prior to re-occupancy.

8 **Durable building materials** should be used to eliminate the need for strong cleaning chemicals. For example, ceramic tile makes a good substitute for carpeting in entry areas and hallways.

9 **Vinyl wall paper** should not be used on interior surfaces of exterior walls where moisture in wall cavities can condense on the back of the vinyl and harbor hidden mold growth.

10 **"Wet" applied** and formaldehyde-containing wall coverings should be minimized.

11 **Ventilation, temperature and humidity** should comply with ASHRAE Standard 62-1989.

12 **Isolate renovation work areas** with plastic sheeting. Tape-off HVAC ductwork in renovation work areas to prevent dust and debris from entering the ducts.

13 **Newly installed materials,** such as carpets and other flooring products, should be "aired out" before installation.

References

EPA, *Building Air Quality: A Guide for Building Owners and Facility Managers*, EPA/400/1-91/033, DHHS (NIOSH) Publication No. 91-114, December 1991.

American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE) Standard 62-1989, *Ventilation for Acceptable Indoor Air Quality.*

Indoor Air Review, monthly newsletter, IAQ Publications, Inc., Bethesda, MD

Daylighting and artificial lighting are required in order to perform visual tasks, to provide views to the outside, and to provide a connection to the daily rhythms of the natural environment. Sunlight provides an equal spectral distribution of visible light frequencies to produce 'white light' and provides the truest color rendition. Artificial light is limited in the frequencies it can emit, often producing blue- or yellow-tinted light. Lighting levels and distribution can either enhance or detract from the efficient use of both daylighting and artificial light for energy savings and occupant comfort. The two components of interior lighting are ambient and task lighting. Ambient lighting provides general lighting for orientation and background visual identification. Task lighting provides focused lighting, which will aid in the performance of concentrated and small-scale tasks such as reading. Windows and light fixtures should be properly located and balanced to provide the most efficient and visually pleasing lighting in interior environments.

Action Moment

Additions offer opportunities to plan for daylight through the glazing, exterior wall, and roof designs. There are interior measures that can be utilized without any changes to the building envelope and some that can be applied in conjunction with normal space usage changes.

Technical Information

Daylighting is integral to the building shell and will always require modification of the exterior envelope to provide it in retrofits. Artificial lighting requires integration with building electrical systems and controls that may be prohibitively expensive, depending on the extent of the interstitial space modifications that are required. Lamps and fixtures are the most easily modified components of the lighting system, depending upon power supply voltages.

Daylighting can help create healthy indoor environments and save on utility bills.

1 **Daylight factor** is the percentage of available outdoor light that illuminates an interior space. Simple to moderate tasks require a daylight factor of 1.5 to 4.0.

2 **Many products are available to bring daylight into building interior spaces** and distribute it to the best advantage while mitigating the potential negative effects of heat gain and loss, and excessive glare. Architectural devices can be used to redistribute daylight by diffusion and reflection, eliminate excessive illumination, and prevent glare and direct solar radiation. Devices include: overhangs, exterior and interior light shelves, reflective blinds, window design and selective glazings, roof monitors, atriums, and skylight collection devices.

3 **Incandescent lamps provide the best color rendition of natural light** but are also the most energy intensive. Energy-efficient fluorescent lights are available with coatings that more closely reproduce natural "white light." Full-spectrum lamps that are specifically designed to reproduce natural light also are available.

4 **Monotonous lighting levels and poorly distributed light** that produces glare can create uncomfortable conditions for building occupants.

Glare is produced when the position of the light source and its intensity create extreme contrasts that the eye is unable to adjust to. Flickering ballasts are a significant source of discomfort to office occupants.

5 **Interior space partition changes offer** opportunities for removing full-height walls, within structural constraints, and replacing them with partial-height open-plan partitions. These allow perimeter windows and interior fixtures to distribute light as widely as possible. Interior windows on perimeter walls and over doors allow for internal spaces to borrow perimeter daylight.

6 **Daylight is more useful as a substitute** for ambient lighting than task lighting because of the difficulty of control. Spaces that occupants do not inhabit for long periods of time, such as lobbies, corridors, and transient gathering spaces, are prime spaces for daylighting.

7 **The position and type of the artificial light** source reflector or window can increase the usable light without producing glare. Uplighting and windows that are adjacent to light-colored surfaces will spread light more widely and produce less extreme gradations between the source and the viewer's eyes. Avoid windows that look onto highly reflective exterior surfaces.

8 **Interior fixtures located and fitted with diffusers** that "cutoff" a direct view of the lamp by the occupant, and pendant fixtures that can be hung flexibly below permanent ceiling heights, provide for better use of artificial lighting.

9 **Sun-tracking devices, concentrator devices,** and light tubes are variations on typical skylights that can focus and direct daylight into the interior spaces of a building. Fresnel lenses can be used in conjunction with fiber-optic cables to distribute light to interior spaces at diffuser panels and lenses. Fiber optic cables can transmit light throughout a building with 0.1% to 1.0% loss per foot.

10 **Lighting controls** utilizing combinations of manual switches, photocell sensors, time switching, and occupancy sensors—in on/off, or dimming capacities—can provide flexible and energy-efficient means of controlling electric light usage independently or in conjunction with the use of daylight. Localized controls and appropriate fixture switching combinations will reduce wasteful overlighting.

11 **Daylighting is an important energy** conservation and occupant satisfaction consideration. The best lighting strategy will balance the costs of providing daylighting opportunities, given local daylighting availability and building orientation.

Daylighting and artificial light fixtures can be significant sources of heat gain in commercial buildings. All daylighting strategies need to be designed to minimize heat gain along with the commensurate reduction in the heat gain of the fixture. The additional first costs of daylighting devices—such as light shelves and other daylight collection devices should be balanced against the reductions in costs for interior light fixture—and long term electricity-use costs.

Direct sunlight can damage interior furnishings, and the ultraviolet radiation component of sunlight can combine with volatile organic compounds (VOCs) that might be present to form ground-level ozone, which is hazardous to human lung tissue. VOCs should be minimized as a matter of course, and space planning should specify interior finishes and furnishings that have low to zero VOC emissions.

References

CADDET—Centre for the Analysis and Dissemination of Demonstrated Energy Technologies, *Efficient Lighting in Commercial Buildings*, 1995.

Contacts

FEMP at (800) DOE-EREC for information on lighting and lighting quality.

Building acoustics have traditionally been a low priority compared to other problems faced by facility managers. Yet acoustically-acceptable indoor environments increase worker satisfaction and morale. Irritating and unexpected noises create distractions that reduce productivity. Bathrooms, plumbing fixtures, exhaust fans, mechanical ducts, outdoor condensing units, lawn maintenance equipment, traffic, and airplanes are all irritating sources of noise. Some noises created in building systems, such as fluorescent lamp ballasts that buzz, or HVAC systems that generate and transmit various noises, can be difficult to trace.

Action Moment

Some acoustical issues can be addressed during normal operations and maintenance activities, such as servicing noise-producing equipment. When replacing equipment such as transformers, motors, and air handlers, vibration-isolation techniques can be employed effectively. When spaces are renovated or additions made, design and material selection can help attenuate the transmission of annoying sound into work areas.

Technical Information

Concepts important for addressing acoustical problems in buildings include the following:

1 **Noise criteria** (NC) is the continuous background noise from sources such as mechanical systems, desktop PCs, traffic noise, background music, and the general low noise from the combined activities of dozens of workers in the same space. Background noise is beneficial if it is of the proper level and tonal quality. Above a level of NC-40, background noise interferes with speech and telephone conversations. If it is too low, it fails to drown out intrusive noises and diminishes privacy.

2 **Acoustical privacy** relates to the amount of sound perceived from sources outside a worker's space. The noise is audible when it exceeds the background noise level, and is a particular problem with open office plans. Intrusive sounds include telephones, office equipment, and adjacent conversations.

3 **Speech privacy potential (SPP)** quantifies the percentage of words that can be understood from an adjacent conversation, and is related to sound isolation and background noise. SPP is directly proportional to occupant satisfaction, and GSA recommends a minimum value of 60 decibels for SPP in open offices. As the table on the following page shows, an SPP of 70 decibels is considered good for closed office plans. GSA-sponsored research for open office areas revealed that speech privacy can be improved either by increasing the sound attenuation between work stations or by increasing the background noise. The physical constraints of existing spaces often make background noise enhancement more practical.

Improving acoustics in interior environments requires problem analysis, goal setting, and use of sensible and appropriate solutions. Some of the methods and technologies listed here may help in addressing specific problems within a facility.

1 **Active noise cancellation** (ANC) systems consist of microphones that receive the target noise and speakers that create an identical sound field 180 degrees out of phase with the original noise. The sound field created effectively reduces the effect of the offending noise, but does not cancel it. Some ANC systems are made for use in HVAC ductwork to prevent problem noise from disturbing occupants. In general these systems are expensive and do not have wide acceptance for use in buildings.

2 **High-performance glazing** can be used to mitigate external ground- or air-traffic noise in work areas. Windows with wide air spaces between the glazing units give better attenuation than standard insulating windows.

Degrees of Speech Privacy for Closed Office Plans	
dB	Description of Privacy
85	Total privacy. Shouting is only barely audible.
80	Highly confidential. Raised voices barely audible but not intelligible.
75	Excellent. Normal voice levels barely audible. Raised voices are mostly unintelligible.
70	Good. Normal voices audible but mostly unintelligible. Raised voices partially intelligible.
65	Fair. Normal voices audible and intelligible some of the time. Raised voices intelligible.
60	Poor. Normal voices audible and intelligible most of the time.
<60	No speech privacy.

3 **Natural earth berms** and constructed barriers can yield significant shielding and acoustical attenuation. Natural vegetation also augments sound-dampening of physical barriers, but to a limited degree.

4 **Provide separation** of noise-generating areas and noise-sensitive areas. Meeting rooms and offices should not be adjacent to equipment rooms. Instead, bathrooms, storage rooms, and copier rooms are better suited for adjacency.

5 **Air handler noise** transmission can be reduced by providing flexible connections between the air handler and ductwork and by using duct liners. New nonporous duct liners are available that do not support the growth of bio-contaminants.

6 **Partition walls** between offices often stop at, or inches above, dropped ceilings, creating pathways for office-to-office sound transmission in the plenum area. For superior attenuation, run wallboard on at least one wall surface all the way up to the top of the plenum.

7 **Acoustically absorptive** interior surfaces can be coupled with acoustically reflective, hard surfaces to control how sound travels. Sound-deadening panels and partitions can be specified with natural fabrics, which also enhance beauty and minimize problems with indoor air pollutants.

8 **White noise** or sound-masking systems artificially raise the background noise level to maintain speech privacy. They consist of an array of speakers that are usually located above the finished ceiling. Central systems are available for offices that allow adjusting levels at various frequencies to meet the acoustical objectives, similar to the way an equalizer functions on a stereo system. These systems are usually installed to provide a background noise level of NC-38 to NC-42. However, many people find the use of white noise systems objectionable.

References

Foulkes, Timothy J., “Technics: Office Acoustics,” *Progressive Architecture*, Sept 1992.

Ortega, Jose, “Acoustical Fenestration,” *The Construction Specifier*, Feb 1994.

Longman, John D., “Acoustics,” *Sustainable Building Technical Manual*, Public Technology Initiative, June 1996.

Careful operations and maintenance (O&M) procedures are absolutely essential in all efforts to reduce the energy and environmental impacts of the built environment. Even the best efforts of designers and builders are of little use unless those who operate and maintain the buildings and facilities perform their roles with sufficient knowledge about how to "green" their functions. Effective operation and maintenance is the starting point for a resource efficiency program. This guide provides a wide variety of O&M information on the important systems typically found in Federal facilities. This information should be factored into the routine operational procedures of facility managers and can contribute greatly to lowered energy and water costs, higher employee productivity, and a generally improved working environment.

Indoor air quality (IAQ) is becoming one of the greatest concerns of facility managers throughout the world. Poor IAQ lowers productivity, can cause illness, and has resulted in lawsuits. As noted earlier in this guide, there is a wide variety of causes of poor IAQ that may have their origins in the design and construction of the facility. O&M procedures can contribute either positively or negatively to the quality of the indoor air.

Energy consumption is heavily tied to O&M procedures. HVAC equipment must be well-maintained for the complex array of chillers, boilers, air handlers, controls, and other hardware to function at peak performance. A well thought-out, well executed O&M program can provide huge savings in energy and equipment costs.

Water utilization is becoming a bigger issue every day as many regions of the country place increasing pressure on the remaining sources of high-quality, potable water. It would be a prudent assumption on the part of any facility manager that this situation will lead to dramatically increased water prices in the near future as well as possible restrictions on water use in some areas of the country. The sections in this guide on water conservation provide a wide range of possible options for the facility manager. However, none is more important than a routine inspection and maintenance program that verifies that fixtures are operating as planned and that leaks are immediately repaired.

Environmental effects of O&M received only minor attention until concerns about handling and disposal of hazardous materials came to light. Now, facility managers, and everyone else, must pay close attention to the environmental impacts of their activities. As is the case with their other responsibilities, facility managers must take a proactive stance with regard to environmental impacts. Every day, new products and processes become available that claim reduced environmental impacts. The facility manager has to carefully scrutinize these claims to separate those with merit from those of little or no worth. This guide also addresses recycling programs, which may be under the facility manager's jurisdiction. These programs and their supporting hardware need continual attention and maintenance.

Some O&M Greening Strategies to help facility managers integrate the main O&M ideas from this guide into the routine O&M procedures are presented below:

1. **Ensure that the major issues,** such as IAQ, energy conservation, water utilization, landscape maintenance, and general environmental effects, are carefully woven into O&M procedures.
2. **Acquire access to publications** that feature the greening of the built environment as their theme. Some of these are listed below.
3. **Integrate the ideas** in this guide into the routine training programs for O&M personnel.
4. **Start a facility-wide "Green Team"** with representatives of all stakeholders to design and activate a facility-wide "Greening" plan.

5 **Incorporate green ideas** into all contracts, maintenance, and procurement.

By installing a state-of-the-art operations and maintenance monitoring system in early 1993, the Marine Corps Air/Ground Combat Center at Twenty-Nine Palms, California was able to increase its hot water plant capacity by 30% and eliminate the need for a $1.5 million boiler installation. This artificial, intelligence-based system saved $138,000 in natural gas costs during its first year of operation and its advanced diagnostics system is expected to reduce plant maintenance costs by up to 30%.

Steps for creating an effective operation and maintenance program:

1 **Ensure up-to-date operational procedures** and manuals are available.

2 **Obtain up-to-date documentation** on all building systems, including system drawings.

3 **Implement preventive maintenanc**e program complete with maintenance schedules and records of all maintenance performed for all building equipment.

4 **Create a well-trained maintenance staff** with a professional development and training plan for each staff member.

5 **Implement a monitoring program** that tracks and documents building systems performance to identify and diagnose potential problems and tract the effectiveness of the O&M program. This includes cost and performance tracking to allow effective program management.

References

Environmental Building News, PO Box 161, Brattleboro, VT 05301 is a newsletter devoted to environmental issues in the building industry. (802) 257-7300 telephone; (802) 257-7304 fax; Home Page at http://www.ebuild.com; e-mail at EBN @Sover.net

Interior Concerns Newsletter, PO Box 2386, Mill Valley, CA 94942 covers indoor air quality and other environmental issues. (415) 389-8049 telephone; (415) 388-8322 fax.

Meador, Richard, "Maintaining the Solution to Operations and Maintenance Efficiency Improvement," Association of Energy Engineers, *Proceedings of the World Engineering Congress, Atlanta, 1995*.

Szydlowski, R., "No Maintenance—No Energy Savings," Association of Energy Engineers, *Proceedings of the World Engineering Congress, Atlanta, 1995*.

Contacts

There is an advertising-supported webpage that supports idea exchange among facilities managers located at http://www.fmdata.com

Perhaps there is no more visible and important issue facing facility managers today than that of indoor environmental and air quality. Operations and maintenance procedures are of the greatest importance because a healthy indoor environment cannot be sustained without careful attention to routine maintenance, including cleaning.

Action Moment

Good O&M procedures are absolutely essential in order to create and maintain a healthy interior environment. Attention to O&M can actually reverse poor working conditions and greatly improve the work spaces of the Federal work force. Areas for improvement include HVAC system maintenance, lighting bulb and fixture replacement, elimination of sources of unpleasant noise, and general cleaning of the facility.

Healthy Indoor Environment Issues:

What makes a healthy indoor environment? There are several factors that keep the interiors of buildings healthy:

- Proper temperature control
- Proper humidity control
- Adequate outside air
- Low emissions (usually VOCs) within the indoor environment
- Proper cleaning procedures
- Lack of mold- and mildew-producing conditions
- Elimination of smoking

Note that almost every one of these conditions can be either maintained or reversed by O&M procedures.

1 **HVAC and indoor environmental health** are tightly connected. Proper maintenance will ensure that HVAC systems continue to function over their operational life as originally intended by the designer. Controls such as dampers and their pneumatic or electric motors must be checked periodically to ensure their proper operation. Filters have to be changed at regular intervals. Flow rates of chilled water, hot water, cooling tower water, and other fluids have to be monitored to maintain their design values.

2 **Volatile organic compounds (VOCs)** are the greatest chemical source of indoor air problems. When operating and maintaining buildings, all materials used in maintenance should be scrutinized for their emissions properties. Sources of high-VOC emissions are finishes, carpeting, paints, varnishes, sealants, and adhesives. As noted in the Material Selection and Indoor Air Quality sections of this guide, good products are becoming available on the market specifically designed to either eliminate or greatly reduce VOC emissions.

3 **Cleaning procedures** can have significant impacts on indoor environmental health. First, lack of cleaning allows the buildup of dirt and dust, which can become airborne due to a variety of reasons, not the least of which is the movement of people through the building. Second, attention should be given to the types of cleaners being utilized, including disinfectants, waxes, polishes, and cleaning solutions. Some of these merely contribute unpleasant odors, while others actually emit compounds that can make people feel sick.

4 **Other considerations for healthy indoor environments include:**

- Glare-free lighting;
- Good color rendition of lighting;
- Good maintenance of light fixtures; and,
- No irritating noises from lighting, transformers, air handlers.

The General Services Administration is committed to achieving a 50% toxic chemical reduction goal by December 31, 1999 by reducing the agency's total releases and off-site transfers of toxic chemicals. GSA's New Item Program (NIP) promotes pollution prevention technologies and environmentally beneficial products and services, including cleaning products.

References

Sustainable Design and Construction Database, National Park Service, Denver Service Center, Denver, CO www.nps.gov/dsc.dsgncnstr/

Indoor Air Quality Update, monthly newsletter, Cutter Information Corp., Arlington, MA

Contacts

For more information about suitable cleaning products, visit the GSA website at http://es.inel.gov/program/p2dept/general/gsap2.html.

Many buildings occupied by the Federal workforce are leased. The range of actions that can be taken by facility managers may be limited by lease agreements. However, even with these constraints there are still many O&M procedures that can be implemented to reduce the environmental effects of these buildings. The O&M problems of leased buildings are virtually identical to those of owned buildings.

Action Moment

Prior to leasing a building, a detailed survey of all energy and environmental issues should be conducted to ensure that all problems are corrected prior to occupancy.

Technical Information

New Leases for Existing Facilities, Executive Order 12902 March 8, 1994. 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.

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 requirements of this order. Agency heads shall work with their procurement officials to identify and eliminate internal regulations, procedures, or other barriers to implementation of this order.

Leased Building Issues

1 **Indoor air quality.** One of the greatest contributors to poor indoor environmental quality and poor health is improperly designed, sized, installed, and maintained HVAC systems. A major factor that the facility manager can control is maintenance. A good program of filter changing, control system checks, and air/water system balancing will positively affect the air quality of the interior spaces. Interior finishes can also cause air quality problems. For chemically sensitive people, the effects can be severe. A properly prepared leased space contains low-emission finishes, with particular attention paid to carpets, painting, wall coverings, sealants, and varnishes. Require these in the lease terms. The facility manager can also verify that the building air quality complies with all regulatory and contractual requirements.

2 **Energy consumption.** Depending on the lease provisions, the energy consumption of the building can vary greatly. If a relatively high-energy-consuming building is acquired, there are many options (centering around control systems and lighting) that can dramatically affect operational costs. Energy Management Systems (EMS) that permit HVAC system operation during work hours, and setback controls that vary the temperature setpoints of the building based on time, are generally simple, easy-to-implement measures that will greatly lower energy consumption. High efficiency T-8 fluorescent and compact fluorescent lighting can be installed in place of conventional lighting, providing the same lighting levels at a fraction of the energy input. In every case care should be taken to ensure that all the ramifications of system changes are carefully determined to insure that the desired result is achieved. For example, extensive lighting retrofits to low-energy systems can significantly affect HVAC loads. The same is true of changes in insulation and fenestration. The local power company can provide energy surveys and often will have incentive programs to

help reduce power consumption. Although not an energy issue, control of power demand levels is an important step in reducing costs of building operation.

3 **Water utilization.** Older leased buildings have a high likelihood of having older fixtures with high flow characteristics. There are a variety of devices that can be installed in toilets to reduce water consumption per flush without significant adverse effects on the performance of the fixture. Ensuring that malfunctioning and leaking fixtures are quickly repaired can greatly reduce water utilization. A Water Management Plan as described in section 4.1 provides the basis for the types of cost-effective measures that can be implemented.

4 **Recycling programs.** Reducing the environmental impacts of Federal buildings, whether leased or owned, can be helped greatly by controlling the generation of waste. Paper waste accounts for the greatest quantity of solid waste generated. The implementation of programs to recycle this valuable material is fairly straightforward.

Before Leasing a Building . . .

Contact the GSA to help specify the full set of energy, water, HVAC, and other requirements for the leased space.

1 **Be sure that energy-efficient lighting and reliable control systems are provided** and that their operation is clearly documented.

2 **Require electronic controls** on all fixtures or insist that the lease contains provisions to allow retrofit with electronic controls.

3 **Be sure that full technical**, operational, and maintenance documentation of the HVAC system and its controls are provided to the facility manager.

4 **If a building has lead**, asbestos, mercury, or PCB problems or contamination, do not lease it!

DOE's Denver Regional Support Office (DRSO). In 1993, with its lease expiring, DRSO determined the energy efficient features that would be acceptable in its next leased space: energy-efficient lighting systems, insulation, low-E windows, and energy-efficient HVAC systems. For reasons cited as competitiveness, the GSA included only DRSO's requirements for energy-efficient lighting in the solicitation for its new office space. Working together with in-house personnel, the local utility company (Public Service Company of Colorado) and the building owner, a lighting retrofit was planned and executed.

References

Department of Energy, Federal Energy Management Program, *Energy Efficient Leased-Space Toolbook*, Washington, DC. Available from the FEMP Help Desk at (800) DOE-EREC.

To actually make changes that reduce the energy and environmental impacts of Federal facilities, the various standards, operational procedures and other documents that define how the facilities are managed must be changed. Additionally, a comprehensive training program is required to really foster change in any organization. The contents of this guide can be utilized as the basis for training, and can be supplemented with a wide range of government, industry, and academic information on the energy and environmental issues as they relate to the maintenance of the built environment.

Setting Standards

Leadership by example is imperative in inspiring the deep changes that are required to shift to low consumption and efficient utilization of resources, low waste, and the creation of healthy interior environments. The culture of the organization must be transformed from one that pays little attention to energy and environmental issues to one that has internalized the benefits of using our resources wisely. This kind of change demands firm commitment and leadership from senior management. Consequently it is necessary for the facility manager to educate and inform management regarding how the organization should function, what its priorities should be, and what the “organizational culture" should be.

High standards are the most important ingredient in success. There are abundant standards from a variety of sources that facility managers must follow. However, it is difficult to grasp the wide range of requirements and potential solutions available. Even more critical and difficult are the monetary and financing issues associated with change. The facility manager needs to create a blueprint for those laboring in all aspects of facilities management, from the planners, architects, and engineers working on renovation or expansion of existing spaces, to those performing routine maintenance or cleaning the buildings. This wide range of individuals must be made aware of their roles, both individually and collectively, to make the change to a resource-efficient organization.

Section 1.2 of this guide outlines the **major Federal laws and Executive Orders** that require facility managers to reduce the energy and environmental impacts of their facilities. These should be of prime importance when writing local standards.

Training

High-quality training programs are the key to changing the behavior of the wide range of people involved in the management of Federal facilities. The training must be interesting, relevant, up-to-date, and tailored to the specific audience. It should be action-oriented and hands-on whenever possible. Architects should receive a different pitch on the same subject than engineers or HVAC maintenance personnel.

Who should deliver the training? Training is often a function of money, as is the case with many other issues. In any organization’s budgeting process, setting aside resources for education and training is essential because the success of the organization depends on its employees having the most up-to-date information on their particular work, trade, or discipline. It pays to find the best delivery system possible, whether it be from the government, private organizations specializing in training, industry, universities, or professional associations. Utility companies often have presentations on demand-side management, energy-efficient lighting, and a wide variety of other topics. Manufacturers’ representatives will often agree to participate directly in training because their job is to position their products in the marketplace.

The keys to training—commitment and imagination. For the training to be effective it must have the backing of the facility manager and management and it must be delivered periodically to continually reinforce the priority ideas. The best trainers are creative and imaginative. They maintain high interest levels, and their information is usually retained.

A wide variety of publications is available from government organizations—DOE, FEMP, GSA, DOD, and EPA. An even larger quantity of reference materials is available from the private sector—magazines, books, journals, and technical publications from hundreds of manufacturers and from consensus organizations such as ASHRAE and AIA. The International Facilities Managers Association (IFMA) has an extensive list of publications and training programs that are useful for this purpose.

Videotapes make training more interesting and varied. A training library with a collection of videotapes is a valuable training asset.

Case studies are valuable training aids. A wide variety of case studies about greening of facilities is rapidly becoming available in printed form and videotape. Among them is "Greening the White House." There are also a number of good, relevant examples from the private sector, such as the Audubon House in New York.

References

American Institute of Architects, *AIA Environmental Resource Guide*, Demkin, J.A., Ed., John Wiley & Sons, New York, NY, 1996.

National Audubon Society and Croxton Collaborative, Architects, *Audubon House: Building the Environmentally Responsible, Energy-Efficient Office*, John Wiley & Sons, New York, NY, 1996.

Contacts

The FEMP Help Desk at (800) DOE-EREC can provide a copy of the *FEMP Training Catalog*.

FEMP's Home Page at http:// www.eren.doe.gov/femp and EREN's Home Page at http:// www.eren.doe.gov list examples of Federal Initiatives.

For information about training offered by other governmental agencies, colleges and universities, as well as private sector organizations such as ASHRAE and AEE, call FEMP's Training Course Locator System at (202) 586-5772 telephone; (202) 586-3000 fax (attn: Locator System).

When an organization makes a substantial commitment to change the direction of its operations in order to give high priority to protecting the environment and reducing energy costs, it still must determine what the net effects of all the associated investment and actions have been. This normally will be required by senior management, who need to be able to justify short-term higher-cost budgets for capital improvements to produce long-term benefits. Some of these benefits may be relatively easy to quantify. For example, energy and water quantities and associated costs are provided monthly to the facility manager for the facilities under their control, and the cost benefits of some energy and water reduction measures can be readily determined from those bills. Many other issues are not so readily quantified, for example: durability, maintenance, drought-tolerant landscaping, or good indoor air quality. However, to create a complete picture of the impacts of the various measures selected for implementation, the facility manager will have to perform analyses that cover time spans longer than a year. This is especially true for indoor air quality, where the only measurable quantity—employee productivity—is an indirect measure of improvement.

Technical Information

The FEMP Measurement and Verification (M&V) Guideline provides a methodology for quantifying the savings resulting from the installation of energy conservation measures. The M&V Guidelines help to provide verification of energy savings at a minimum of cost, and are intended for use with Energy Savings Performance Contracting (ESPC) and utility program projects that are discussed in sections 9.3 and 9.4 of this guide. The M&V Guideline was developed by FEMP in parallel with the North American Energy Monitoring and Verification Protocol (NEMVP), ensuring consistency for companies doing business with both public and private sectors.

The M&V Guidelines address a wide range of project complexities by allowing the user to select one of three approaches. Factors affecting costs of measurement and verification include:

- number of energy measures implemented;
- size and complexity of energy conservation measures;
- number of interactive energy conservation measures; and
- risk allocation issues.

EMS tracking features are an effective way for collecting consumption and demand information.

1 **Electrical energy.** Determining electrical energy consumption is relatively straightforward, and an ordinary electrical meter is adequate for simple daily, weekly, or other longer period electrical energy determination. If consumption versus time is required, either the manual method of taking frequent meter readings, or automated data collection are necessary. For collection of time-based information, split-core current transducers (CTs) and power transducers (PTs) can be installed without disconnecting power. Data loggers can be used to collect data which can be downloaded by modem as needed.

2 **Electrical demand.** Time-based information is essential if electrical demand is to be determined, and, in this case, it is essential to have the appropriate software to determine the "peak" value. In reality the peak is normally a time-averaged value over a sliding 15- or 30-minute time frame. Single or multiple spikes are not indicative of the peak as measured by the local utility.

3 **Chilled water and hot water.** Btu meters can be installed to determine energy consumption of HVAC equipment lines: chilled water, hot water, and steam. Simple, reasonably accurate meters can be installed "hot," that is, without needing to turn off the system.

4 **Indoor environmental quality (IEQ).** Measuring the benefits of IEQ is very difficult but not impossible. IEQ is an aggregate of the environment created by air quality, light, noise, temperature and humidity. Indoor Air Quality (IAQ) has received the most recent attention, but the other factors also are important contributors to the sense of well-being of the facility occupants.

The only way to determine the impacts of measures designed to improve IEQ is to keep track of how employees are performing. Some of the statistics that may be examined are employee absenteeism, sick days, and productivity. Note that to make sense of this information, the data must be collected for a significant period of time both before and after the changes. The Rocky Mountain Institute (RMI) has conducted several studies linking improvements in IEQ to improvements in productivity. In most Federal facilities, the cost per square foot of the workforce is 20 times greater than the cost per square foot of the building. This huge difference readily demonstrates that investments in IEQ that improve worker productivity and that translate into a rather small cost per square cost, will be rapidly repaid by positive benefits to the work force.

Before making any major energy- or water-system upgrades or improvements, it is useful to have a complete monitoring system installed to be able to determine the effects of the changes.

References

Romm, Joseph, *Lean and Clean Management: How to Boost Profit and Productivity by Reducing Pollution*, Kodansha America, New York, NY, 1994.

Fryer, Lynn, "Tapping the Value of Energy Use Data: New Tools and Techniques," *E-Source Strategic Memo*, Mar, 1996.

The FEMP M&V Guideline and the NEMVP are available through the FEMP Help Desk at (800) DOE-EREC or through the FEMP home page at http://www.eren.doe.gov/femp.

Contacts

For additional information on the Federal Measurement and Verification (M&V) Guideline, please contact Brad Gustafson of FEMP at (202) 586-2204 Brad.Gustafson@hq.doe.gov.

To download the M&V Guideline, please visit the Lawrence Berkeley National Laboratory (LBNL) Home Page at http://www.lbl.gov

Facility managers are required to re-examine their procurement practices to focus on the acquisition of energy-efficient, water-conserving, renewable energy (Executive Order 12902) and products with recovered materials content (Executive Order 12873). Energy Savings Performance Contracting (ESPC) bid documents and specifications must be amended to remove obstacles to the use of products with recovered materials content.

Action Moment

The Federal government is the world's largest single buyer. The facility manager can help increase the availability and reduce the cost of recycled-content, energy-efficient, water-conserving, and renewable energy products by specifying and purchasing these products. FEMP, DOE, DOE National Laboratories, DOD, GSA, and EPA have publications containing a wealth of information and guidelines on these subjects, which facility managers can use to substantially reduce energy operating costs and the environmental effects of their operations.

Technical Information

The Federal Procurement Challenge is a voluntary government-wide program to assist agenciesin meeting the energy and water conservation goals to the Energy Policy Act of 1992 and Executive Order 12902. The Federal Procurement Challenge uses the buying power of the Federal government to:

- Support and expand markets for today's best practice products;
- Assist in the commercialization of new technologies;
- Lower the costs of efficient products for all consumers by providing a large, reliable market;
- Reduce operating costs for Federal agencies, saving taxpayers' money;
- Reduce Federal energy use and greenhouse gas emissions; and,
- Provide a model for government, corporate, and institutional purchasers.

FEMP supports Challenge participants with technical support, product efficiency recommendations and fact sheets, software, Basic Ordering Agreements (BOAs) for specifying energy saving products and services, and help using Energy Savings Performance Contracts (ESPC) to finance long term savings through partnerships with the private sector.

Purchasing and specifying energy-efficient products. Executive Order 12902 (§507) and the Energy Policy Act of 1992 (EPACT) direct all Federal agencies to choose energy-using products which are among the 25% most energy-efficient products available, or at least 10% more efficient than required by Federal standards. Such products must also meet the agency's requirements and be cost effective.

In September 1995, 22 agencies, representing over 95% of Federal purchasing power, signed what was then called the Energy Efficiency and Resource Conservation Challenge, now simply referred to as the Procurement Challenge. These agencies committed themselves to provide leadership in energy-efficient purchasing. The purpose of the Challenge is to assist agencies in meeting the energy and water conservation goals of EPACT and Executive Order 12902.

DOE issues *Product Energy-Efficiency Recommendations* for certain energy-using products that are:

- widely purchased by Federal agencies;
- use a significant amount of energy;
- offer a range of efficiencies (above any mandatory standard); and
- have a generally accepted method of testing and reporting energy performance.

The *Recommendations* are easy-to-use, two-page summaries that provide Federal buyers with information on the efficiency level for products that comply with the requirements of Executive Order 12902. They also provide information on cost effectiveness, buyer tips, and where to find additional information. *Recommendations* are being issued for more than 50 products. See Appendix A for a list of these products and a sample *Recommendation*.

In addition, DOE has been working with the General Services Administration (GSA) and the Defense Logistics Agency (DLA) to designate products that meet or exceed the efficiency levels included in the *Recommendations*. Agencies can achieve major savings in energy operating costs by purchasing products from GSA and DLA with the **E_E designation**.

The Federal government represents the single largest customer in the world for most energy-using products, spending $10 billion to 20 billion a year on them. The annual energy bill to operate Federal buildings and facilities is $3.7 billion. Lower energy use also means reduced greenhouse gas emissions over the life of the product. By providing a large, reliable market for energy-efficient products, Federal purchasing helps lower the costs of these products for all consumers and provides a model for other levels of government and for corporate and institutional buyers. See Appendix A for more product information on product recommendations.

Specifying recycled or 'recovered' materials content is an important step in helping to close the materials loop. EPA has been tasked by Executive Order to assist this process in the Federal government in this effort by streamlining the process for designating these types of items. The EPA issued the Comprehensive Procurement Guideline (CPG) in the *Federal Register* on May 1, 1995 designating 19 new items containing recovered materials. Additionally the EPA published a "Recovered Materials Advisory Notice" (RMAN) recommending recycled content ranges and procurement practices for each product. Included were recommendations for the 19 products, and revisions of previous recommendations for products such as building insulation and concrete containing fly ash. A total of 24 products have been covered to date. In addition to the CPG and RMAN, EPA has generated detailed fact sheets on each of the 24 products.

Note that if (1) your agency is a procuring agency and (2) is purchasing $10,000 or more of a designated product, or purchased $10,000 or more of a designated product in the preceding fiscal year, then the agency is required to purchase EPA-designated products.

For facility managers, the current EPA-designated products of interest are concrete, building insulation, patio blocks, paper products, office waste receptacles, structural fiberboard, traffic barricades, and traffic cones.

In addition to the CPG and RMAN, under RCRA §6003, Federal specification writing agencies are required to examine their specifications that prohibit the use of recovered materials.

Contacts

To obtain copies of the *Product Energy-Efficiency Recommendations*, call the FEMP Help Desk at (800) DOE-EREC or visit the FEMP Home Page at http://www.eren.doe.gov/femp.

To obtain copies of the Comprehensive Procurement Guideline as listed in the Federal Register, the RMAN, or Fact Sheets, visit the EPA Home Page at http://www.epa.gov.

Many of the objectives of this guide can be greatly assisted by forming partnerships with capable organizations external to the government. One group of organizations that can readily provide assistance are the local utility companies, who supply electrical power, natural gas, and water, and who process waste water and solid waste. The current regulatory climate often makes it more profitable for the local utility to assist its customers, including the Federal government, to use less of the energy and water resources they provide. Another type of business, Energy Service Companies (ESCOs), can make capital investments in energy improvements in return for a share of the savings.

Action Moment

It is good practice on the part of any facility manager to be thoroughly familiar with the programs offered by the local electric, gas, water, and wastewater utilities. They will generally have a broad range of incentive programs for helping their customers use less resources. The laws governing utilities and Public Utility Commissions provide incentives for many utilities to actually sell less energy and other resources and profit from this—a truly extraordinary shift in thinking. The rapid move toward utility deregulation will probably reduce the availability of DSM programs and other types of utility incentives.

Technical Information

In an era of decreasing Federal resources, private sector partnerships will be critical for financing energy saving projects. There are a variety of programs that facility managers can use to take advantage of private-sector capabilities to reduce energy- and water-resource consumption and costs: utility partnering, using energy services companies, cogeneration programs, and fuel acquisition. An additional important factor is the deregulation of the electric utility industry. Learning how to purchase electricity at the lowest possible cost will become increasingly significant. Utilities often are interested in retaining their large Federal customers. This gives the facility manager a real advantage when working with a utility.

Virtually every electric utility in the country has a range of energy conservation services available to help the facility manager reduce energy consumption and costs. The utility will generally have personnel with experience and expertise in energy audits and will often provide their services free. They can recommend a wide range of measures—energy-efficient lighting, control systems, building envelope modifications, and many others.

These programs are often in the form of area-wide contracts (AWCs) or Basic Ordering Agreements (BOAs) available for use by Federal agencies located in the utility's service territory. These programs allow the Federal government to implement energy and water conservation measures through financing provided by the utility. AWCs and BOAs are used to provide general terms and conditions of the contract for ease in procuring these programs.

Energy Savings Performance Contracts (ESPC), authorized by the Energy Policy Act of 1992, and utility incentive programs, offer ESCOs and others ample incentives to improve the energy efficiency of Federal buildings. These incentives apply whether the building is leased or owned.

ESPC, formerly known as Shared Energy Savings Contracting, offers alternative financing of energy and water efficiency improvements in Federal buildings. By employing ESCOs the Federal government retains a portion of the energy savings and all the equipment they install. ESCOs can provide turnkey services and derive their income from the savings experienced by their customers. In effect the capital required to accomplish the upgrades is provided by the ESCO instead of having to be obtained through the usually long and laborious Federal budgeting process.

ESPC and other programs can be used when: (1) updating aging equipment with newer, more efficient products; (2) helping agencies meet the energy cost reduction goals of Executive Order

12902 and the Energy Policy Act of 1992 (EPACT); (3) conserving nonrenewable fuels and achieving environmental benefits by reducing energy consumption; and, (4) reducing utility costs without sacrificing service.

A broadening and simplification of energy savings performance contracting (ESPC) is being developed by the Department of Energy, Federal Energy Management Program. ESPCs are a contracting method whereby the contractor incurs the cost of implementing energy savings measures-including performing an audit, designing the project, acquiring and installing the equipment, training personnel, and operating and/or maintaining equipment-in exchange for a share of the energy savings directly resulting from such measures during the term of the contract. Current procedures that have resulted in site-specific facility contracts will be modified to allow the development of regional contracts, known as **FEMP Energy Savings Performance Contracts** or **Super ESPCs.**

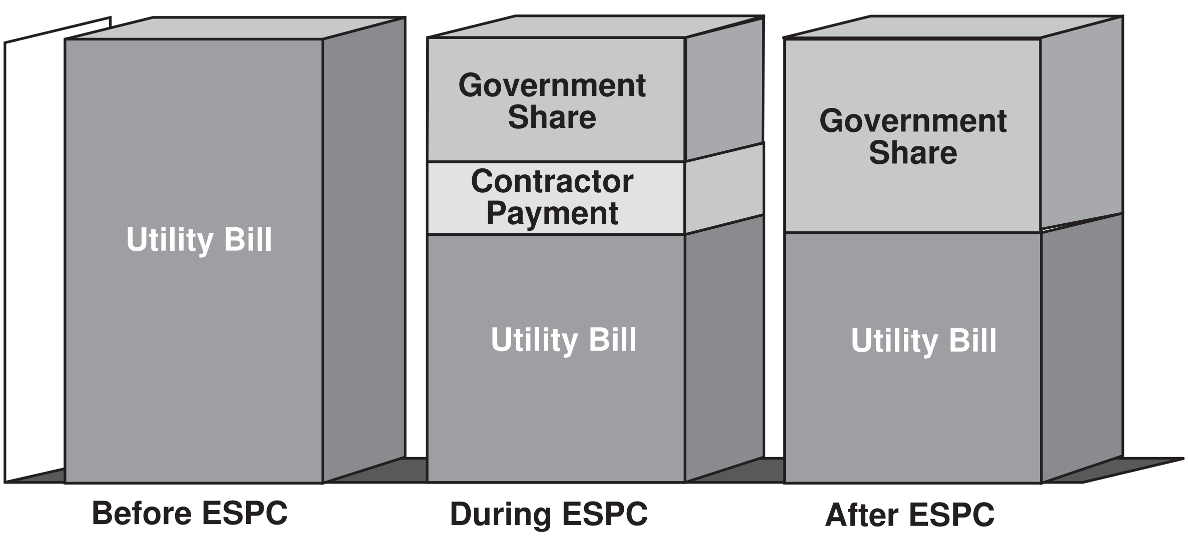
Super ESPCs will deliver performance-based energy services and will be available to Federal agencies with Government-owned facilities within a region through delivery orders executed under a regional Indefinite Delivery Indefinite Quantity (IDIQ) contract under the Federal Acquisition Regulation (FAR) process. These new ESPCs will involve the competitive selection of a small number of contractors (multiple awards). Federal agencies then have the option of placing delivery orders against the contract and selected energy service companies would be allowed to conduct negotiations with individual facilities.

FEMP has developed model procurement documents and two workshops on ESPC and utility financing mechanisms. The workshops teach Federal employees how to fully develop energy savings performance contracts successfully. Workshop I covers methods for: (1) identifying energy-conservation measures; (2) determining if the project economics are sufficient for a contract; (3) developing procurement documents; and, (4) executing the contract. Workshop II is an optional hands-on session to assist participants in refining their specific projects and covers: (1) developing a Statement of Work; (2) establishing proposal requirements; (3) establishing criteria for award; and, (4) preparing a *Commerce Business Daily* synopsis.

Contact

The schedule for FEMP Workshops on ESPC can be obtained by calling the FEMP Help Desk at (800) DOE-EREC or by fax at (202) 586-3000. FEMP's address: Federal Energy Management Program, EE-90, U.S. Department of Energy, 1000 Independence Avenue, SW, Washington, DC 20585-0121.

Energy Savings Performance Contracts



Employee Incentive Programs 9.5

Incentive programs are an excellent way to produce change in an organization. Rewarding good ideas with tangible benefits not only helps those who take the time and effort to put forward ideas on how to increase energy efficiency and reduce waste, but helps motivate others to perform in a similar fashion. The Federal government has a long and successful history of incentive programs to motivate its workforce to save money. More recent versions provide financial incentives for employees to suggest how to save money due to reductions in water and energy consumption. A sophisticated incentive program can help dramatically reduce the energy and environmental impacts of the facility.

Action Moment

When implementing a broad range of energy and environmental actions to "green" their operations and functions, facility managers can use incentive programs to stir up a high level of interest in the greening effort.

Technical Information

Facility managers should note that in addition to incentive programs they may be trying to promulgate, utility companies also have incentives to serve the government as client and consumer. Utilities can now earn revenue by providing energy-efficiency services and technologies to both owner-occupied and leased buildings.

1 **The Energy Policy Act of 1992 (EPACT)** and Executive Order 12902 encourage energy efficiency in workspaces leased by Federal agencies. By improving energy efficiency in their leased space, agencies can derive energy savings benefits with a corresponding benefit for taxpayers. EPACT offers Federal agencies the opportunity to participate in any and all electric and gas utility incentive programs that utilities offer to their non-Federal customers.

2 **Utility incentives include rebates,** customized services, bidding programs and other offerings. In utility incentive bidding programs, tenants, owners, utilities, and energy service companies (ESCOs) work together as a team to create energy-efficient systems.

Group incentive programs can be just as important as individual incentive programs. For example, in DOD, agencies can use up to 40% of savings from their energy conservation efforts for quality-of-life improvements at military bases and other facilities. It is not difficult to convince Base Commanders of the worth of these programs, as it provides them with valuable resources in an era of money shortages and budget cuts.

3 **The standard Federal suggestion program** is also a good vehicle for creating a pathway from an employee with good suggestions to the facility manager. This program can be enhanced by conducting broadly delivered classes or training sessions that specifically address energy and environmental problems and the role of the standard suggestion program in tackling these problems.

4 **An annual award called the Federal Energy and Water Management Awards** is presented by DOE in conjunction with the Federal Interagency Energy Policy Committee (the "656" Committee). The program recognizes outstanding achievements in the efficient use of water and energy, the use of renewable energy sources, and cost-beneficial landscaping practices by the Federal government. Renewable measures include, but are not limited to, photovoltaics, solar thermal, passive solar design, biomass, wind, geothermal heat pumps, and low-head hydro dams. FEMP coordinates this program for the Federal government.

Contacts

For additional information on the FEMP Awards Program, contact the FEMP Help Desk at (800) DOE-EREC.

Each year, the Federal Government purchases an estimated $10 to $20 billion in energy-related products and pays an $8 billion energy bill. Nearly half of this energy cost is in buildings alone. There is an enormous opportunity for savings, and one conspicuous target is the purchase of efficient energy-using equipment. Energy-efficient procurement has three strong positive impacts.

1 **First and foremost,** it saves agency and taxpayer dollars. The great majority of energy-efficient products sell at small or nonexistent first-cost increments.

2 **Second, energy savings** from more efficient models translate to less pollution. Annual electricity savings from typical use of a 36,000 btu/hour central air conditioning unit with a 12 Seasonal Energy Efficiency Rating (SEER), compared to a 10 SEER unit is 600 kilowatt-hours. This means that, on average, 900 pounds of CO_2, 9.2 pounds of SO_2, and 3.3 pounds of NO_x emissions will be prevented from entering the environment yearly. CO_2, SO_2, and NO_x are the principle pollutants responsible for global warming, acid rain, and smog, respectively, and are by-products of fossil fuel-powered electricity generation.

3 **The third substantial benefit** of the government's buying more efficient products is that it "pulls" the overall market for these products upwards, as economies of scale cut costs for the more efficient products, while greater demand spurs innovations in efficient designs. This serves to strengthen the companies in these markets, as well as further reducing costs to users and further diminishing pollution.

The Department of Energy is trying to let government purchasers know what is energy-efficient and what is not. President Clinton's Executive Order 12902, in conjunction with the Energy Policy Act of 1992, has established a clear mandate to agencies to use life-cycle costing analysis in their purchasing of energy-consuming equipment, and where practicable, to purchase in the upper quartile (top 25%) of energy efficiency within comparable classes of products. Pursuant to this, DOE is creating simple two-page guidelines called *Product Energy Efficiency Recommendations*. The *Recommendations* identify this upper quartile of efficiency in several dozen common energy-using products, and let government purchasers see the lifetime savings that will accrue from purchasing these instead of comparable but less efficient models.

Included in the next few pages are two of the Recommendations, on room air conditioners and exit signs. The Recommendations are available for no charge. For an ordering brochure, call (800) DOE-EREC.

How to Buy an Energy-Efficient Room Air Conditioner

Energy Efficiency and Renewable Energy
Federal Energy Management Program

Why Agencies Should Buy Efficient Products

- *Section 161 of the Energy Policy Act of 1992 (EPACT) encourages energy-efficient federal procurement. Executive Order 12902 and FAR section 23.704 direct agencies to purchase products in the upper 25% of energy efficiency.*
- *Agencies that use these guidelines to buy efficient products can realize substantial operating cost savings and help prevent pollution.*
- *As the world's largest consumer, the federal government can help "pull" the entire U.S. market towards greater energy efficiency, while saving taxpayer dollars.*

Federal Supply Sources:

- General Services Administration (GSA)
Phone: (816) 926-2389 (Gail Allen)
http://www.fss.gsa.gov
- Defense Logistics Agency (DLA)
Phone: (215) 697-2429
DSN 442-2429

For More Information:

- DOE's Federal Energy Management Program (FEMP) Help Desk and World Wide Web site have up-to-date information on energy-efficient federal procurement, including the latest versions of these recommendations.
Phone: (800) 363-3732
http://www.eren.doe.gov/femp/procurement
- DOE has ENERGY STAR® room air conditioner model listings.
Phone: (800) 363-3732
http://www.energystar.gov
- American Council for an Energy-Efficient Economy (ACEEE) publishes the *Consumer Guide to Home Energy Savings*.
Phone: (202) 429-0063
http://aceee.org
- Consumers Union publishes the *Consumer Reports Annual Buying Guide*, and provides an on-line room air conditioner sizing guide.
Phone: (800) 500-9760
http://www.consumerreports.org
- Air Conditioning Contractors of America (ACCA) publishes *Manual J*, a load calculation guide for residential heating and air conditioning.
Phone: (202) 483-9370
http://www.acca.org
- *Home Energy* magazine provides energy conservation tips on air conditioning.
Phone: (510) 524-5405
http://www.homeenergy.org
- Lawrence Berkeley National Laboratory provided supporting analysis for this recommendation.
Phone: (202) 484-0880

Efficiency Recommendation

Product Type and Cooling Capacity	Recommended EER[a]	Best Available EER
with louvers[b]; < 6,000 Btu/hr	9.2 or more	10.0
with louvers; 6,000-19,999 Btu/hr	10.0 or more	11.7
with louvers; ≥ 20,000 Btu/hr	9.2 or more	10.0
without louvers; all cooling capacities	9.2 or more	9.5

a) Based on DOE test procedure; see 10 CFR 430, Sup-part B, Appendix F.

b) Louvered sides improve the energy performance of window-installed A.C. units by enhancing airflow over the outdoor coil. Units intended for through-the-wall installation require a smooth-sided cabinet (no louvers).

Definitions

Cooling Capacity is the amount of cooling that can be provided by the unit (in Btu/hr) at standard rating conditions.

EER, or Energy Efficiency Ratio, is equal to the measured cooling capacity of the unit (in Btu/hr) divided by its electrical input (in watts) at standard rating conditions.

Where to Find Energy-Efficient Room Air Conditioners

The federal supply sources for room air conditioners are the Defense Logistics Agency (DLA) and the General Services Administration (GSA). DLA's FED LOG purchasing software includes EERs of room air conditioners. GSA sells room air conditioners through Schedule 41-I, as well as through its on-line shopping network, *GSA Advantage!* (starting in 1999). Look for products that meet the recommended efficiency levels.

When buying from a commercial source (retailer or distributor), choose models that qualify for the EPA/DOE ENERGY STAR® label (see "For More Information), all of which meet the recommended levels. Some manufacturers and retailers display the label on complying models. Alternatively, look at the yellow "EnergyGuide" label to identify models with EERs that meet these Efficiency Recommendations. For a contractor-supplied air conditioner, specify an EER that meets the recommended level for that type and size.

Sizing

Oversizing of air conditioners, besides raising purchase cost, will lead to excessive energy consumption and poor humidity removal due to excessive on-off cycling. The required air conditioner capacity should be determined based on the referenced ACCA or Consumer Reports calculation procedures (see "For More Information").

Environmental Tips

Refrigerants with ozone-destroying chlorofluorocarbons (CFCs) were used many years ago in room air conditioners but most existing equipment today uses HCFC refrigerants, which have a much lower ozone-depleting effect; ask your supplier for information. In the future, room air conditioners with ozone-safe refrigerants are expected to be available.

When retiring an air conditioner which contains CFCs or HCFCs, the Clean Air Act requires that the refrigerant be recovered prior to final disposal of the appliance. For compliance information, contact the EPA Stratospheric Ozone Information Hotline at (800) 296-1996.

Room Air Conditioner Cost-Effectiveness Example (10,000 Btu/hr - louvered)

Performance	Base Model[a]	Recommended Level	Best Available
EER	9.0	10.0	11.7
Annual Energy Use	830 kWh	750 kWh	640 kWh
Annual Energy Cost	$50	$45	$38
Lifetime Energy Cost	$500	$450	$390
Lifetime Energy Cost Savings	–	**$50**	**$110**

a) The efficiency (EER) of the Base Model is just sufficient to meet current U.S. DOE national appliance standards.

Definition

Lifetime Energy Cost is the sum of the discounted value of annual energy costs based on average usage and an assumed air conditioner life of 15 years. Future electricity price trends and a discount rate of 4.1% are based on federal guidelines (effective from April, 1998 to March, 1999).

Cost-Effectiveness Assumptions

Annual energy use in this example is based on the standard DOE test procedure for a louvered model with a cooling capacity of 10,000 Btu/hr and 750 operating hours per year. The assumed electricity price is 6¢/kWh, the 1996 federal average electricity price in the U.S.

Using the Cost-Effectiveness Table

In the example shown above, a room air conditioner with an EER of 10.0 is cost-effective if its purchase price is no more than $50 above the price of the Base Model. The Best Available model, with an EER of 11.7, is cost-effective if its price is no more than $110 above the price of the Base Model.

What if my Electricity Price or Operating Hours are different?

To calculate Lifetime Energy Cost Savings for a different electricity price, multiply the savings in the above table by this ratio: $\left(\frac{Your\ price\ in\ ¢/kWh}{6.0\ \ ¢/kWh}\right)$. Similarly, for a different operating hours figure, multiply the savings by this ratio: $\left(\frac{Your\ operating\ hours}{750\ hours}\right)$.

Metric Conversions

1,000 Btu/hr = 293 watts
*°F = (1.8 * °C) + 32*

FEMP FEDERAL ENERGY MANAGEMENT PROGRAM

How to Buy Energy-Efficient Exit Signs

Energy Efficiency and Renewable Energy
Federal Energy Management Program

Why Agencies Should Buy Efficient Products

- *Section 161 of the Energy Policy Act of 1992 (EPACT) encourages energy-efficient federal procurement. Executive Order 12902 and FAR section 23.704 direct agencies to purchase products in the upper 25% of energy efficiency.*
- *Agencies that use these guidelines to buy efficient products can realize substantial operating cost savings and help prevent pollution.*
- *As the world's largest consumer, the federal government can help "pull" the entire U.S. market towards greater energy efficiency, while saving taxpayer dollars.*

Federal Supply Sources:

- Defense Logistics Agency (DLA)
  Phone: (800) DLA-BULB
- General Services Administration (GSA)
  Phone: (817) 978-2792
  http://www.fss.gsa.gov

For More Information:

- DOE's Federal Energy Management Program (FEMP) Help Desk and World Wide Web site have up-to-date information on energy-efficient federal procurement, including the latest versions of these recommendations.
  Phone: (800) 363-3732
  http://www.eren.doe.gov/femp/procurement
- Environmental Protection Agency has ENERGY STAR product listings.
  Phone: (888) 782-7937
  http://www.energystar.gov
- American Council for an Energy-Efficient Economy (ACEEE) publishes the *Guide to Energy-Efficient Commercial Equipment*, which includes a chapter on lighting.
  Phone: (202) 429-0063
  http://aceee.org
- Lighting Research Center's Web site has the ENERGY STAR specification and other valuable information covering exit signs and other lighting systems.
  Phone: (518) 276-8716
  http://www.lrc.rpi.edu
- Lawrence Berkeley National Laboratory provided supporting analysis for this recommendation.
  Phone: (202) 484-0880

Efficiency Recommendation

Product Type	Recommended	Best Available
Single Face	5.0 watts or less	1.8 watts
Double Face	10.0 watts or less	1.8 watts

Where to Find Energy-Efficient Exit Signs

The federal supply sources for exit signs are the Defense Logistics Agency (DLA) and the General Services Administration (GSA). DLA sells exit signs through its *Energy Efficient Lighting* catalog. GSA offers them through Schedule 99-IV, "Signs," as well as through its on-line shopping network, *GSA Advantage!* (starting in 1999). Select exit signs that meet the recommended levels. Both DLA and GSA also sell exit sign retrofit kits, which allow conversion of existing signs to energy-efficient light-emitting diode (LED) models.

For exit signs purchased through commercial sources, look for products with the EPA/DOE ENERGY STAR® label, all of which meet this Recommendation. For a contractor-supplied exit sign, specify products with the ENERGY STAR® label, or with power consumption (in watts) that meets the recommended levels.

EPA DOE
SAVING THE EARTH. SAVING YOUR MONEY.

Buyer Tips

Most light-emitting diode (LED) exit signs meet this Efficiency Recommendation for both single and double face configurations. Some compact fluorescent lamp (CFL) exit signs meet the double-face Recommendation; CFL models require lamp replacements about every 2 years compared with an estimated life of 10 years or more for LED lamps.

To ensure adequate visibility, the ENERGY STAR® label also requires that exit signs exceed visibility guidelines established by the National Fire Protection Association (NFPA) Life Safety Code 101, and most building code requirements. Many LED and CFL signs meet these criteria. Be sure to check compliance with your own state or local codes before selecting exit signs.

Before purchasing exit signs, make sure that the manufacturer's warranty covers replacement of defective parts for at least 5 years from the date of purchase, as required by the ENERGY STAR specification.

Retrofits

Retrofitting existing exit signs may be more economical than replacing entire signs, but proper installation is vital to ensuring adequate visibility. The ENERGY STAR program does not cover retrofit kits.

Exit Sign Cost-Effectiveness Example (Double Face Model)

Performance	Base Model	Recommended Level	Best Available
Power Consumption	40 watts	10 watts	1.8 watts
Annual Energy Use	350 kWh	88 kWh	16 kWh
Annual Energy Cost	$21	$5	$1
Lifetime Energy Cost	$160	$40	$10
Lifetime Energy Cost Savings[a]	–	**$120**	**$150**

a) Note that these savings do not include lamp replacement costs, including labor, which are discussed in the text below.

Definition

Lifetime Energy Cost is the sum of the discounted value of annual energy costs, based on constant usage and an assumed exit sign life of 10 years. Future electricity price trends and a discount rate of 4.1% are based on federal guidelines (effective from April, 1998 to March, 1999).

Cost-Effectiveness Assumptions

The Base Model in this example uses two 20-watt incandescent lamps. The Recommended Level sign uses two CFLs, which draw 5 watts each (in combination with their ballasts). The Best Available model uses a 1.8-watt LED array.

Annual energy use in this example is based on constant use, or 8,760 operating hours per year. The assumed electricity price is 6¢/kWh, the 1996 federal average electricity price in the U.S. The calculations are for energy cost savings only, and do not include lamp replacement or labor costs. Considering lamp replacement and labor costs would significantly increase the total savings of a CFL sign relative to an incandescent, as well as the total savings from an LED sign relative to either a CFL or incandescent model. Over the 10-year life of an exit sign, the total number of lamps required would be approximately 30 incandescents, 10 CFLs, or a single LED array.

Using the Cost-Effectiveness Table

In the example shown above, cost-effectiveness is determined solely on energy savings, and excludes benefits from fewer replacement lamps and labor savings. A recommended exit sign with a power consumption of 10 watts is cost-effective if its purchase price is no more than $120 above the price of the Base Model. The Best Available model, with a power consumption of 1.8 watts, is cost-effective if its price is no more than $150 above the price of the Base Model.

What if my Electricity Price is different?

To adjust the Lifetime Energy Cost Savings in the table above for a different electricity price, multiply the dollar figures listed by this ratio: $\left(\frac{\text{Your price in ¢/kWh}}{6.0\ \text{¢/kWh}}\right)$.