Title
Managing Your Energy: An ENERGY STAR(R) Guide for Identifying Energy Savings in Manufacturing Plants

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Publication Date
2010-07-29

LBNL-

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BERKELEY NATIONAL LABORATORY

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Environmental Energy Technologies Division

Sponsored by the U.S. Environmental Protection Agency

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This work was funded by U.S. Environmental Protection Agency's Climate Protection Partnerships Division as part of ENERGY STAR. ENERGY STAR is a government-backed program that helps businesses protect the environment through superior energy efficiency. The work was supported by the U.S. Environmental Protection Agency through the U.S. Department of Energy Contract No. DE-AC02-05CH11231.

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ABSTRACT

In the United States, industry spends over $100 billion annually to power its manufacturing plants. Companies also spend on maintenance, capital outlay, and energy services. Improving energy efficiency is vital to reduce these costs and increase earnings. Many cost-effective opportunities to reduce energy consumption are available, and this Energy Guide discusses energy-efficiency practices and energy-efficient technologies that can be applied over a broad spectrum of companies. Strategies in the guide address hot water and steam, compressed air, pumps, motors, fans, lighting, refrigeration, and heating, ventilation, and air conditioning. This guide includes descriptions of expected energy and cost savings, based on real-world applications, typical payback periods, and references to more detailed information. The information in this Energy Guide is intended to help energy and plant managers achieve cost-effective energy reductions while maintaining product quality. Further research on the economics of all measures—as well as on their applicability to different production practices—is needed to assess their cost effectiveness at individual plants.

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Energy Efficiency: A Commitment to Good Business

Finding the most effective ways to manage your energy strengthens the bottom line. In fact, for many sectors, well-run energy programs reduce energy costs by 3% to 10% annually. As a result, increasing energy efficiency not only reduces waste and emissions, but gives you a competitive edge.

Organizations often differ dramatically in their energy performance, even when they belong to the same industrial or commercial sector, operate under the same market conditions, and use the same equipment. Why the big performance gap?

Research has shown that the high performers adopt a structured approach to energy management and establish policies and procedures needed to ensure long-term results. They have senior-level support, commit to allocating staff and resources to energy management, establish goals, develop management structures that empower staff to address energy efficiency issues directly, and adopt a philosophy of continuous improvement.

Managing Your Energy provides the information you need to establish this structure and identify and implement cost-effective processes and technologies to reduce energy use throughout your company's operations.

1 Reducing Energy Use to Meet Energy, Cost, and Environmental Targets

Volatile energy markets, growing competition, and worldwide regulation of greenhouse gas emissions are moving many U.S. manufacturers to consider energy management as an untapped opportunity. Production cost reductions can be achieved without negatively affecting the yield and quality of products by effectively reducing energy consumption and costs.

This goal can often be met through investments in energy efficiency, which can include the implementation of plant-wide energy-efficiency practices and the purchase of energy-efficient technologies. These technologies can often offer additional benefits, such as quality improvement, increased production, and increased process efficiency—all of which can lead to productivity gains. As a component of a company's overall environmental strategy, energy-efficiency improvements can often lead to reductions in emissions of greenhouse gases (GHGs) and other important air pollutants. Investments in energy efficiency are a sound and key business strategy in today's manufacturing environment.

This Energy Guide provides an overview of available measures for energy efficiency, with a special emphasis on the small and medium enterprises (SMEs). How energy is used varies considerably among companies, making it impossible to discuss all energy-using processes and specifics in detail. Instead, this Energy Guide focuses on energy used in common industrial applications:

- Lighting
- Heating, ventilation and air conditioning (HVAC)
- Motors
- Compressed air
- Pumps
- Hot water and steam systems
- Process integration
- Process heating – furnaces

This Energy Guide is offered as part of the ENERGY STAR® program. For some industries, more detailed and tailored Energy Guides specific to those industries can be found on the ENERGY STAR Industries in Focus website.[1]

ENERGY STAR® is a voluntary partnership program of the U.S. Environmental Protection Agency (EPA). Its primary purpose is to help U.S. industry improve its competitiveness through increased energy efficiency and reduced environmental impact. Through ENERGY STAR, the U.S. EPA stresses the need for strong and strategic corporate energy management programs and provides a host of energy management tools and strategies to help companies implement such programs. This Energy Guide reports on research conducted to support the U.S. EPA's ENERGY STAR program with the National Association of Manufacturers (NAM) and small- and medium-sized manufacturers that commit to ENERGY STAR. For further information on ENERGY STAR and its available tools for facilitating corporate energy management practices, visit the ENERGY STAR Industries in Focus website.

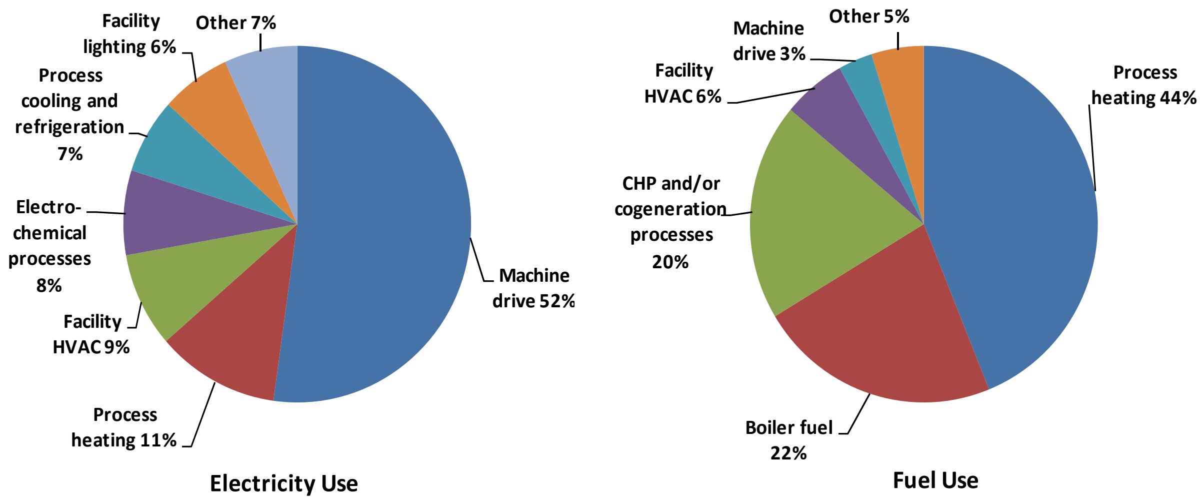
[1] See www.energystar.gov/industry.

Section 2 briefly describes how energy is used in various U.S. industries, to help you identify potential high-value opportunities for your type of plant. Section 3 outlines successful general practices that you can use to design and implement an energy management program for your company, based on ENERGY STAR guidelines. Section 4 describes specific efficiency strategies you can use to manage energy in each area of your plant, starting with a general description of each system's equipment and how energy is used. All measures are technically proven, are commercially available, and have an extensive track record. Section 5 provides a brief summary, and the appendices provide further detail on available resources.

2 U.S. Industrial Energy Use

Energy is used throughout industrial facilities. Fuels heat materials in furnaces or generate hot water and steam in boilers. Steam dries, heats, or separates product flows. Electricity powers motor systems for air conditioning, lighting, and appliances. Motor systems pump fluids and compress gases or air and move them around. Compressed air drives machinery. ENERGY STAR studies and experiences have demonstrated that all of these systems offer considerable potential for energy-efficiency improvement and energy cost reductions, for nearly all facilities.

Despite the diversity in energy end uses, in most plants just a few pieces of equipment consume the majority of fuel or electricity. Naturally, each plant's energy use distribution is unique, but some overall patterns hold true. As shown in Figure 1, motor systems use the greatest amount of electricity in virtually any industrial facility. Motor systems are followed by process heating and cooling; building heating, ventilation, and air conditioning (HVAC); and lighting as key electricity uses. Process heating, boiler fuel, and combined heat and power (CHP) and/or cogeneration processes typically dominate fuel use.



Source: U.S. DOE 2010

Figure 1. Distributions of electricity and fuel use in U.S. industry. Actual distribution of electricity and fuel use will vary from facility to facility.

For more specific fuel and electricity consumption data for various applications in selected industrial sectors, see Appendix A.

2.1 Industrial Energy's Environmental Impact

The use of energy results in the emission of a variety of pollutants. Moreover, scientists are increasingly concerned about the release of carbon dioxide (CO_2) as a greenhouse gas. Emissions of CO_2 and other GHGs are changing the atmosphere's composition and the planet's climate, which affects our environment and our economy. Greenhouse gas emissions arise from three sources: (1) CO_2 from fossil-fuel combustion; (2) non-energy uses of fossil fuels in chemical processing and metal smelting; and (3) emissions of CO_2 from cement and lime manufacturing.

Industrial processes, primarily chemical manufacturing and metal smelting, also emit other GHGs.

Total U.S. greenhouse gas emissions have risen 17% from 1990 to 2007 (U.S. EPA 2009). Carbon dioxide from fossil fuel combustion accounted for roughly 80% of 2007 emissions. Historically, changes in emissions from fossil fuel combustion have dominated U.S. emission trends. Changes in CO_2 emissions from fossil fuel combustion are influenced by many factors, including population and economic growth, energy price fluctuations, technological changes, and seasonal temperatures.

Globally, industry uses almost 40% of all energy consumed, to produce materials and products, and contributes almost 37% of global GHG emissions. In the United States, industry accounts for 32% of GHG emissions—the vast majority of which are CO_2.

Improving energy efficiency is the largest and most cost-effective way to reduce CO_2 emissions, making it an important part of any company's GHG emission mitigation strategy. Other opportunities include switching to low-carbon fuels (such as natural gas) and increasing the use of renewable fuels (such as biomass, solar, and wind) for electricity. Reducing non-CO_2 greenhouse gases (such as HFC/CFCs from refrigeration equipment) also offers benefits, as these gases have a relatively large impact on the climate.

3 General Practices for Managing Your Energy Use

Make energy management a priority, and take action by implementing an organization-wide energy management program. It's one of the most successful and cost-effective ways to bring about energy efficiency improvements. Sustaining those savings and driving further energy efficiency requires building energy management into your company's culture. Energy management programs help to ensure that energy efficiency improvements are continuously identified and implemented. Without the backing of a sound energy management program, energy efficiency improvements may not reach their full potential, due to lack of a systems perspective and/or the lack of proper maintenance and follow-up. ENERGY STAR offers a variety of tools and resources to help companies develop strategic energy management approaches.

ENERGY STAR® Energy Management Resources

The U.S. Environmental Protection Agency's (EPA) ENERGY STAR® Guidelines for Energy Management Overview (EPA, No Date) provides a management structure for organizations to follow in developing a strategy for achieving sustained performance.

Another ENERGY STAR guide, *Teaming Up to Save Energy* (EPA 2006), outlines how to form an energy team. By establishing a program, forming an energy team, increasing employee awareness, monitoring progress, and incorporating feedback into the process, companies can reduce their energy use and emissions, and potentially save money.

3.1 Effective Principles for Energy Savings

Companies that apply a few basic principles to energy management achieve greater savings. These principles can be applied by any company, regardless of size, that is serious about reducing energy use:

- **Make it a priority**
  Saving energy starts by making energy management a priority. Everyone in the company must recognize that reducing energy use is an important business objective and incorporate it into their decision making.

- **Commit to energy savings**
  Every level of the organization, from senior management on down, must commit to continuous energy efficiency improvement.

- **Assign responsibility**
  If you want to save energy, someone must take responsibility for achieving that goal. Initially, this might be a designated "energy champion," but over time the responsibility can be expanded across the company.

- **Look beyond first cost**
  With energy efficiency, you get what you pay for. It is critical to recognize that energy-efficient equipment and products may cost the company more initially but that the lasting savings gained from their use will save more money over time.

- **Make energy management a continuous process**
  Successful energy management involves more than just installing a few energy-efficient technologies. It involves establishing a committed company-wide program to manage energy continuously as a function of your business. It's an ongoing process that involves:
  - understanding your energy use,
  - setting goals,
  - implementing good operational and maintenance practices,
  - making behavioral changes,
  - tracking and benchmarking energy use, and
  - involving every employee.

ENERGY STAR works with leading industrial manufacturers to identify the basic aspects of effective energy management programs.[2] Figure 2 depicts the major steps.

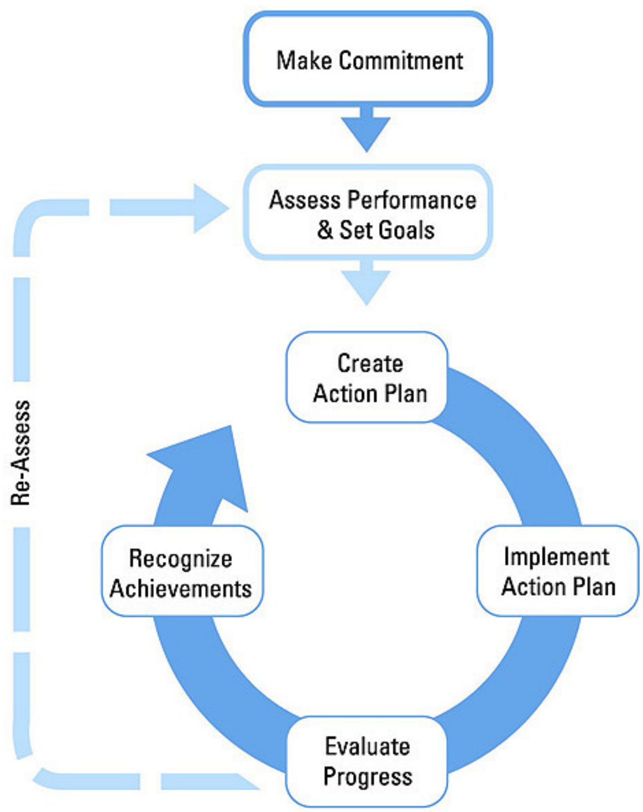


Figure 2. Elements of strategic energy management

[2] Read more about strategic energy management at ENERGY STAR for Industry (www.energystar.gov/industry).

Throughout the process, personnel at all levels should be aware of energy use and efficiency goals. Staff should be trained in both skills and general approaches to energy efficiency in day-to-day practices (examples of simple tasks employees can do are outlined in Appendix B). In addition, regularly evaluate and communicate performance results to all personnel, and reward and recognize high achievement. Evaluating action plan progress requires a regular review of both energy use data and the activities carried out as part of the plan. A quick assessment of an organization's efforts to manage energy can be made by comparing its current energy management program against the ENERGY STAR Energy Program Assessment Matrix provided in Appendix C.

Four key elements contribute to the process of energy management: energy audits/assessments, energy teams, employee awareness, and energy monitoring. Technical aspects will be discussed in Section 4.

3.2 Energy Audits: Technical Assistance and Assessments

Once the company has committed to an energy management program, conduct an energy audit, to assess how much energy is consumed and to evaluate what measures could improve the facility's energy efficiency. Whether the audit focuses on a whole site or on specific end uses, systems, or processes, it will often find opportunities that may, when implemented or corrected, save significant amounts of energy and money.

Audits can be conducted by internal staff, by the local electric utility, or through government programs.

- **Staff Teams**
  If company staff perform self-audits, it is most effective to team up several staff members from different departments of the facility or from across the company. The team brings together experience and knowledge on the plant and processes used. Several companies (such as Sunoco, Corning, and Toyota) organize special teams consisting of staff from different plants and divisions of the company to do a so-called "treasure hunt" to identify and evaluate opportunities. Such efforts can be successfully replicated at a smaller scale in smaller facilities. The U.S. Department of Energy (U.S. DOE) also offers various tools to help with audits (see Appendix D).

- **Electric Utility Program**
  Local utility companies work with industrial clients to achieve energy savings in both existing facilities and in the design of new facilities. Check with your local electric utility to see what assistance they can provide. Sometimes, end-use-specific programs are offered for systems such as lighting or motors.

- **Federal Government Programs**
  The U.S. DOE supports audits through its Save Energy Now[3] initiative and the Industrial Assessment Center (IAC) program.[4] The IAC program (see Assessment and Technical Assistance in Appendix D) is most suited to small- and medium-sized enterprises. Thirty

[3] See www1.eere.energy.gov/industry/saveenergynow.
[4] See http://iac.rutgers.edu.

universities around the country participate in the program and offer free audits, performed by students and university staff, to local companies.

3.3 Energy Teams

Establishing an energy team helps solidify a commitment to continuous energy-efficiency improvement.[5] The team is responsible for planning, implementing, benchmarking, monitoring, and evaluating the organization's energy management program. However, duties can also include delivering training, communicating results, and providing employee recognition (U.S. EPA 2006).

Any size company can create an energy team

Its size and time commitment depends on the size and resources of the facility, its energy use, and the complexity of the key energy-consuming processes. Generally, in large facilities this will be a more substantial effort than in small facilities, where the team is likely to be a part-time effort of a few staff members.

Forming the Team

When forming an energy team:

- establish the organizational structure,
- designate team members, and
- specify roles and responsibilities.

Senior management needs to perceive energy management as part of the organization's core business activities, so ideally the energy team leader will be someone at the corporate level who is empowered by support from senior-level management. The team should include members from each key energy-using process within the company. Ensure adequate funding, preferably as a line item in the normal budget cycle, as opposed to a special project.

Prior to the energy team's launch, hold a series of team strategy meetings to consider key goals, as well as potential pilot projects that could be showcased at the program's kickoff. The team should then perform facility audits (see above) with key plant personnel to identify opportunities for energy-efficiency improvements. As part of the facility audits, the energy team should also look for best practices in action to help highlight successful strategies.

Tracking and Communicating Results

A key energy team function is to develop mechanisms and tools for (1) tracking and communicating progress, and (2) transferring the knowledge gained through the audits across an organization. Such mechanisms and data tools include best practice databases, facility benchmarking tools, intranet sites, performance tracking scorecards, and case studies of successful projects.

A best practices database may be as simple as documenting the best practices and case studies of successful projects identified in your company and have them accessible to all energy, plant, and shift managers. This can be done through a dedicated intranet site for the company or through other communication tools.

Benchmarking is a tool to compare the (energy) performance over time and between peer facilities in a consistent manner. Benchmarking can be very helpful to track plant performance

[5] For a comprehensive overview of establishing, operating, and sustaining an effective energy management team, consult the U.S. EPA's *Teaming Up to Save Energy* guide, available at www.energystar.gov (U.S. EPA 2006).

and to identify opportunities for improvement (when, for example, energy intensity increases in a given period or is higher than that of facilities with a similar mix of products). The ENERGY STAR program offers various industrial benchmarking tools.[6]

To sustain the energy team and build momentum for continuous improvement, progress results and lessons learned must be communicated regularly to managers and employees, and a recognition and rewards program should be established.

Appendix E provides a checklist of key steps for forming, operating, and sustaining an effective energy management team.

3.4 Employee Awareness

Energy management involves changing a company's culture as well as changing out old, inefficient equipment, so employees must be trained in how to follow new processes or operate new energy-efficient equipment.

Educated, empowered employees better identify and achieve energy savings

Engage employees and operators in energy assessments, projects, and the program—especially in day-to-day decisions. An effective energy awareness campaign:

- educates employees and operators about how their work practices affect energy use, costs, and the environment,
- informs employees on how they can manage energy in their day-to-day responsibilities, and
- reminds employees about the company's energy goals.

To implement an effective energy awareness campaign, you must:

- identify employees' current level of energy awareness,
- identify what will encourage them to change behavior, and
- determine how to get them actively involved.

It is important to identify your audience and message, which will help you to design and implement the program. It is very important to review and evaluate the awareness campaign, to ensure that it is generating the desired results, and to continuously improve it.

A wide array of activities can be included in an awareness campaign. ENERGY STAR has encountered a number of successful corporate approaches, including placement of stickers at light switches (at Kodak), distribution of energy-efficient lamps to personnel (at ArcelorMittal), and handing out leaflets on home energy savings (at Toyota). Additional ideas include hanging posters in conspicuous locations and having information stands at employee events or during lunch.

[6] See www.energystar.gov/index.cfm?c=industry.industrybenchmarkingtools.

Assistance with Employee Awareness Programs

Many companies and other organizations, such as the U.S. Department of Defense, run large energy-awareness campaigns, often in collaboration with the U.S. Environmental Protection Agency's ENERGY STAR program or the Federal Energy Management Program (FEMP). These programs offer advice on how to run an energy-efficiency campaign and provide materials (such as posters) that can be tailored to your company. See the following websites for examples:

- Federal Energy Management Program[7]
- The ENERGY STAR Challenge: Communication Materials[8]
- Carbon Trust (UK): Publications[9]

3.5 Energy Monitoring Systems

Sustaining energy savings over time requires managing energy continuously. Without data, this is impossible, because you cannot manage what you do not measure. So the company needs to create an energy monitoring system that compiles and tracks data, and helps the energy manager interpret energy-efficiency trends over time.

Data on energy use can be taken from utility billing or from self-installed meters. Preferably, different parts, departments, or processes of the plant are sub-metered, so that changes in individual activities can be measured, and problems with increasing energy use can easily be identified. These systems alert the energy teams to problem areas.

Energy monitoring can also provide useful data for corporate greenhouse gas accounting initiatives. Successful monitoring programs regularly report energy use (sometimes daily) to identify increasing energy use and costs that could be caused by operational inefficiencies. Energy monitoring and metering systems can also help companies participate in emergency demand response programs, in which utility companies provide financial incentives to customers who reduce their energy loads during peak demand times.

Except for installation of sub-meters, an energy monitoring system requires little or no upfront capital, and it may result in immediate savings. Strategies developed in-house, such as a spreadsheet, may be sufficient. If the budget can support it, tailored software is also available, and it may help better identify problems and savings.

In its simplest form, an energy monitoring system could be made based on the following:

- Monthly utility billing and energy use data for the past 12 to 24 months
- Monthly production figures

Using a simple spreadsheet, both can be plotted in various graphs to understand the relationship between energy use and production, and to identify any trends:

- Graph of energy use and production in a single graph over time
- Graph of energy costs and production in a single graph over time
- Graph of energy use on vertical axis against production on horizontal axis

[7] See www1.eere.energy.gov/femp/services/yhtp/campaign_materials.html.
[8] See www.energystar.gov/index.cfm?c=challenge.challenge_toolkit.
[9] See www.carbontrust.co.uk/publications/publicationdetail?productid=CTG001.

- Graph of energy use divided by production (showing specific energy consumption)

Tools offered within commonly used spreadsheet packages can help to identify relationships and quantify trends. Graphs can be made for fuel and electricity separately, as well as for total energy use (showing both in the same units, such as megajoules or British thermal units) and costs.

Often the analysis will show periods of good performance and subpar performance—information that can help you set targets for energy consumption based on expected production volumes. Tracking energy use by entering new data and evaluating it as regularly as the data allow will help you to identify problems and improve energy savings.

Reading self-installed or utility meters daily or weekly enables you to collect data more frequently than is possible with utility billing data. That can improve your ability to quickly address changes in energy use and intensity. Sub-metering different production departments will give you not only improved metrics but also enable you to more quickly pinpoint the area where energy problems may occur. Moreover, the monitoring tool will supply the information you need to calculate energy and cost savings from implemented energy management activities.

4 Opportunities to Reduce Energy Use through Efficiency

Many of the energy efficiency measures discussed in this section require either a limited investment or none at all. Energy efficiency is often the lowest risk investment that a company can make, because energy costs continually contribute to operating costs. Energy price trends and forecasts demonstrate that energy use and costs increase over time, making energy efficiency a surefire method of reducing a company's bottom line.

Energy efficiency measures are described below by different end-use categories. Generally, each section starts with easier-to-implement measures. For each measure typical savings are identified if meaningful, as are payback periods. Case studies of companies that implemented successful specific measures illustrate and highlight potential savings.

4.1 Building Lighting

Lighting contributes significantly to electrical energy consumption, and savings can be substantial. In 2002, industrial lighting consumed some 59 terawatt-hours (TWh)—equivalent to 7% of all industrial electricity use. Of course electricity demand attributed to lighting varies from industry to industry (see Chapter 2) and from site to site.

Lighting provides overall ambient light throughout manufacturing, storage, and office spaces and provides low-bay and task lighting to specific areas. Lighting demand can be quantified by a quantity of lumens of visible light needed at a certain point of time. The quantity of electricity (in watts) needed to supply the demand for lighting (in lumens) is expressed as the *efficacy* of the light source (in lumens/watt). The maximum theoretical efficiency is 700 lumens/watt. The term *luminaire* refers to the hardware, and *lamp* refers to the bulb. Another important parameter is the *color rendering index (CRI)*. The CRI is a measure of a light source's ability to show colors " "naturally" compared to a familiar reference source, such as daylight. More information about factors to consider when choosing appropriate lighting is offered through the Lighting Research Center at Rensselaer Polytechnic Institute.[10]

Generally, high-intensity discharge (HID) sources—including metal halide, high-pressure sodium, and mercury vapor lamps—are used for manufacturing and storage areas. Fluorescent, compact fluorescent (CFL), and incandescent lights are typically used for task lighting and offices. Lighting controls should be used in all areas of the plant.

Only a small part of the energy used in a lighting fixture is for lighting; the remainder is lost as heat. So, even when lighting is a relatively small part of a plant's energy use, it may be possible to find considerable energy savings from using more efficient lighting systems. For specific applications, such as lighting in refrigerated or air-conditioned spaces, increasing lighting efficiency (and therefore reducing heat) may result in other savings. Next to energy use, the lifetime of a lamp is important because a long lamp life reduces maintenance costs.

[10] See http://www.lrc.rpi.edu/.

Table 1 provides an overview of the typical performance and applications of various lamp types.

Table 1. Typical performance comparison of lighting sources

Lamp	Efficacy (lumens/watt)	Typical Lifetime (hours)	Applications
Incandescent	5–20	1,000	Task
Halogen	< 24	1,000	Task
CFL	20–70	8,000–15,000	Task
Fluorescent T-12	60	20,000	Any
Fluorescent T-8	80–100	20,000	Any
Fluorescent T-5	80–105	20,000	Any
Mercury Vapor	30-50	60,000	Hi-Bay
Induction	80	100,000	Exterior, Hi-Bay
High-Pressure Sodium	85–150	10,000–50,000	Exterior, Hi-Bay
Metal Halide	70–115	20,000	Hi-Bay
LED	10–120	50,000	Task

Notes: Values are typical performance. Performance of individual products may vary. The performance of fluorescent lamps assumes the use of an electronic ballast. Technology development may change the future performance. LED=light-emitting diode.

The ENERGY STAR program suggests cost-effective ways to save on lighting energy. Measures to improve lighting efficiency range from simple measures such as switching off lights to replacing lights and fixtures to installing innovative lighting systems. Check with your local electric utility to see what programs and incentives they may offer to improve lighting performance.

Turn off lights in unoccupied areas Encourage personnel to turn off lights in unoccupied building spaces. An awareness program will help staff get in the habit of switching off lights and other equipment when not in use. Often, lights are on in areas (such as warehouses or parts of production areas) at times where they are not needed, and occupancy controls may help to reduce their use appropriately (see Lighting Controls below).

Establish lighting level standards

For both new facilities and retrofits, lighting levels (expressed as lumens per surface area) should be set in the design of each section of a plant and followed in ordering, manufacturing, and installation. Work with both manufacturers and suppliers to ensure that the proper system is installed.

Different lighting standards can be set for different work areas. For example, Toyota set different lighting standards for quality check areas, warehouses, and office buildings. By setting a lumens/surface area standard and sticking to it, Toyota claims savings of 30% on lighting energy use. Moreover, lighting levels were reduced in areas (such as automated warehouses and robot-operated process areas) that need lighting only for safety. Similarly, use of sections in a plant may change over time (for example, from assembly to storage), resulting in overlit areas. Ford Motor Company reduced energy costs for lighting by eliminating some lights in overlit areas.

Use lighting controls

Automatic controls

Lights can be shut off during non-working hours by automatic controls, such as occupancy sensors that turn off lights when a space is unoccupied. Occupancy sensors can save 10% to 20% of a facility's lighting energy use. Numerous case studies throughout the country suggest an average payback period of one year. Daylight controls for indoor and outdoor lights can adjust lighting intensity based on the availability of daylight.

CASE STUDY: Controls

In a pharmaceutical industry case study, lighting panels at the Merck office and storage building in Rahway, New Jersey, were programmed to turn off automatically during expected periods of building non-use. Override switches in entrance halls allowed lights to be turned on manually during these times, if needed. Annual savings amounted to 380 megawatt-hours per year, avoiding energy-related CO_2 emissions of nearly 260 tons/year.

Manual controls

Manual controls can be used in conjunction with automatic controls to save additional energy in smaller areas. One of the easiest measures is to install switches to allow occupants to control lights.

Lighting controls in practice

An example of an energy-efficient lighting control is illustrated in Figure 3, which depicts five rows of overhead lights in a workspace. During the brightest part of the day, ample daylight for most of the room is provided by the window, so only row C would need to be lit. At times when daylight levels drop, all B rows would be lit and row C would be turned off. Only at night or on very dark days would it be necessary to have both rows A and B lit. These methods can also be used as a control strategy on a retrofit by adapting the luminaires already present.

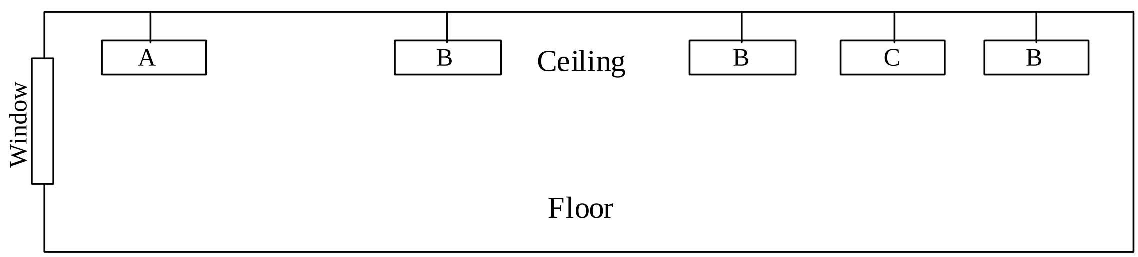


Figure 3. Lighting placement and controls

Use daylighting

Daylighting involves the efficient use of natural light in buildings to minimize the need for artificial lighting. Increasing levels of daylight within rooms can reduce electrical lighting loads by up to 70%. Unlike conventional skylights, an efficient daylighting system may provide evenly dispersed light without creating heat gains, reducing the need for cooling compared to skylights. Daylighting is applied primarily to new buildings and incorporated at the design stage. However, existing buildings can sometimes be cost-effectively refitted with these systems.

Daylighting technologies include properly placed and shaded windows, atria, clerestories, light shelves, and light ducts—all of which can accommodate various angles of the sun and redirect daylight using walls or reflectors. Because daylighting is variable, it is almost always combined with artificial lighting to ensure the necessary illumination on cloudy days or after dark. Combining daylighting with lighting controls can maximize its benefits. More information can be found at the website of the Daylighting Collaborative[11] led by the Energy Center of Wisconsin.

Replace incandescent lamps with compact fluorescent lamps (CFL)
A fluorescent lamp lasts roughly ten times longer than an incandescent light and is significantly more energy efficient. The payback period for the replacement varies, but it can be as low as five months.

Replace T-12 tubes with T-8 tubes
T-12 lighting tubes are the long fluorescents 12/8 inches in diameter (the "T" designation refers to a tube's diameter in terms of 1/8 inch increments). Many industrial facilities still use these tubes. T-12 tubes consume significant amounts of electricity and also have poor efficacy, lamp life, lumen depreciation, and color rendering index. As a result, T-12 maintenance and energy costs are high. T-8 lighting tubes have about twice the efficacy of T-12 tubes and can last up to 60% longer, which leads to maintenance cost savings. Typical energy savings from the replacement of a T-12 lamp by a T-8 lamp are about 30%.

Replace mercury lamps
Where color rendition is critical, metal halide lamps can replace mercury or fluorescent lamps with energy savings of up to 50%. Where color rendition is not critical, high-pressure sodium lamps offer energy savings of 50% to 60% compared to mercury lamps.

Reduce high-intensity discharge (HID) voltage
Reducing lighting system voltage can also save energy. Commercially available voltage controllers can easily be fitted to a central panel switch and constrict the flow of electricity to lighting fixtures, thereby reducing voltage and saving energy, with an imperceptible loss of light. A Toyota production facility installed reduced-voltage HID lights and reduced lighting energy consumption by 30%. Voltage controllers work with both HID and fluorescent lighting systems and are available from multiple vendors.

CASE STUDY: Metal Halide Lamps

At a Basic American Foods facility in Shelley, Idaho, the production area lighting system was upgraded using metal halide lamps. The improved color rendition and increased light levels offered by the new lamps helped production workers better detect defects in the plant's potato products. Plant sanitation was also improved, because staff could better see debris on equipment and floors.

Consider replacing HID lighting with high-intensity fluorescent lights
Traditional HID lighting can be replaced with T-5 high-intensity fluorescent lighting systems, which incorporate high-efficiency fluorescent lamps, electronic ballasts, and high-efficacy fixtures that maximize output to work areas. These systems can often have lower energy consumption, lower lumen depreciation over the lifetime of the lamp, better dimming options, faster startup and re-strike capabilities, better color rendition, higher pupil lumens ratings, and

[11] See www.daylighting.org.

improved glare performance than traditional HID systems. The payback period is typically below three years.

Replace magnetic ballasts with electronic ballasts
A ballast regulates the amount of electricity required to start a lighting fixture and maintain steady light output. Electronic ballasts can require 12% to 30% less power than their magnetic predecessors. New electronic ballasts have smooth and silent dimming capabilities, in addition to longer lives (up to 50% longer), faster run-up times, and cooler operation than magnetic ballasts. New electronic ballasts also have automatic switch-off capabilities for faulty or end-of-life lamps.

Use energy-efficient exit signs
Energy costs can be reduced by switching from incandescent lamps to light-emitting diodes (LEDs) or radium strips in exit sign lighting. An incandescent exit sign uses about 40 watts (W), while LED signs may use only about 4 W to 8 W, reducing electricity use by 80% to 90%. A 1998 Lighting Research Center survey found that about 80% of exit signs being sold use LEDs. The lifetime of an LED exit sign is about 10 years, compared to one year for incandescent signs, which reduces maintenance costs considerably.

New LED exit signs are inexpensive, with prices typically starting at about $20. In addition to exit signs, LEDs are increasingly being used for path marking and emergency way finding systems. The U.S. EPA's ENERGY STAR program website[12] lists LED exit sign suppliers.

Tritium exit signs are an alternative to LED versions. Tritium signs are self-luminous, so they do not require an external power supply. Their advertised lifetime is about 10 years, and prices typically start at about $150 per sign.

4.2 Building HVAC

HVAC stands for heating, ventilation, and air conditioning, and refers to the equipment, distribution network, and terminals used either collectively or individually to provide fresh filtered air, heating, cooling, and humidity control in a building. The main goals of HVAC are to provide comfort and indoor air quality, which depend on many factors, such as thermal regulation, control of internal and external sources of pollutants, supply of acceptable air, removal of unacceptable air, occupant's activities and preferences, and proper operation and maintenance of building systems (ASHRAE 2005).

Air exchange between outdoor and indoor air is needed to maintain good air quality and agreeable indoor temperatures. Two processes—ventilation and infiltration—affect this exchange. *Ventilation* is intentional use of air to provide acceptable indoor air, either through natural movement (such as windows and doors) or mechanical means, by using fans or vents.
Infiltration is the flow of outdoor air into a building through cracks and other unintentional openings, and should be minimized.

[12] See www.energystar.gov.

CASE STUDY: HVAC Upgrades

Raytheon upgraded a plant's HVAC system, including the following measures:

- Replaced the hot water heating system with high-efficiency natural gas infra-red heaters in selected production areas
- Improved the building envelope, including sealing warehouse shipping doors and dock levelers
- Added return air to the warehouse air handling unit
- Configured air handler shutdown and controls to switch off unneeded units during production and non-production days
- Implemented programmable logic controller (PLC) control of all heaters to schedule with production equipment.

The measures combined resulted in annual savings of 16,000 MMBtu.

Air and water are heated by means of a boiler, furnace, or heat pump, and they are distributed evenly through ducts for air or pipes and radiators for water. Air cooling is performed by cooling coils (based on refrigeration cycles) or evaporation (when the incoming air humidity is low). Many combinations of heating and cooling sources supply the HVAC system. With heating, for example, a gas- or oil-fired boiler or furnace, heat pump, rooftop unit, new technology (such as infrared radiation), or electric heat could be employed. For cooling, common sources include rooftop units, chillers, heat pumps, air conditioners, or off-peak cooling systems.

Employ an energy-efficient system design
For HVAC systems in new industrial facilities, the greatest opportunities for energy efficiency arise at the design stage. Sizing equipment properly and designing energy efficiency into a new facility generally minimizes the energy consumption and operational costs of HVAC systems from the outset. This practice often saves money in the long run, as it is generally cheaper to install energy-efficient HVAC equipment during construction than it is to upgrade an existing building with an energy-efficient system later on, especially if those upgrades lead to downtime.

CASE STUDY: Efficient System Design

Mission Foods, a California manufacturer of specialty Mexican foods, worked with Southern California Edison to design its new production facility in Rancho Cucamonga to be as energy-efficient as possible. The new facility had 50,000 square feet of office space, 125,000 square feet of manufacturing space, and 134,000 square feet of warehouse space. Mission Foods chose to install energy-efficient technologies for its HVAC systems and lighting systems, room occupancy sensors that turned off lights automatically, low-emissivity windows that reduced building heat gain, and skylights that provided natural lighting. The total project (including refrigeration system measures) allowed the company to reduce their new facility's electricity consumption by roughly 18% compared to its existing facilities, leading to annual energy savings of over $300,000 per year.

Commission and recommission

Before replacing HVAC system components to improve energy efficiency, explore the possibility of HVAC system recommissioning. Recommissioning is essentially the same process as commissioning, but it is applied to a building's existing HVAC, controls, and electrical systems (U.S. EPA 2008).

Commissioning is the process of verifying that a new building functions as intended and communicating the intended performance to the building management team. This usually occurs when a new building is turned over for occupancy. In practice, commissioning costs are not included in design fees and often compete with other activities, so commissioning is seldom pursued properly. To ensure that energy performance and operational goals are met, however, the building must be commissioned. To achieve this, ENERGY STAR recommends the following:

- Communicate your energy performance goals during commissioning to ensure that the design target is met. Encourage energy-use tracking so that performance comparisons are made over time.
- Specify detailed commissioning activities in project contracts. Seek separate funding for commissioning work, to ensure that it will be done and done well.
- Hire building commissioning experts. Include the commissioning firm as part of the design team early in the project.
- Finalize and transfer a set of technical documents, including manufacturers' literature for systems and components. Supplement technical literature with summaries of how to operate and manage the systems. Provide additional explanation for innovative design features.

Recommissioning involves a detailed assessment of existing equipment performance and maintenance procedures. This is compared to the intended or design performance and maintenance procedures in order to identify and fix problem areas that might be hampering building energy efficiency. Recommissioning can be a cost-effective retrofit in itself, sometimes generating more savings than the cost of the retrofit measure. For example, recommissioning may help avoid the need to install new or additional equipment, leading to savings in capital investments.

The U.S. EPA's *ENERGY STAR® Building Upgrade Manual* (U.S. EPA 2008) recommends a stepwise approach to recommissioning, in which a series of strategically-ordered building "tune up" strategies are pursued. First, lighting and supplemental loads should be assessed; then the building envelope; then controls; then testing, adjusting, and balancing; then heat exchange equipment; and finally heating and cooling systems. Most of these steps relate to HVAC system components or factors that will directly affect HVAC system energy consumption (such as building envelope and lighting). For more information, consult the manual.

Install energy monitoring and control systems

An energy monitoring and control system supports the efficient operation of HVAC systems by monitoring, controlling, and tracking system energy consumption. Such systems continuously manage and optimize HVAC system energy consumption while also providing building engineers and energy managers with a valuable diagnostic tool for tracking energy consumption and identifying potential HVAC problems. Several projects indicate that the average payback period for HVAC control systems is about 1.3 years.

Adjust non-production hours set-back temperatures
Setting back building temperatures (that is, turning building temperatures down in the winter or up in the summer) during periods of non-use, such as weekends or non-production times, can significantly reduce HVAC energy consumption.

CASE STUDY: Set Points

Fetter Printing decreased the set point temperature in a secondary facility that was now used for storage only. It was set just high enough to keep the pipes from freezing, and the rate of return was almost 200% due to the natural gas savings.

Repair leaking ducts
Leaking air ducts can waste significant amounts of energy in HVAC systems. To remedy this leakage, install duct insulation and perform regular duct inspection and maintenance, including ongoing leak detection and repair. According to studies by Lawrence Berkeley National Laboratory, repairing duct leaks in industrial and commercial spaces could reduce HVAC energy consumption by up to 30%. The study also showed that duct tape should not be used for leak repair; aerosol sealants are preferred.

CASE STUDY: Duct Leakage Repair

A commercial building in Apple Valley, California, adopted a technique called the mobile aerosol-sealant injection system (MASIS) to reduce duct leakage. The application of MASIS resulted in a reduction in overall duct leakage from 582 cubic feet per minute (cfm) to 74 cfm, leading to a 34% increase in the overall efficiency of the building's HVAC system.

Consider variable-air-volume systems
Variable-air-volume systems adjust the rate of air flow into a room or space based on the current air flow requirements of that room or space. Variable-air-volume systems therefore work to more closely match HVAC load to heating and cooling demands, which reduces energy use.

Install adjustable-speed drives (ASDs)
Adjustable speed drives can be installed on variable-volume air handlers and recirculation fans to match precisely the flow and pressure requirements of air handling systems. Energy consumed by fans can be lowered considerably since they do not constantly run at full speed. Adjustable-speed drives can also be used on chiller pumps and water systems pumps to minimize power consumption based on system demand. See Section 4.3 for more information.

Consider heat recovery systems
Heat recovery systems reduce the energy required to heat or cool facility intake air by recovering the thermal energy of the exhaust air. Common heat recovery systems include heat recovery wheels, heat pipes, and run-around loops. Heat pipes recover about 45% to 65% of the exhaust heat, while the efficiency of run-around loops can be in the 55% to 65% range.

Modify your fans
Changing the size or shape of the sheaves of a fan can help to optimize fan efficiency and airflow, reducing energy consumption. Toyota optimized the sheaves of its fans instead of

installing adjustable-speed drives (ASDs) on fans, finding better savings and payback periods than expected.

Use ventilation fans

Ventilation fans installed in the ceilings of work areas can help destratify workspace air, leading to better circulation of cool air in summer and warm air in winter, as well as more even temperature distributions from floor to ceiling. Such fans can help reduce the load on building heating systems by helping to "push down" warm air that rises during heating months.

CASE STUDY: Ceiling Fans

Yasama Corporation U.S.A., a manufacturer of soy sauce, installed new high-bay ceiling fans to improve air circulation at its Salem, Oregon, facility in 2004. Previously, to provide heat during the winter, the company operated ceiling-mounted heaters with 15 horsepower (hp) fans in its production area. However, the fans did not destratify the air in the production area's tall ceilings nor take advantage of the heat given off by process equipment. Furthermore, to provide ventilation in the summer, the company ran the fans in "fan only" mode along with six 3 hp exhaust fans to remove hot air. The new high-bay ceiling fans were operated using 1.5 hp motors, which were expected to lead to electrical energy savings of 48,000 kilowatt-hours (kWh) per year and electricity cost savings of $2,500 (FIRE 2005). Furthermore, the company expected to save significant amounts of natural gas in heating months through reduced heater operation.

Install efficient exhaust fans

Exhaust fans are standard components in any HVAC system. Mixed flow impeller exhaust fans offer an efficient alternative to traditional centrifugal exhaust fans. They are typically 25% more efficient than centrifugal fans and can be cheaper to install and maintain. The expected payback period is about two years (Tetley 2001).

Cooling water recovery

If available, secondary cooling water from municipal sources can be leveraged to reduce chiller energy consumption. In Washington, Boeing partnered with Puget Sound Power and Light and the King County Department of Metropolitan Services to recycle secondary treated cooling water into its chiller system. By doing so, Boeing reduced its water consumption by 48 million gallons per year, leading to projected savings of 20% in its cooling energy consumption (Michaelson and Sparrow 1995). As an additional benefit, Boeing also expected to save on refrigerants and treatment chemicals for its cooling tower water. The reduction in cooling load reduces the volume of refrigerants needed in the system, and hence the replenishing of lost (evaporated) refrigerant. Fresh water is demineralized for use in the cooling tower. Recovering cooling water reduces fresh water intake, and the need for demineralization.

Employ solar air heating

Solar air heating systems, such as Solarwall®, use conventional steel siding painted black to absorb solar radiation for insulation. Fresh air enters the bottom of the panels where it is heated as it passes over the warm absorber, and fans distribute the air. Using this technology, the Ford Motor Company's Chicago Stamping Plant turned its south wall into a huge solar collector (CREST 2001). Energy savings were estimated to be over $300,000 per year compared to conventional natural gas air systems. Capital costs were $863,000 (about $15 per square foot, including installation), resulting in a payback period of less than three years. In addition to energy savings, the system was said to provide clean fresh air for employees. This measure is only of interest for buildings in cold climates, and the potential benefits should be analyzed based on each site's local conditions.

Modify building reflection

Reflective roofing

Use of a reflective coating on the roof of buildings in sunny, hot climates can save on air conditioning costs inside. Using reflective roofs, two medical offices in Northern California reduced air conditioning demand; one by 8% and the other by 12%. For colder climates, the heat lost due to cool roofs (in winter, for example) needs to be considered, as it could negate savings. In addition to location and weather, other primary factors (such as roof insulation, air conditioning efficiency, and building age) also influence energy savings. Reflective roof materials are available in different forms and colors.

"Green" roofs

Roof gardens on a flat roof improve the insulation of buildings against both hot and cold by providing both heat (in winter) and air conditioning (in summer). In winter, "green" roofs can freeze, so they carry a slight heating penalty but often still yield net energy savings. In addition, a roof garden can increase the lifetime of the roof, reduce runoff, and reduce air pollution and dust. The Gap Headquarters in San Bruno, California, installed roof gardens in 1997. In addition to saving energy and lasting longer than traditional roofs, a roof garden absorbs rain, slowing run-off to local storm drains.

Shading and windbreaks

Shade trees reduce the need for cooling in hot climates. Shade trees should be deciduous (providing shade in the summer and none in the winter) and planted on the west and southwest sides of the building (based on the path of the summer sun). Trees planted on the north side of the building in cold climates can reduce heating in winter by shielding the building from the wind. Vines can provide both shade and wind shielding.

Add building insulation

Adding insulation will reduce utility bills. Older buildings are likely to use more energy than newer ones, leading to very high heating and air conditioning bills. However, even in new buildings, adding insulation may reduce utility bills enough to pay for itself within a few years.

Various states have regulations and guidelines for building insulation—for example, California's *Energy Efficiency Standards for Residential and Nonresidential Buildings* (Title 24).[13] Going beyond regulated insulation levels may be economically beneficial and should be considered as part of a new building's design, as well as for reconstruction of existing buildings. For refrigerated warehouses, much higher levels of insulation are preferred.

[13] See www.energy.ca.gov/title24.

Install low-emittance (Low-E) windows
Low-emittance windows are another effective strategy for improving building insulation. Low-emittance windows can lower the heat transmitted into a building to increase its insulating ability. There are two types of Low-E glass: high solar transmitting (for regions with higher winter utility bills) and low solar transmitting (for regions with higher summer utility bills). The U.S. DOE supports the development of new window and glazing technology, and the ENERGY STAR website includes a selection of rated Low-E windows. New window and glazing technology is being developed worldwide.[14]

4.3 Motors

Motors are the main industrial electricity consumer and are used in many plant systems, such as HVAC, compressed air, refrigeration and cooling, and various processes. This section applies to any system that uses motors. Examples are used to detail specific applications and their success.

When considering energy-efficiency improvements to a facility's motor systems, take a "systems approach." Rather than considering the energy efficiency of just the motor, the systems approach strives to optimize the energy efficiency of the entire motor system (including the motor; driven equipment such as pumps, fans, and compressors; and controls). A systems approach analyzes both the energy supply and energy demand sides of motor systems, as well as how both sides interact to optimize total system performance. The focus is on both energy use and system uptime and productivity.

A systems approach for motors typically involves the following five steps:

1. Locate and identify all motors in the facility.
2. Document conditions and specifications of each motor to provide a current systems inventory.
3. Assess the needs and the actual use of the motor systems to determine whether or not motors are properly sized and how well each motor meets the needs of its driven equipment.
4. Collect information on potential repairs and upgrades to the motor systems, including the economic costs and benefits of implementing repairs and upgrades, to enable the energy-efficiency improvement decision-making process.
5. If upgrades are pursued, monitor the performance of the upgraded motor systems to determine actual costs savings.

Did You Know?

Up to 95% of a motor's costs can be attributed to the energy it consumes over its lifetime, while only about 5% of a motor's costs are typically attributed to its purchase, installation, and maintenance (MDM 2007).

The motor system energy-efficiency measures below reflect important aspects of this approach, including matching motor speeds and loads, proper motor sizing, and upgrading system components.

This section focuses on motors and motor systems in general. The following two sections focus more specifically on the energy-efficiency opportunities in the two key motor systems: compressed air (Section 4.4) and pumps (Section

[14] See, for example, www.efficientwindows.org.

4.5). Industrial refrigeration systems are another important user of motors (for compressors). For a more detailed description of energy-efficiency opportunities in refrigeration systems, please consult the report *Energy Efficiency Improvement and Cost Saving Opportunities for the Fruit and Vegetable Processing Industry*[15] (Masanet et al. 2008) on the ENERGY STAR website.

Develop a motor management plan

A motor management plan is an essential part of a plant's energy management strategy. It helps to support long-term motor system energy savings and to ensure that motor failures are handled quickly and cost effectively. The National Electrical Manufacturers Association (NEMA) and other organizations have created the Motor Decisions Matter℠ campaign to help industrial and commercial customers evaluate their motor repair and replacement options, promote cost-effective applications of NEMA Premium® motors and "best practice" repair, and support the development of motor management plans before motors fail. The national campaign suggests the following actions for a sound motor management plan (MDM 2007):

1. Create a motor survey and tracking program.
2. Develop guidelines for proactive repair/replace decisions.
3. Prepare for motor failure by creating a spares inventory.
4. Develop a purchasing specification.
5. Develop a repair specification.
6. Develop and implement a predictive and preventive maintenance program.

The Motor Decisions Matter Campaign's *Motor Planning Kit*[16] contains further details on each of these elements (MDM 2007).

Select motors strategically

Important factors to consider when selecting a motor include speed, horsepower, enclosure type, temperature rating, efficiency level, and quality of power supply. When selecting and purchasing a motor, consider the motor's life-cycle costs rather than just its initial purchase and installation costs. Up to 95% of a motor's costs can be attributed to the energy it consumes over its lifetime, while only about 5% of a motor's costs are typically attributed to its purchase, installation, and maintenance (MDM 2007). Life cycle costing (LCC) is an accounting framework that enables users to calculate total ownership costs of different investment options, leading to a sound evaluation of competing motor purchasing, repair, or replacement alternatives. A specific LCC guide developed for pump systems (Fenning et al. 2001) also provides a general introduction to LCC for motor systems.

Motor efficiency

Selecting energy-efficient motors is an important strategy for reducing motor system life-cycle costs because they reduce energy losses through improved design, better materials, tighter tolerances, and improved manufacturing techniques. With proper installation, energy-efficient motors can also run cooler (which may help reduce facility heating loads) and have higher service factors, longer bearing life, longer insulation life, and less vibration.

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[15] See www.energystar.gov/ia/business/industry/Food-Guide.pdf.

[16] See www.motorsmatter.org/tools/mpkv21.pdf.

To be considered energy-efficient in the United States, a motor must meet NEMA performance criteria. The Consortium for Energy Efficiency (CEE) has described the evolution of standards for energy-efficient motors in the United States, which is helpful for understanding the "efficient" motor nomenclature (CEE 2007):

- NEMA Energy-efficient motor standard (NEMA EE) was developed in the mid-1980s (NEMA 2002), and in 1992 the Energy Policy Act (EPACT) required that many motors comply with NEMA "energy-efficient" ratings if sold in the United States.
- A CEE Premium Efficiency Criteria specification was designed in 1996 to promote motors with higher efficiency levels than EPACT required.
- In 2001, the NEMA Premium Efficiency Electric Motor specification was developed to address confusion with respect to what constituted the most efficient motors available in the market. This specification was developed by NEMA, CEE, and other stakeholders, and was adapted from the CEE 1996 criteria. It currently serves as the benchmark for premium energy-efficient motors. NEMA Premium® also denotes a brand name for motors which meet this specification. Specifically, this specification covers motors with the following attributes:
    - Speed: 2-, 4-, and 6-pole
    - Size: 1 to 500 horsepower (hp)
    - Design: NEMA A and B
    - Enclosure type: open and closed
    - Voltage: low and medium voltage
    - Class: general, definite, and special-purpose

CASE STUDY: Efficient Motors

Cummins Engine Company, Inc. is a leading manufacturer of diesel engines. The MidRange Engine Plant in Indiana, which produces diesel engines for Daimler Chrysler trucks, exchanged 296 of its standard efficiency motors (motors sold before the Energy Policy Act of 1992) with energy-efficient motors, saving 3,771 kW and $80,000 per year with a payback period of less than two years (CDA 2000). In the Columbus (Indiana) plant, Cummins specified new energy-efficient motors for their HVAC system and found a payback period of less than two years, which resulted in annual savings of $128,000.

The choice of whether or not to install a premium efficiency motor strongly depends on (1) motor operating conditions, and (2) the life cycle costs associated with the investment. In general, premium-efficiency motors are most economically attractive when replacing motors with an annual operation exceeding 2,000 hours/year. Software tools such as MotorMaster+ (see Tools for Self-Assessment in Appendix D) can help identify attractive applications of premium-efficiency motors based on specific plant conditions. Given the quick payback time, it usually makes sense to buy the most efficient motor available.

Sometimes, replacing an operating motor with a premium-efficiency model may have a short payback period. According to data from the Copper Development Association, the upgrade to high-efficiency motors, as compared to motors that achieve the minimum efficiency as specified by EPACT, can have paybacks of less than 15 months for 50 hp motors. Payback times will vary based on size, load factor, running time, local energy costs, and available rebates and/or incentives.

Rewind versus replace

In some cases, it may be cost-effective to rewind an existing energy-efficient motor instead of purchasing a new one. As a rule of thumb, when rewinding costs exceed 60% of the costs of a new motor, purchasing the new motor is a better choice (MDM 2007). If you do decide to rewind, choose a motor service center that follows best-practice motor rewinding standards in order to minimize potential efficiency losses. An ANSI-approved recommended best-practice standard has been offered by the Electric Apparatus Service Association (EASA) for the repair and rewinding of motors (EASA 2006). When best rewinding practices are implemented, efficiency losses are typically less than 0.5% to 1% (EASA 2003). However, poor quality rewinds may result in larger efficiency losses, so it is important to ask whether the motor service center follows EASA best practice standards (EASA 2006).

Did You Know?

As a rule of thumb, when rewinding costs exceed 60% of the costs of a new motor, purchasing the new motor is a better choice (MDM 2007).

Maintain your motors

Motor maintenance helps you prolong motor life and foresee potential failures. Maintenance measures can be categorized as either preventative or predictive. The purpose of *preventative* measures is to prevent unexpected downtime. These measures include voltage imbalance minimization, load consideration, motor ventilation, alignment, and lubrication. The purpose of *predictive* motor maintenance is to observe ongoing motor temperature, vibration, and other operating data to determine when it will become necessary to overhaul or replace a motor before failure occurs. Savings from an ongoing motor maintenance program can range from 2% to 30% of total motor system energy use.

Ensure that motors are properly sized

Inappropriately sized motors result in unnecessary energy losses; if peak loads on driven equipment can be reduced, so can motor size. Replacing oversized motors with properly sized motors saves, on average for U.S. industry, 1.2% of total motor system electricity consumption. Higher savings can often be realized for smaller motors and individual motor systems.

To determine the proper motor size, gather the following data: load on the motor, operating efficiency of the motor at that load point, the full-load speed of the motor to be replaced, and the full-load speed of the replacement motor. The U.S. DOE's BestPractices program provides fact sheets[17] that can help you to decide whether to replace oversized and under-loaded motors. Additionally, software packages such as MotorMaster+ (see Tools for Self-Assessment, Appendix D) help in proper motor selection.

Consider adjustable speed drives (ASDs)

Adjustable-speed drives better match speed to load requirements for motor operations, and therefore ensure that motor energy use is optimized to a given application. These systems are offered by many suppliers worldwide. Energy savings may vary from 7% to as high as 60%.

Computer controls can be used with ASDs to control the adjustment of power to match demand.

[17] See www1.eere.energy.gov/industry/bestpractices/techpubs_motors.html.

CASE STUDY:
Motor System Controls

General Motors installed computer controls on the electric blower motors in its Fairfax Assembly Plant in Kansas City. The controls were programmed to regulate the motors' speeds by continuously monitoring the speed and adjusting the power to meet the speed demand. The computer chips saved the plant more than 4.3 million kWh of energy annually. This total capital investment of $3,724 resulted in a payback period of approximately one month.

CASE STUDY: ASDs

At its metal plating facility in Burlington, Vermont, General Dynamics Armament Systems installed ASDs along with an energy management control system (EMS) to control the ASDs as a unit. They found electricity savings of over 443,000 kWh and natural gas savings of 17,480 million British Thermal Units (MMBtu). The project cost $99,400 to implement, and saved $68,600 annually, providing a simple payback period of 1.5 years. The installation also reduced CO_2 emissions by 213 tons/year; improved overall productivity, control, and product quality; and reduced wear of equipment, thereby reducing future maintenance costs.

Correct power factor
Inductive loads like transformers, electric motors, and HID lighting may cause a low power factor, resulting in increased power consumption and electricity costs. The power factor can be corrected by minimizing idling of electric motors (a motor that is turned off consumes no energy), replacing motors with premium-efficient motors (see above), and installing capacitors in the AC circuit to reduce the magnitude of reactive power in the system.

Minimize voltage unbalances
A voltage unbalance degrades the performance and shortens the life of three-phase motors. It also causes a current unbalance, which will result in torque pulsations, increased vibration and mechanical stress, increased losses, and motor overheating (which can reduce the life of the motor's winding insulation).

Voltage unbalances may be caused by faulty operation of power factor correction equipment, an unbalanced transformer bank, or an open circuit. A rule of thumb is that the voltage unbalance at the motor terminals should not exceed 1%. Even a 1% unbalance will reduce motor efficiency at part load operation, while a 2.5% unbalance will reduce motor efficiency at full load operation. For a 100 hp motor operating 8,000 hours per year, a correction of the voltage unbalance from 2.5% to 1% will result in electricity savings of 9,500 kWh, or almost $500 at an electricity rate of $0.05/kWh.

Voltage unbalances may be identified by regularly monitoring the voltages at the motor terminal and through regular thermographic inspections of motors. Verify that single-phase loads are uniformly distributed and install ground fault indicators as required. Another indicator that a voltage unbalance may be a problem is 120 Hz vibration; which should prompt an immediate check of voltage balance. The typical payback period for voltage controller installation on lightly loaded motors in the United States is 2.6 years.

4.4 Compressed Air

Compressed air is probably the most expensive form of energy used in an industrial plant because of its poor efficiency, typically about 10% from start to end use. If compressed air is used, it should be at the minimum quantity for the shortest possible time, and it should be constantly monitored and reweighed against alternatives. Many energy-reduction opportunities in compressed air systems are not prohibitively expensive and payback periods for some are extremely short, often less than one year.

Maintain compressed air systems

Inadequate maintenance can lower compression efficiency and increase air leakage or pressure variability, and can lead to increased operating temperatures, poor moisture control, and excessive contamination of compressed air system components. Better maintenance will reduce these problems and save energy.

The following bullets summarize compressed air problems and maintenance solutions:

- *Blocked pipeline filters increase pressure drop*. Keep the compressor and intercooling surfaces clean and foul-free by inspecting and periodically cleaning filters. Seek filters with just a 1 pound per square inch (psi) pressure drop. The payback period for filter cleaning is usually under two years. Fixing improperly operating filters will also prevent contaminants from entering into tools, which causes them to wear out prematurely. Generally, when pressure drop exceeds 2 to 3 psig, replace the particulate and lubricant removal elements. Inspect all elements at least annually. Also, consider adding filters in parallel to decrease pressure drop. Expect a 2% reduction of annual energy consumption in compressed air systems when filters are changed frequently.
- *Poor motor cooling* can increase motor temperature and winding resistance, shortening motor life and increasing energy consumption. Keep motors and compressors properly lubricated and cleaned. Sample and analyze compressor lubricant every 1000 hours and ensure that it is at the proper level. In addition to energy savings, this maintenance can help avoid system corrosion and degradation.
- *Inspect fans and water pumps* regularly to ensure proper performance.
- *Inspect drain traps* periodically to ensure they are not stuck in either the open or closed position and are clean. Some users leave automatic condensate traps partially open at all times to allow for constant draining; however, this practice wastes substantial amounts of energy and should never be implemented. Instead, install simple pressure-driven valves. Clean and repair malfunctioning traps instead of leaving them open. Some automatic drains or valves do not waste air, such as those that open when condensate is present. According to vendors, inspecting and maintaining drains typically has a payback period of less than two years.

CASE STUDY: Compressor Load Management

Impressive savings were realized with a compressor upgrade at a Sara Lee bakery in Sacramento, California, in 2004. Prior to the upgrade, the company used one 100 hp and two 150 hp rotary screw compressors in its compressed air system. After the upgrade, the company used the 100 hp fixed-speed unit as its base compressor and a new 100 hp ASD compressor for variable loads. The project reduced annual facility energy consumption by 471,000 kWh and annual energy costs by around $40,000, while also saving the company $10,000 per year in avoided maintenance costs. The reported payback period was just 6.5 months.

- *Maintain the coolers* on the compressor and the aftercooler to ensure that the dryer gets the lowest possible inlet temperature.
- If using compressors with belts, *check the belts* for wear and adjust them. A good rule of thumb is to adjust them every 400 hours of operation.
- *Check water cooling systems* for water quality (pH and total dissolved solids), flow, and temperature. Clean and replace filters and heat exchangers as suggested by the manufacturer.
- *Minimize leaks* (see also Leaks section, below).
- *Specify pressure regulators* that close when failing.
- Applications requiring compressed air should be *checked for excessive pressure*, duration, or volume. They should be regulated, either by production line sectioning or by pressure regulators on the equipment itself. Tools not required to operate at maximum system pressure should use a quality pressure regulator, since poor quality regulators tend to drift and lose more air. Otherwise, the unregulated tools operate at maximum system pressure at all times and waste excess energy. System pressures operating too high also result in shorter tool life and higher maintenance costs.

Monitor compressed air use

As with maintenance, proper monitoring of compressed air systems can save energy and money.

Proper monitoring includes the following:

- Pressure gauges on each receiver or main branch line, and differential gauges across dryers and filters.
- Temperature gauges across the compressor and its cooling system to detect fouling and blockages.
- Flow meters to measure the quantity of air used.
- Dew point temperature gauges to monitor air dryer effectiveness.
- Kilowatt-hour meters and hours-run meters on the compressor drive.

Reduce leaks in pipes and equipment

Air leaks can be a significant source of wasted energy. A typical plant that has not been well maintained could have a leak rate between 20% to 50% of total compressed air production capacity. Leak repair and maintenance can reduce this number to less than 10%. Overall, fixing leaks in a compressed air system is projected to reduce annual energy consumption by 20%.

The magnitude of a leak varies with the size of the hole in the pipes or equipment. It is estimated that

CASE STUDIES: Leak Repair

Ford has included a leak program in its assessment projects. Assessors identify compressed air leaks using ultrasonic equipment and note problem areas using leak tags. After fixing leaks, controls are added to the compressors to take advantage of the extra capacity gained by the repair.

Visteon's plant in Monroe, Michigan, implemented a leak management program that included support from management as well as line workers and skilled tradespeople. They achieved cost savings of $560,000 per year from reduced electricity—equal to a 12% reduction in electricity consumption (8.9 million kWh annually). They also found reduced wear on all components within the system (compressors, dryers, piping, filters, and end-use applications) due to lower plant pressure.

losses based on a compressor operating 2,500 hours per year at 6 bar (87 psi) will experience the following losses:

- With a leak diameter of 0.02 inches (½ millimeter [mm]): 250 kWh/year
- With a leak diameter of 0.04 in. (1 mm): 1,100 kWh/year
- With a leak diameter of 0.08 in. (2 mm): 4,500 kWh/year
- With a leak diameter of 0.16 in. (4 mm): 11,250 kWh/year

The most common areas for leaks are couplings, hoses, tubes, fittings, pressure regulators, open condensate traps and shut-off valves, pipe joints, disconnects, and thread sealants. Quick-connect fittings always leak and should be avoided. Leaks can make air tools less efficient and adversely affect production, shorten the life of equipment, lead to additional maintenance requirements, and increase unscheduled downtime. Leaks also cause an increase in compressor energy and maintenance costs. However, it is cost-effective to fix leaks, with typical repairs costing $400. In more than one thousand examples of reducing leaks in pipes and equipment, the average payback period was about five months.[4]

Detecting leaks
A simple way to detect large leaks is to apply soapy water to suspect areas, or to use a bag to monitor the velocity of the air filling the bag, although this may be time consuming. In the "bag test," a plastic bag is put up to the leak and used to monitor the velocity of the air filling the bag.

The best way to detect leaks is to use an ultrasonic acoustic detector, which can recognize the high-frequency hissing sounds associated with air leaks. After identifying them, leaks should be tracked, repaired, and verified. Leak detection and correction programs should be ongoing efforts.

Turn off unnecessary compressed air
Equipment that is no longer using compressed air should have the air turned off completely. This can be done using a simple solenoid valve. Check compressed air distribution systems when equipment has been reconfigured to ensure no air is flowing to unused equipment or obsolete parts of the compressed air distribution system.

Modify the system instead of increasing system pressure
For individual applications that require a higher pressure, consider special equipment modifications instead of raising the operating pressure of the whole system. For example:

- use a booster,
- increase a cylinder bore,
- change gear ratios, and
- change operation to off -peak hours.

Use sources other than compressed air
Many operations can be accomplished more economically and efficiently using other energy sources. Some industry engineers believe this measure has the largest potential for compressed air energy savings. As shown in Table 2, various options can replace compressed air use.

Table 2. Alternatives for compressed air

Application	Alternative
Air motors	Compressed air should only be used for positive displacement.
Cooling electrical cabinets	Air conditioning fans should be used instead of using compressed air vortex tubes.
Flowing high-pressure air past an orifice to create a vacuum	A vacuum pump system should be applied instead of compressed air venturi methods.
Cooling, aspirating, agitating, mixing, or package inflating	Blowers
Cleaning parts or removing debris	Brushes, blowers, or vacuum pump systems or nozzles that are more efficient
Moving parts	Blowers, electric actuators, or hydraulics
Blowguns, air lances, and agitation	Low-pressure air
Tools or actuators	Consider efficient electric motors because they are more efficient. Some sources, however, have reported that motors can have less precision, shorter lives, and lack safety. In these cases, using compressed air may be a better choice.

Note: Numerous case studies across industry estimate an average payback period of 11 months for replacing compressed air with other applications.

Manage the load

Because of the large amount of energy consumed by compressors, whether in full operation or not, partial load operation should be avoided. Centrifugal compressors are cost effective when operated at high loads.

Use air at lowest possible pressure

Although system pressure may be higher, air used for a particular application should be at the lowest pressure needed.

Minimize pressure drop in distribution system design

An excessive pressure drop results in poor system performance and excessive energy consumption. Flow restrictions of any type, such as an obstruction or roughness, require operating pressures to be higher than necessary. Flow resistance increases pressure (and associated compressor energy use) by 1% for each 2 psi of pressure rise. The highest pressure drops are usually found at the points of use. These include:

- undersized or leaking hoses
- tubes
- disconnects
- filters
- regulators

- valves
- nozzles and lubricators (demand side)
- air/lubricant separators on lubricated rotary compressors and aftercoolers
- moisture separators
- dryers, and
- filters.

Compressor Facts

- Air receivers can be employed near high-demand areas to provide a supply buffer to meet short-term demand spikes that can exceed normal compressor capacity. In this way, required online compressors may be reduced.
- Multiple-stage compressors theoretically operate more efficiently than single-stage compressors.
- Many multi-stage compressors save energy by cooling the air between stages, reducing the volume and work required to compress the air.
- Replacing single-stage compressors with two-stage compressors typically provides a payback period of 2 years or less.
- Using multiple smaller compressors instead of one large compressor can save energy as well.
- Large compressors consume more electricity when they are unloaded than do multiple smaller compressors with similar overall capacity.
- An analysis of case studies around the country shows an average payback period of about 1.2 years.

Minimizing pressure drop requires a systems approach in design and maintenance. Select air treatment components with the lowest possible pressure drop at the specified maximum operating conditions and best performance. Follow manufacturers' recommendations for maintenance, particularly for air filtering and drying equipment, which can have damaging moisture effects like pipe corrosion. Finally, minimize the distance that air travels through the distribution system.

Reduce inlet air temperature

If air flow is kept constant, reducing the inlet air temperature reduces energy used by the compressor. In many plants, it is possible to reduce inlet air temperature to the compressor by taking suction from outside the building. As a rule of thumb, each 5°F (3°C) will save 1% of compressor energy. A payback period may be between one to five years.

Controls

The total air requirement is the sum of the average air consumption for each tool on the system, so a control strategy should focus on shutting off unneeded tools. This can mean shutting off compressors or not turning on additional compressors until needed. All compressors that are on should be running at full load, except for one, which should handle trim duty.

To determine proper control systems, assess compressed air requirements over time, establishing a load profile. When demand is less than peak, the most efficient strategy is to use multiple smaller compressors with sequencing controls. Facilities with a flatter load profile can use simpler control strategies.

Control loop positioning is also important; reducing and controlling the system pressure downstream of the primary receiver can reduce energy consumption up to 10% to 12%. Various control types exist:

- *Start/stop* (on/off) is the simplest control strategy and can be applied to small reciprocating or rotary screw compressors. Start/stop controls turn the motor driving the compressor on or off in response to the machine's discharge pressure. These controls are used for applications with very low duty cycles. Applications with frequent cycling will cause the motor to overheat. Typical payback period for start/stop controls is one to two years.

- *Load/unload control*, or *constant speed control*, allows the motor to run continuously but unloads the compressor when the discharge pressure is adequate. In most cases, unloaded rotary screw compressors still consume 15% to 35% of full-load power when fully unloaded, while delivering no useful work. Therefore, load/unload controls can be inefficient and require ample primary receiver volume.
- *Modulating or throttling controls* allow the output of a compressor to be varied to meet flow requirements by closing down the inlet valve and restricting inlet air to the compressor. Throttling controls are applied to centrifugal and rotary screw compressors. Changing the compressor control to a variable speed control can save up to 8% of electricity and electricity cost per year.

CASE STUDY: Compressors

Modern Forge of Tennessee, a metal component manufacturing facility, undertook a compressed air system optimization project to correct the following problems: a lack of air storage to respond to demand spikes; high pressure drop from intermittent demand; poorly designed components; dirty filtration devices; poorly operating controls; lubricant and moisture carryover; and excessive compressor power on weekends. System improvements in controls, air storage receivers, and piping distribution—as well as installing a new dryer, replacing dirty filters, fixing leaks, replacing and upgrading drains, and purchasing a small compressor for weekend use—saved the plant energy and avoided the purchase of an additional compressor, worth $120,000. Total cost for the improvements was $105,000. The annual electricity savings totaled 2.4 million kWh, ($120,000/year), 8% of total electric costs for the plant. These energy savings, along with reduced maintenance costs of $40,000, generated a payback period of eight months, or even less when considering the avoided purchase of the additional compressor.

- *Multi-step or part-load controls* can operate in two or more partially loaded conditions. Output pressures can be closely controlled without requiring the compressor to start/stop or load/unload.
- *System controls* work on multiple compressors. Single master sequencing system controls take individual compressor capacities on and offline in response to monitored system pressure demand, and shut down any compressors running unnecessarily. System controls for multiple compressors typically offer a higher efficiency than individual compressor controls.

Properly size regulators
Regulators can provide the largest energy savings in compressed air systems. By properly sizing regulators, compressed air that is otherwise wasted as excess air will be saved. Specify pressure regulators that close when failing.

Size pipe diameter correctly
Inadequate pipe sizing can cause pressure losses, increase leaks, and increase generating costs. Pipes must be sized correctly for optimal performance or resized to fit the current compressor system. Increasing pipe diameter typically reduces annual energy consumption by 3%.

Implement system improvements
Adding additional compressors should be considered only after a complete system evaluation. Implementing some of the measures discussed in this section can reduce air demand considerably, negating the need to purchase additional compressors. The Compressed Air Challenge®[18] offers free web-based guidance for selecting the right integrated service provider, as well as guidelines defining walk-through evaluations, system assessments, and fully instrumented system audits.

Recover heat for water preheating
As much as 80% to 93% of the electrical energy used by an industrial air compressor is converted into heat. In many cases, a heat recovery unit can recover 50% to 90% of the available thermal energy for the following applications:

- Space heating
- Industrial process heating
- Water heating
- Makeup air heating
- Boiler makeup water preheating
- Industrial drying
- Heat pumps
- Preheating combustion air for burners or boilers

Payback periods are typically less than one year. It is estimated that approximately 50 kBtu/hour of energy is available for each 100 cubic foot per minute of capacity (at full load). Note that heat recovery for space heating is not as common with water-cooled compressors because an extra stage of heat exchange is required and the temperature of the available heat is lower.

[18] See www.compressedairchallenge.org/.

4.5 Pumps

> **Did You Know?**
>
> As much as 20% of the energy consumed by pumping systems could be saved through changes to pumping equipment and/or pump control systems.

Pumps are particularly important pieces of motor-driven equipment in many small- and medium-sized plants. They are used extensively to pressurize and transport water in cleaning, water fluming, and wastewater handling operations; for transporting liquid streams between processes; and for circulating liquids within processes. The basic components in a pump system are pumps, drive motors, piping networks, valves, and system controls. Some of the most significant energy-efficiency measures applicable to these components and to pump systems as a whole are described below.

Take a systems approach when assessing pump energy efficiency improvement opportunities within a facility. Although an individual pump might be operating efficiently, it could be generating more flow than the system requires for a given application, so it is wasting energy. Assess both individual pump efficiencies and how well the various pump system end uses are being served by its pumps.

A pump's initial capital cost is typically only a small fraction of its total life cycle costs. In general, maintenance and energy costs represent by far the most significant fraction of a pump's total life cycle costs. In some cases, energy costs can account for up to 90% of the total cost of owning a pump. So, when choosing pumping equipment, base your decision on projected energy and maintenance costs rather than on initial capital costs alone.

The Pump Systems Matter™ program,[19] conceived by the Hydraulic Institute, provides detailed information on improving the performance of pump systems. The most important opportunities for increasing efficiency are discussed below.

Implement a pump system maintenance program

Inadequate maintenance can lower pump system efficiency, cause pumps to wear out more quickly, and increase pumping energy costs. Implementing a pump system maintenance program will help you avoid these problems by keeping pumps running optimally. Improved pump system maintenance can lead to pump system energy savings from 2% to 7%.

A solid pump system maintenance program will generally include the following tasks (U.S. DOE 2006a):

- Replace worn impellers, especially in caustic or semi-solid applications.
- Inspect and repair bearings.
- Replace bearing lubrication annually or semiannually.
- Inspect and replace packing seals. Allowable leakage from packing seals is usually between 2 to 60 drops per minute.
- Inspect and replace mechanical seals. Allowable leakage is typically 1 to 4 drops per minute.

[19] See www.pumpsystemsmatter.org.

- Replace wear ring and impeller. Pump efficiency degrades by 1% to 6% for impellers less than the maximum diameter and with increased wear ring clearances.
- Check pump/motor alignment.
- Inspect motor condition, including the motor winding insulation.

CASE STUDY: Pump Controls

Cisco Systems upgraded the controls on its fountain pumps so that pumps would be turned off automatically during periods of peak electrical system demand. A wireless control system was able to control all pumps simultaneously from one location. The project saved $32,000 and 400,000 kWh annually, representing a savings of 61.5% in the total energy consumed by the fountain pumps. With a total cost of $29,000, the simple payback period was 11 months. In addition to energy savings, the project reduced maintenance costs and increased the pump system's equipment life.

Monitor pump systems

Monitoring, combined with a proper maintenance program, will help detect pump system problems before they escalate into major performance issues or equipment repairs. Monitoring can be done manually on a periodic basis (for example, performing regular bearing oil analyses to detect bearing wear, or using infrared scanning to detect excessive pump heat), or it can be performed continuously using sensor networks and data analysis software (such as using accelerometers to detect abnormal system vibrations) (U.S. DOE 2006a). Monitoring can help keep pump systems running efficiently by detecting system blockages, impeller damage, inadequate suction, clogged or gas-filled pumps or pipes, pump wear, and if pump clearances need to be adjusted.

In general, a good pump monitoring program should include the following aspects:

- Wear monitoring.
- Vibration analysis.
- Pressure and flow monitoring.
- Current or power monitoring.
- Monitoring of differential head and temperature rise across pumps (also known as *thermodynamic monitoring).*
- Distribution system inspection for scaling or contaminant build-up.

Reduce pump demand

An important component of the systems approach is to minimize pump demand by better matching pump requirements to end-use loads. Two effective strategies for reducing pump demand are (1) the use of holding tanks, and (2) the elimination of bypass loops.

Holding tanks can be used to equalize pump flows over a production cycle, which can allow for more efficient operation of pumps at reduced speeds and lead to energy savings of up to 10% to 20%. Holding tanks can also reduce the need to add pump capacity.

The elimination of bypass loops and other unnecessary flows can lead to similar energy savings, as can lowering process static pressures, minimizing elevation rises in the piping system, and lowering spray nozzle velocities.

Install controls
Control systems can increase the energy efficiency of a pump system by shutting off pumps automatically when demand is reduced or by putting pumps on standby at reduced loads until demand increases.

Install high-efficiency pumps
It has been estimated that up to 16% of pumps in use in U.S. industry are more than 20 years old. Considering that a pump's efficiency may degrade by 10% to 25% over the course of its life, replacement of aging pumps can lead to significant energy savings. The installation of newer, higher-efficiency pumps typically leads to pump system energy savings of 2% to 10%.

A number of high-efficiency pumps are available for specific pressure head and flow rate capacity requirements. Choosing the right pump often saves both operating costs and capital costs. For a given duty, selecting a pump that runs at the highest speed suitable for the application will generally result in a more efficient selection, as well as the lowest initial cost (U.S. DOE 2001).

Properly size pumps
Pumps that are oversized for an application consume more energy than is necessary. Replacing oversized pumps with properly sized ones can often reduce pumping system electricity use by 15% to 25%. Where peak loads can be reduced through improvements to pump system design or operation (for example, through the use of holding tanks), pump size can also be reduced. If a pump is dramatically oversized, often its speed can be reduced with gear or belt drives, or with a slower-speed motor. The typical payback period for these strategies can be less than one year.

Use multiple pumps for variable loads
The use of multiple pumps installed in parallel can be a cost-effective and energy-efficient solution for pump systems with variable loads. Parallel pumps offer redundancy and increased reliability, and can often reduce pump system electricity use by 10% to 50% for highly variable loads. Parallel pump arrangements often consist of a large pump, which operates during periods of peak demand, and a small (or "pony") pump, which operates under normal, more steady-state conditions (U.S. DOE 2006a). Because the pony pump is sized for normal system operation, this configuration operates more efficiently than a system that relies on a large pump to handle loads far below its optimum capacity.

Consider trimming impellers
Impeller trimming is machining to reduce an impeller's diameter. This reduces the energy added by the pump to the system fluid. According to the U.S. DOE (2006a), one should consider trimming an impeller when any of the following conditions occur:

- Many system bypass valves are open, indicating that excess flow is available to system equipment.
- Excessive throttling is needed to control flow through the system or process.
- High levels of noise or vibration indicate excessive flow.
- A pump is operating far from its design point.

Trimming an impeller is slightly less effective than buying a smaller impeller from the pump manufacturer, but it can be useful when an impeller at the next smaller available size would be too small for the given pump load. The energy savings associated with impeller trimming are dependent upon pump power, system flow, and system head, but are roughly proportional to the cube of the diameter reduction (U.S. DOE 2006a). An additional benefit of impeller trimming is a decrease in pump operating and maintenance costs.

> **CASE STUDY: Impeller Trimming**
>
> To reduce energy consumption and improve the performance of its beer cooling process, the Stroh Brewery Company analyzed the glycol circulation system used for batch cooling of beer products at its G. Heileman Division brewing facility in La Crosse, Wisconsin. By simply trimming down the diameter of the pump impeller and fully opening the discharge gate valve, cooling circulation system energy use was reduced by 50%, resulting in a $19,000 savings in the first year. With a cost of $1,500, the simple payback period for this measure was about one month.

Avoid throttling valves
Throttling valves and bypass loops are indications of oversized pumps. They also indicate the inability of the pump system design to accommodate load variations efficiently, so they should always be avoided. Pump demand reduction, controls, impeller trimming, and multiple pump strategies (all previously discussed) are preferred over throttling valves.

Replace drive belts
According to industrial pump inventory data, up to 4% of pumps are equipped with V-belt drives. Many of these V-belt drives can be replaced with direct couplings, which are estimated to lead to energy savings of about 1%.

Properly size pipes
Pipes that are too small for the required flow velocity can significantly increase the amount of energy required for pumping, in much the same way that drinking a beverage through a small straw requires a greater amount of suction. Where possible, pipe diameters can be increased to reduce pumping energy requirements, but the energy savings due to increased pipe diameters must be balanced with increased costs for piping system components. Increasing pipe diameters will likely only be cost effective during greater pump system retrofit projects. Typical energy savings are estimated at 5% to 20%.

Consider adjustable-speed drives (ASDs). Pumps that experience highly variable demand conditions are often good candidates for ASDs. As pump system demand changes, ASDs adjust the pump speed to meet this demand, thereby saving energy that would otherwise be lost to throttling or bypassing. The resulting energy and maintenance cost savings can often justify the investment costs for the ASD. However, ASDs are not practical for all pump system applications—for example, those that operate at high static head and those that operate for extended periods under low-flow conditions (U.S. DOE 2006a).

4.6 Hot Water and Steam Systems

Hot water and steam is used for many industrial applications. The size and use of modern systems vary greatly; however, steam systems do follow a typical pattern, as illustrated in

Figure 4. Treated cold feed water is fed to the boiler, where it is heated to form steam. Chemical treatment of the feed water removes many impurities that would otherwise collect on boiler walls, but some remain, so the water is periodically purged from the boiler in a process known as *blowdown.* The generated steam travels along distribution pipes to the process where the heat will be used. If the process requires lower pressure steam, the steam from the boiler may be passed through a pressure reduction valve before final use. As the steam is used to heat processes, and even as it travels through the distribution system to get there, the steam cools and some is condensed. This condensate is removed by a steam trap, which passes the condensate through but blocks passage of the steam. The condensate can be recirculated to the boiler, thus recovering some heat and reducing the need for fresh treated feed water. The recovery of condensate and blowdown also reduces the costs of boiler feed water treatment.

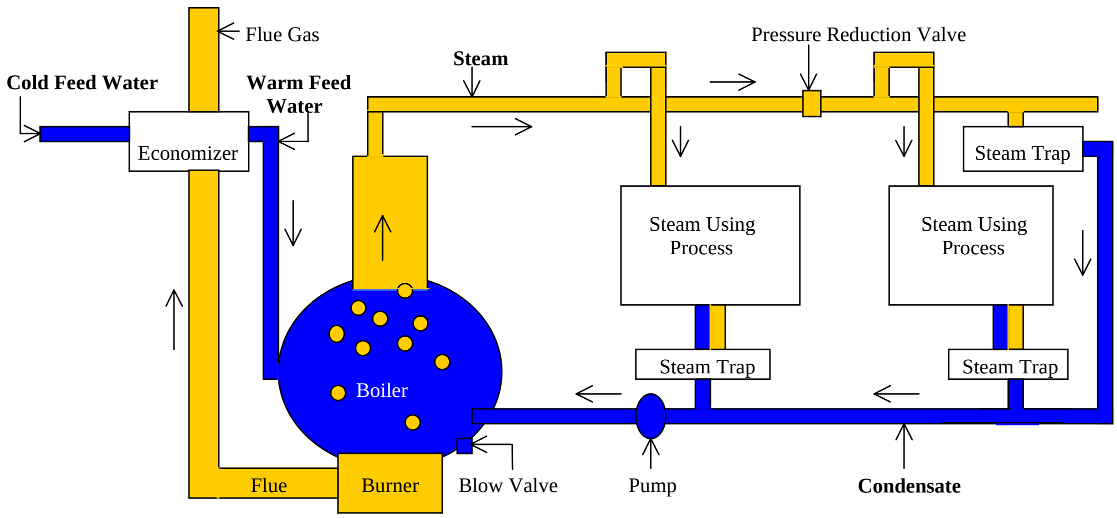

Figure 4. Simplified schematic of a steam production and distribution system. Back-pressure steam turbines, which may be used to recover power from super-heated steam, are not depicted.

The most important industrial applications for steam are:

- process heating,
- drying,
- concentrating,
- steam cracking,
- distillation, and
- driving machinery such as compressors.

Whatever the use or the source of the steam, efficiency improvements in steam generation, distribution, and end use are possible. According to the U.S. DOE, a typical industrial steam system assessment can identify potential energy use and cost savings of 10% to 15% per year (U.S. DOE 2006b).

Take a system approach in evaluating steam systems. First, identify where and how steam is used and identify the efficiencies with which it is used, because often this can result in the largest savings. Typically, a process integration study (see Section 4.7) would be applied to identify opportunities to optimize steam network use and integration.

Because steam, like any other secondary energy carrier, is expensive to produce and supply, its use should be carefully considered and evaluated against other options. Often steam is generated at higher pressures than needed or in larger volumes than needed at a particular time. These inefficiencies may lead steam systems to let down steam to a lower pressure or to vent it to the atmosphere. So evaluate the steam system on the use of appropriate pressure levels and production schedules.

If it is not possible to reduce the steam generation pressure, it may still be possible to recover the energy through a turbo expander or back-pressure steam turbine. Many systems may produce steam at higher pressures, to allow for the efficient cogeneration of power and heat through the use of back-pressure turbines. Excess steam generation can be reduced through improved process integration and improved management of steam flows in the industry.

The normal replacement investment cycle might offer opportunities to change to more energy-efficient steam systems.

CASE STUDY:
Reducing Steam Pressure

At Nalco Chemical Company in Bedford Park, Illinois, steam pressure could be reduced from 125 to 100 psig without affecting plant performance. The project did not require any capital investment and the specific energy use per pound of product was reduced by 8%. Annual savings are 56,900 MMBtu, cutting costs by $142,000.

4.6.1 Boiler energy efficiency measures

The boiler energy-efficiency measures presented below focus primarily on improved process control, reduced heat loss, and improved heat recovery. When new boiler systems are needed, they should be designed and installed in a custom configuration that meets that particular plant's needs. Often, pre-designed boilers cannot be fine-tuned to meet the unique steam generation and distribution system requirements of a specific plant in the most efficient manner.

Control boiler processes

Flue gas monitors maintain optimum flame temperature and monitor carbon monoxide (CO), oxygen, and smoke. The oxygen content of the exhaust gas is a combination of excess air (which is deliberately introduced to improve safety or reduce emissions) and air infiltration. By combining an oxygen monitor with an intake airflow monitor, it is possible to detect even small levels of air infiltration.

A small 1% air infiltration will result in 20% higher oxygen readings. A higher CO or smoke content in the exhaust gas is a sign that there is insufficient air to complete fuel burning. Using a combination of CO and oxygen readings, it is possible to optimize the fuel/air mixture for high flame temperature (and thus the best energy efficiency) and lower air pollutant emissions.

Typically, this measure is financially attractive only for large boilers, because smaller boilers often will not make up the initial capital cost as easily. Case studies indicate that the average payback period for this measure is about 1.7 years.

Reduce flue gas quantities using visual inspection
Often excessive flue gas results from leaks in the boiler and/or in the flue. These leaks can reduce the heat transferred to the steam and increase pumping requirements. However, such leaks are often easily repaired, saving 2% to 5% of the energy formerly used by the boiler.

This measure differs from flue gas monitoring in that it consists of a periodic repair based on visual inspection. The savings from this measure and from flue gas monitoring are not cumulative, as they both address the same losses.

Reduce excess air
When too much excess air is used to burn fuel, energy is wasted, because excessive heat is transferred to the air rather than to the steam. Air slightly in excess of the ideal stoichiometric fuel-to-air ratio (that is, the amount of inlet air per unit of fuel combusted) is required for safety and to reduce nitrogen oxide (NO_x) emissions, but approximately 15% excess air is generally adequate. Most industrial boilers already operate at 15% excess air or lower, and thus this measure may not be widely applicable (Zeitz 1997). However, if a boiler is using too much excess air, numerous industrial case studies indicate that the payback period for this measure is less than one year.

Properly size boiler systems
Designing the boiler system to operate at the proper steam pressure can save energy by reducing stack temperature, piping radiation losses, and leaks in steam traps. In a Canadian study of 30 boiler plants, savings from this measure ranged from 3% to 8% of total boiler fuel consumption (Griffin 2000). Costs and savings will depend heavily on the current boiler system utilization at individual plants.

Improve boiler insulation
It is possible to use new insulation materials, such as ceramic fibers, that both insulate better and have a lower heat capacity (thus allowing for more rapid heating). Savings of 6% to 26% can be achieved if improved insulation is combined with improved heater circuit controls. Due to the lower heat capacity of new insulating materials, the steam output temperature will vary more quickly with variations in the heating element temperature. Improved boiler process control is therefore often required in tandem with new insulation to maintain the desired output temperature range.

Implement a boiler maintenance program
A simple maintenance program to ensure that all boiler components are operating at peak performance can result in substantial savings. In the absence of a good maintenance system, burners and condensate return systems can wear or get out of adjustment. These factors

Did You Know?

On average, the energy savings associated with improved boiler maintenance are estimated to be 10%. Improved maintenance may also reduce the emission of criteria air pollutants.

can end up costing a steam system up to 30% of its initial efficiency over two to three years.

Control fouling on the fire side of boiler tubes and scaling on the water side of boilers. Fouling and scaling are more of a problem with coal-fed boilers than natural gas or oil-fed boilers. Boilers that burn solid fuels like coal should be checked more often because they have a higher fouling tendency than liquid fuel boilers do. Tests of various Canadian boilers show that a fire-side soot layer of 0.03 inches (0.8 mm) reduces heat transfer by 9.5%, while a 0.18 inch (4.5 mm) soot layer reduces heat transfer by 69% (CIPEC 2001). For water side scaling, 0.04 inches (1 mm) of buildup can increase fuel consumption by 2% (CIPEC 2001).

Recover flue gas heat

Heat recovery from flue gas is often the best opportunity for heat recovery in steam systems, because it can be used to preheat boiler feed water in an economizer. While this measure is fairly common in large boilers, there is often still room for more heat recovery. The limiting factor is that the economizer wall temperature must not drop below the dew point of acids contained in the flue gas (such as sulfuric acid in sulfur-containing fossil fuels). Traditionally, this has been accomplished by keeping the flue gases exiting the economizer at a temperature significantly above the acid dew point. In fact, the economizer wall temperature is much more dependent on feed water temperature than on flue gas temperature because of the high heat transfer coefficient of water. As a result, it makes more sense to preheat feed water to close to the acid dew point before it enters the economizer. This approach allows the economizer to be designed so that exiting flue gas is just above the acid dew point. Typically, 1% of fuel use is saved for every 45°F (25°C) reduction in exhaust gas temperature.

CASE STUDY: Economizer

At Odwalla Juice Company's facility in Dinuva, California, the installation of an economizer was expected to save over $21,000 per year in energy costs and over 4,000 MMBtu of boiler fuel per year (U.S. DOE 2002). The expected payback period for the economizer was just 10 months.

Return condensate to the boiler

Reusing hot condensate in boilers saves energy, reduces the need for treated boiler feed water, and reclaims water at up to 100°C (212°F) of sensible heat.

Typically, fresh feed water must be treated to remove solids that might accumulate in the boiler; thus, returning condensate (which has already been treated) to a boiler can substantially reduce the amount of purchased chemical required to accomplish this treatment. This measure can save substantial energy costs and, purchased chemicals costs often makes building a return piping system attractive. Payback period will depend on the plant layout, but can vary between two and three years.

Recover blowdown steam
When water is blown from a high-pressure boiler tank, the pressure reduction often produces substantial amounts of steam. This steam is typically low grade, but can be used for space heating and feed water preheating. The recovery of blowdown steam can save about 1% of boiler fuel use in small boilers. In addition to energy savings, blowdown steam recovery may reduce the potential for corrosion damage in steam system piping.

CASE STUDY:
Boiler Replacement

Valley Fig, a manufacturer of fig pastes and concentrates in Fresno, California, replaced an old and inefficient 300 boiler horsepower (bhp) fire tube boiler to meet stringent NO_X emissions limits. The 300 bhp boiler was replaced with two smaller and more efficient 100 bhp boilers, which not only allowed them to meet the facility's steam demands while lowering NO_X emissions, but also reduced natural gas costs by 8% to 10%. Additionally, Valley Fig received a $16,000 rebate check from Pacific Gas & Electric for improved fuel efficiency.

Replace old boilers
Substantial efficiency gains can often be achieved by replacing old boilers with new, higher-efficiency models. In particular, replacing inefficient coal-fired boilers with natural gas-fired boilers is a sound strategy for reducing both boiler fuel costs and air pollutant emissions.

4.6.2 Steam distribution system energy efficiency measures
Steam and hot water distribution systems are often quite extensive and can be major sources of energy losses. Energy efficiency improvements to steam distribution systems primarily focus on reducing heat losses throughout the system and recovering useful heat from the system wherever feasible. The following measures are some of the most significant opportunities for saving energy in industrial steam distribution systems.

Improve distribution system insulation
Using more insulating material or using the best insulation material for the application can save energy in steam systems. Crucial factors in choosing insulating material include low thermal conductivity, dimensional stability under temperature change, resistance to water absorption, and resistance to combustion. Other characteristics of insulating material also may be important, depending on the application, such as tolerance of large temperature variations, tolerance of system vibrations, and adequate compressive strength where the insulation is load bearing. Industrial case studies indicate that the payback period for improved insulation is typically about one year.

Maintain distribution system insulation
It is often found that after heat distribution systems have undergone some form of repair, the insulation is not replaced. In addition, some types of insulation can become brittle or rot over time. A regular inspection and maintenance system for insulation can save energy.

Improve steam traps

Modern thermostatic element steam traps can reduce energy use while improving reliability. Their main efficiency advantages are that they:

- open when the temperature is very close to that of saturated steam (within 4°F or 2°C),
- purge non-condensable gases after each opening, and
- are open on startup to allow a fast steam system warm-up.

These traps also have the advantage of being highly reliable and useable for a range of steam pressures.

> **CASE STUDY: Steam Traps**
>
> Improvement of steam trap maintenance system at the Chestertown, Maryland, facility of Velsicol Chemical Corporation resulted in energy savings of 27,308 million Btu annually ($80,000). In addition, because of the reduced need for boiler feed water, consumption of water treatment chemicals was also reduced by 1,000 pounds, saving $20,000 annually.

Maintain steam traps

A simple program of checking steam traps to ensure that they are operating properly can save significant amounts of energy for very little money. In the absence of such a program, it is common to find 15% to 20% of steam traps in a distribution system malfunctioning. Energy savings from checking steam traps and follow-up maintenance is conservatively estimated at 10%. One industrial case study indicates a payback period of less than four months. Although this measure offers quick payback, it is often not implemented because maintenance and energy costs are generally separately budgeted. In addition to energy and cost savings, properly functioning steam traps reduce the risk of corrosion in the steam distribution system.

Monitor steam traps

Attaching automated monitors to steam traps in conjunction with a maintenance program can save even more energy without significantly adding costs. This measure is an improvement over steam trap maintenance alone, because it gives quicker notice of steam trap failure and can detect when a steam trap is not performing at peak efficiency. This strategy can provide an additional 5% in energy savings compared to steam trap maintenance alone, at a payback period of about one year. Systems that can implement steam trap maintenance are also likely to be able to implement automatic monitoring.

Repair leaks

As with steam traps, steam distribution piping networks often have leaks that can go undetected without a regular inspection and maintenance program. The U.S. DOE estimates that repairing leaks in an industrial steam distribution system will lead to energy savings of about 5% to 10%.

Recover flash steam

When a steam trap purges condensate from a pressurized steam distribution system to ambient pressure, flash steam is produced. This flash steam can be recovered and used for low-grade applications, such as space heating or feed water preheating. The potential for this measure is site dependent, as its cost effectiveness depends on whether or not areas where low-grade heat is useful are located close to steam traps. Where feasible, this measure can be easy to implement and can save considerable amounts of energy.

4.7 Process Integration

Process integration aims to reduce the losses that occur in a system of multiple components. In facilities that have multiple heating and cooling demands, the use of process integration techniques may significantly improve facility energy efficiency by linking hot and cold process streams in a thermodynamically optimal manner. For example, the heat rejected in a facility's cooling process can be recovered and used in process heating applications. Developed in the early 1970s, process integration is now an established methodology for improving the energy efficiency of continuous industrial processes.

Conduct a pinch analysis

Pinch analysis takes a systematic approach to identifying and correcting the performance-limiting constraint (or pinch) in any manufacturing process system. It was developed originally to address the need to reduce steam and fuel consumption in oil refineries and chemical plants by optimizing the design of heat exchanger networks. Since then, the pinch analysis approach has been extended to resource conservation in general.

The critical innovation in applying pinch analysis was the development of "composite curves" for heating and cooling, which represent the overall thermal energy demand and availability profiles for the process as a whole. When these two curves are drawn on a temperature-enthalpy graph, they reveal the location of the process pinch (the point of closest temperature approach) and the minimum thermodynamic heating and cooling requirements. These points are called the *energy targets.* The pinch analysis methodology involves identifying the targets and then following a systematic procedure for designing heat exchanger networks to achieve these targets. The optimum approach temperature at the pinch is determined by balancing capital and energy tradeoffs to achieve the desired payback. The procedure applies equally well to new designs and retrofits of existing plants. Specialized consulting companies and programs exist to analyze the process integration opportunities at a plant.

4.8 Furnaces for Process Heating

Approximately 24% of the fuel used in industry is used in fired heaters. The average thermal efficiency of furnaces is estimated to be 75% to 90%. Accounting for unavoidable heat losses and dew point considerations, the theoretical maximum efficiency is about 92% (HHV).[20] This suggests that savings of 2% to 17% can be achieved in furnace and burner design, and in operations.

The following section discusses various efficiency opportunities, including improving heat transfer characteristics, enhancing flame luminosity, installing recuperators or air-preheaters, and improving controls. New burner designs aim at improved fuel and air mixing and on more efficient heat transfer; many different concepts are developed to achieve these goals. At the same time, furnace and burner design must address safety and environmental concerns, most notably NOx emissions reduction. Improved NOx control will often be necessary to meet air quality standards.

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[20] Higher Heating Value (HHV) is commonly used in the United States to express the heating value of a fuel. It includes the condensation heat of water formed during the combustion process.

Control the air-to-fuel ratio
In heat generation, chemical or electrical energy is converted into thermal energy. A first opportunity to improve the efficiency of heat generation is to control the air-to-fuel ratio in furnaces. Badly maintained process heaters may use excess air, which reduces burner efficiency. Excess air should be limited to 2% oxygen to ensure complete combustion. Typical energy savings of better-controlled air-to-fuel ratios vary between 5% and 25%. The use of an up-to-date exhaust gas oxygen analyzer can help to maintain optimal air-to-fuel ratios. Typical payback times of projects to reduce combustion air flows are about six months or less.

In many areas, air quality regulation demands reductions of NOx and VOC emissions from furnaces and boilers. Instead of installing expensive selective catalytic reduction (SCR) flue-gas treatment units, new burner technology allows you to reduce emissions dramatically. This will result in cost savings, as well as help to decrease electricity costs for the SCR.

Improve heat transfer and heat containment in heaters
Improved heat transfer within a furnace, oven, or boiler can result in both energy savings and productivity gains. Heat transfer can be improved by using soot blowers, burning off carbon and other deposits from radiant tubes, and cleaning heat exchange surfaces. Typical savings are 5% to 10%.

Ceramic-coated furnace tubes can improve the heat transfer of metal process tubing while stabilizing the process tube's surface. They can improve energy efficiency, increase throughput, or both. Applications of ceramic-coated furnace tubes in boilers and petrochemical process units have shown efficiency improvements between 4% and 12%.

Heat containment can be improved by numerous measures, including reducing wall heat losses (typical savings 2% to 5%), controlling furnace pressure (5% to 10%), maintaining door and tube seals (up to 5%), reducing cooling of internal parts (up to 5%), and reducing radiation heat losses (up to 5%).

Typical payback times of projects aiming to reduce heat losses and improve heat transfer are between three months and one year.

Recover flue gas heat
Reducing exhaust losses (for example, by implementing the measures described above) should always be the first concern in any energy conservation program. Once exhaust losses are reduced, the second level—recovery of exhaust gas waste heat—should be considered.

It is common to use waste heat from furnace flue gases to preheat combustion air in medium- to high- temperature furnaces because it is an efficient way to improve the efficiency and increase the capacity of a process heater. Recovering waste heat from the flue will reduce the flue gas exit temperature and increase the combustion feed air temperature, which increases furnace efficiency. In fact, every 35°F (20°C) drop in the exit flue gas temperature increases the furnace's thermal efficiency by 1%. Typical fuel savings range between 8% and 18%, and this strategy is typically economically attractive if the flue gas temperature is higher than 650°F (330°C) and the heater size is 50 million Btu per hour (MMBtu/hr) or more. The optimum flue gas temperature is also determined by the sulfur content of the flue gases, since the temperature of the flue gas needs to remain high enough to prevent the formation of sulfuric acid, which can corrode the flue. When adding a preheater, the burner needs to be re-rated. Energy recovery can also be applied in catalytic oxidizers used to reduce volatile organic compound (VOC) emissions, by taking measures such as using a regenerative heat exchanger in the form of a ceramic packing.

Heat from furnace exhaust gases or from other sources can also be used in waste heat or quench boilers to produce steam, or to cascade heat to other applications that require lower-temperature heat as part of the total plant heat demand and supply optimization. Recovering thermal energy in the form of steam from incineration of waste products should be considered carefully. Because a waste stream is used, the stream will have variations in contaminant and component concentrations that influence the load on the boiler. Also, the contaminants might create acidic gases, causing corrosion problems for the boiler. These aspects should be considered when designing waste heat boilers.

5 Summary

By increasing energy efficiency, companies can reduce costs and increase predictable earnings in the face of ongoing energy price volatility. Considering the negative impacts that energy price volatility can have on an organization’s bottom line, and recent sharp increases in natural gas prices across the nation, energy-efficiency improvements are needed today more than ever. Many companies have already accepted the challenge to improve their energy efficiency in the face of high energy costs and have begun to reap the rewards of energy-efficiency investments. In addition, companies are turning to energy-efficient processes and technologies to reduce their criteria pollutant and carbon emissions, to meet corporate environmental goals.

This Energy Guide has summarized many energy-efficient technologies and practices that are proven, cost-effective, and available for implementation today. These opportunities are applicable at the component, process, facility, and organizational levels. Preliminary estimates of savings in energy and energy-related costs have been provided for many of the measures, based on case study data from real-world industrial applications. Typical investment payback periods and references to further information have been provided, where available.

To achieve ongoing success, establish a focused and strategic energy management program that helps you identify and implement energy-efficiency measures and practices across an organization and ensure continuous improvement. Then assess your company’s energy-using systems and identify areas for improvement. Table 3 summarizes the energy-efficiency measures presented in this guide. Keep in mind that although the expected savings associated with some of the individual measures may be relatively small, their cumulative effect across an entire facility may be quite large. Many measures have relatively short payback periods and are therefore attractive economic investments on their own. The degree to which these measures are implemented will vary among plants and end uses, but continuous evaluation of your facility’s energy use will help to identify further cost savings. For all of the energy-efficiency measures presented in this guide, research their economics and their applicability to your facility’s own unique production practices, in order to assess the feasibility and potential benefits of each measure’s implementation.

Table 3. Summary of energy-efficiency measures

Energy Management Programs and Systems	
Energy management programs	Energy teams
Energy monitoring	
Steam Systems	
Boilers	
Boiler process control	Flue gas heat recovery
Reduction of flue gas quantities	Condensate return
Reduction of excess air	Blowdown steam recovery
Properly sized boiler systems	Boiler replacement
Improved boiler insulation	
Boiler maintenance	
Steam Distribution Systems	
Improved distribution system insulation	Steam trap monitoring
Insulation maintenance	Leak repair
Steam trap improvement	Flash steam recovery
Steam trap maintenance	
Process Integration	
Process integration	Pinch analysis
Motor Systems and Pumps	
Motor Systems	
Motor management plan	Strategic motor selection
Maintenance	Properly sized motors
Adjustable-speed drives	Power factor correction
Minimizing voltage unbalances	
Pumps	
Pump system maintenance	Multiple pumps for variable loads
Pump system monitoring	Impeller trimming
Pump demand reduction	Avoiding throttling valves
Controls	Replacement of belt drives
High-efficiency pumps	Proper pipe sizing
Properly sized pumps	Adjustable-speed drives
Compressed Air Systems	
System improvements	Improved load management
Maintenance	Pressure drop minimization
Monitoring	Inlet air temperature reduction
Leak reduction	Controls
Turning off unnecessary compressed air	Properly sized pipe diameters
Modification of system in lieu of increased pressure	Heat recovery
Replacement of compressed air by other sources	Properly sized regulators
Use air at lowest possible pressure	
Building Energy-Efficiency Measures	
HVAC Systems	
Energy-efficient system design	Fan modification
Recommissioning	Efficient exhaust fans
Energy monitoring and control systems	Use of ventilation fans
Non-production hours set-back temperatures	Cooling water recovery
Duct leakage repair	Solar air heating
Variable-air-volume systems	Building reflection
Adjustable-speed drives	Low-emittance windows
Heat recovery systems	Building insulation

Lighting	
Turning off lights in unoccupied areas	Replacement of mercury lights
Lighting controls	High-intensity discharge voltage reduction
Exit signs	High-intensity fluorescent lights
Electronic ballasts	Daylighting
Replacement of T-12 tubes with T-8 tubes	Replace incandescent with CFL
Lighting level standards	
Furnaces	
Heat generation	Flue gas heat recovery
Heat transfer and heat containment in heaters	Controls, maintenance, and electric heaters

Acknowledgements

This work was supported by the Climate Protection Partnerships Division of the U.S. Environmental Protection Agency as part of its ENERGY STAR program through the U.S. Department of Energy under Contract No. DE-AC02-05CH11231.

Many people supplied useful comments and suggestions to sections included in this Energy Guide and helped to improve the Energy Guides substantially. We would like to especially thank (in alphabetical order) Elizabeth Dutrow (U.S. Environmental Protection Agency [U.S. EPA]), Greg Harrell (Energy Management Services), Don Hertkorn (ICF International), Rebecca Hindin (U.S. EPA), Gunnar Hovstadius (Gunnar Hovstadius Consulting, LLC), Ted Jones (CEE), John Malinowski (Baldor Electric Company), Ilene Mason (CEE), Aimee McKane (LBNL), Fred Schoeneborn (FSC), and Walt Tunnessen (U.S. EPA). Any remaining errors in this Energy Guide are the responsibility of the authors. The views expressed in this Energy Guide do not necessarily reflect those of the U.S. Environmental Protection Agency, the U.S. Department of Energy, or the U.S. government.

Glossary

ASD	Adjustable-speed drive
bhp	Boiler horsepower
CFL	Compact fluorescent lamp
CHP	Combined heat and power
CIPEC	Canadian Industry Program for Energy Conservation
cfm	Cubic feet per minute
CO	Carbon monoxide
CO_2	Carbon dioxide
CRI	Color Rendering Index
EASA	Electrical Apparatus Service Association
HID	High-intensity discharge
hp	Horsepower
HVAC	Heating, ventilation, and air conditioning
IAC	Industrial Assessment Center
kJ	Kilojoule
KWh	Kilowatt hour
LCC	Life cycle costing
LED	Light emitting diode
MMBtu	Million British thermal units
MECS	Manufacturing Energy Consumption Survey
MVR	Mechanical vapor recompression
NAICS	North American Industry Classification System

NEMA	National Electrical Manufacturers Association
NO_X	Nitrogen oxides
PLC	Programmable logic controller
psi	Pounds per square inch
psig	Pounds per square inch gauge
SIC	Standard Industry Classification
SO_2	Sulfur dioxide
SO_x	Sulfur oxides
TBtu	Trillion British thermal units
TWh	Terawatt hour
U.S. DOE	United States Department of Energy
U.S. EPA	United States Environmental Protection Agency

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Appendix A: Key Electricity and Fuel Use, by Sector

Table A.1 provides an overview of the key fuel consumption in different industrial sectors, and Table A.2 shows electricity consumption for various industrial sectors. These tables are based on national statistics, so your plant may be different. The tables can help you focus on key energy uses and to identify "quick wins" to improve energy efficiency and reduce costs.

Table 1 indicates that improving energy use for steam generation (either as boiler or as cogeneration), process heating, and facility heating is likely to return substantial benefits in many sectors.

Table A.1. Fuel consumption and approximate distribution of energy uses in various industrial sectors

NAICS	Sector	Fuel (TBtu)	Boiler	Process Heating	Cooling	Drives	Building HVAC	Other	Not reported
311	Food	887	53%	24%	0%	2%	4%	0%	17%
312	Beverage & Tobacco	77	62%	9%	0%	0%	5%	1%	22%
313	Textile	119	50%	20%	0%	3%	0%	1%	27%
314	Textile Products	32	31%	41%	0%	0%	0%	0%	28%
315	Apparel	17	24%	12%	0%	0%	12%	12%	41%
321	Wood	303	6%	9%	0%	1%	2%	3%	79%
322	Pulp & Paper	2137	28%	7%	0%	1%	1%	1%	62%
323	Printing	48	0%	40%	0%	2%	31%	2%	25%
324	Petroleum	3075	10%	18%	0%	0%	0%	1%	70%
325	Chemicals	3243	38%	19%	1%	1%	1%	0%	39%
326	Plastic & Rubber	145	39%	27%	1%	1%	17%	3%	13%
327	Non-Metallic Minerals	911	1%	40%	0%	1%	2%	1%	54%
331	Primary Metals	1630	5%	35%	0%	0%	3%	1%	57%
3315	Foundries	103	3%	50%	0%	0%	16%	2%	29%
332	Products	219	0%	59%	0%	1%	20%	1%	18%
333	Machinery	91	16%	33%	0%	2%	33%	1%	14%
334	Computer & Electronics	69	42%	13%	0%	0%	29%	3%	13%
335	Appliances	56	11%	48%	0%	0%	27%	2%	13%
336	Equipment	252	23%	25%	1%	1%	25%	2%	23%
337	Furniture	39	5%	28%	0%	0%	31%	0%	36%
339	Miscelleaneous	35	29%	23%	0%	0%	29%	0%	20%

Source: Energy Information Administration, 2002 Manufacturing Energy Consumption Survey

Table A.2 shows that when it comes to electricity consumption, optimizing drives is likely to bring substantial results. For some sectors, optimizing process heat also offers a good opportunity for energy savings.

Table A.2. Electricity consumption and approximate distribution of energy uses in various industrial sectors

NAICS	Sector	Electricity (10^9 kWh)	Process Heat	Cooling	Drives	Electro-chemical Process	Building HVAC	Lighting	Other	Not reported
311	Food	67.4	3%	27%	48%	0%	7%	7%	2%	7%
312	Beverage & Tobacco	7.6	4%	31%	42%	0%	12%	8%	0%	4%
313	Textile	25.2	9%	8%	56%	0%	0%	0%	0%	27%
314	Textile Products	5.0	6%	6%	53%	0%	0%	0%	0%	35%
315	Apparel	3.5	0%	0%	33%	0%	25%	17%	0%	25%
321	Wood	21.1	6%	0%	69%	0%	7%	7%	0%	11%
322	Pulp & Paper	65.4	2%	2%	83%	2%	4%	4%	1%	2%
323	Printing	14.7	2%	4%	50%	0%	18%	12%	2%	12%
324	Petroleum	37.2	8%	4%	81%	0%	3%	2%	0%	2%
325	Chemicals	153.0	4%	9%	57%	14%	7%	5%	1%	3%
326	Plastic & Rubber	49.8	15%	8%	54%	1%	10%	8%	2%	1%
327	Non-Metallic Minerals	41.6	20%	4%	58%	0%	6%	5%	1%	5%
331	Primary Metals	144.5	29%	1%	30%	29%	4%	3%	1%	4%
3315	Foundries	15.8	44%	2%	33%	0%	9%	6%	2%	4%
332	Fabricated Metal Products	47.2	23%	4%	44%	1%	10%	9%	2%	7%
333	Machinery	24.6	7%	4%	49%	2%	18%	13%	2%	5%
334	Computer & Electronics	38.4	11%	9%	23%	3%	28%	13%	7%	5%
335	Appliances	13.8	19%	4%	36%	4%	17%	13%	2%	4%
336	Transportation Equipment	50.4	9%	5%	43%	2%	19%	15%	4%	3%
337	Furniture	7.0	4%	0%	50%	0%	0%	17%	0%	29%
339	Miscelleaneous	10.3	9%	6%	37%	0%	20%	14%	3%	11%

Source: Energy Information Administration, 2002 Manufacturing Energy Consumption Survey

For some sectors, ENERGY STAR has released specific energy guides that contain more details. For more information, see the ENERGY STAR for Industry website.[21]

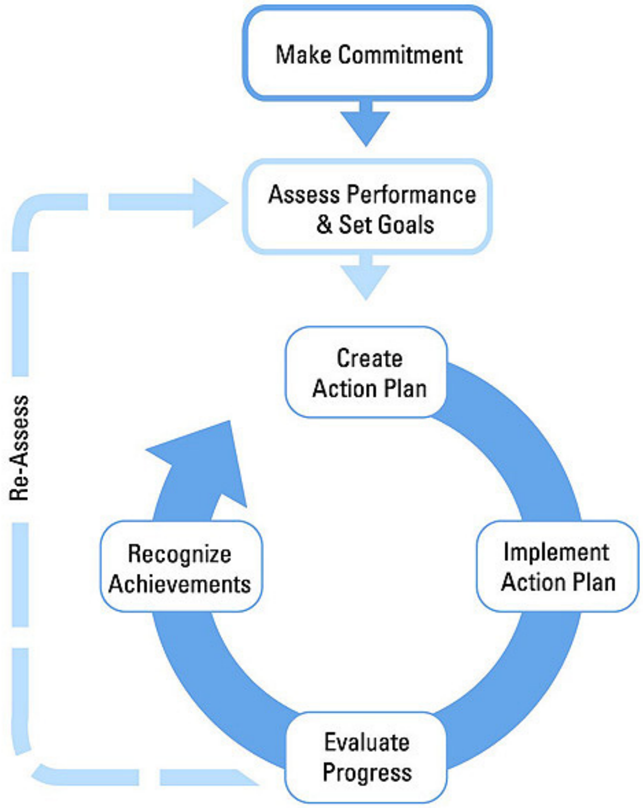
[21] See www.energystar.gov/industry.

Appendix B: ENERGY STAR Energy Management Matrix

The U.S. EPA has developed guidelines for establishing and conducting an effective energy management program based on the successful practices of ENERGY STAR partners.

These guidelines, illustrated in the graphic, are structured on seven fundamental management elements that encompass specific activities.

The assessment matrix on the following page is designed to help organizations and energy managers compare their energy management practices to those outlined in the Guidelines for Energy Management Overview. The full guidelines can be viewed on the ENERGY STAR website.[22]



How To Use The Assessment Matrix
The matrix outlines the key activities identified in the ENERGY STAR Guidelines for Energy Management Overview and three levels of implementation:

- Where there is no evidence
- Where some elements of a program are in place
- Where an energy management program is fully implemented

To apply this tool to your organization, follow these steps:

1. Print the assessment matrix.
2. Compare your program to the guidelines by identifying the degree of implementation that most closely matches your organization's program.
3. Use a highlighter to fill in the cell that best characterizes the level of implementation of your program. You will now have a visual comparison of your program to the elements of the ENERGY STAR Guidelines for Energy Management.
4. Identify the steps needed to fully implement the energy management elements and record these in the Next Steps column.

[22] See http://www.energystar.gov/index.cfm?c=guidelines.guidelines_index.

ENERGY STAR® Facility Energy Management Assessment Matrix

Company Name:		Assessment Date:			
	Little or no evidence	**Some elements/degree**	**Fully implemented**		**Next Steps**
Commit to Continuous Improvement					
Site Energy Leader	None assigned.	Assigned responsibilities but not empowered. 20-40% of time is devoted to energy.	Recognized and empowered leader having site manager and senior energy manager support.		
Site Energy Champion	None identified.	Senior manager implicitly supports the energy program.	Senior manager actively supports the energy program and promotes energy efficiency in all aspects of site operations.		
Site Energy Team	No site energy team.	Informal organization with sporadic activity.	Active cross-functional team guiding site energy program.		
Energy Policy	No energy policy or awareness of organizational policy.	Organizational policy in place. Little awareness by site energy team and limited application of policy.	Organizational policy supported at site level. All employees aware of goals and responsibilities.		
Site Energy Plan	No written plan.	Informal plan not widely known.	Written formal plan endorsed, distributed, and verified.		
Accountability	No energy budgeting and accountability.	Estimates used for allocating energy budgets.	Key users are metered separately. Each entity has total accountability for their energy use.		
Participation Levels	No reporting of energy performance data internally or involvement in external organizations.	Some participation, sharing, mentoring, and professional memberships. Annual reporting of performance.	Participates in energy network/organizations. Shares best practices/mentors other sites. Reports usage quarterly.		

Assess Performance and Opportunities					
Track & Analyze Data	Limited metering or tracking. No demand analysis or billing evaluation.	Some metering, tracking, analyzing, and reporting. Energy bills verified for accuracy.	Key loads metered, tracked, analyzed, and reported. Facility peak demand analyzed. Adjusts for real-time demand.		
Documentation	No manuals, plans, designs, drawings, specs, etc. for building and equipment available.	Some documentation and records available. Some review of equipment commissioning specs conducted.	Critical building and equipment documentation available and used for load surveys/recommissionin g/efficiency goals.		
Benchmarking	Energy performance of systems and facilities not benchmarked.	Limited comparisons of specific functions, or only same-site historical comparisons.	Key systems/sites benchmarked using comparison tools like Portfolio Manager/Energy Performance Indicators.		
Technical Assessments	No formal or external reviews.	Limited review by vendors, location, or organizational and corporate energy managers.	Extensive regular reviews by multi-functional team of internal and external professionals. Full assessment every 5 years.		
Best Practices	None identified.	Ad hoc or infrequent monitoring of trade journals, internal databases, and other facilities' best practices.	Regular monitoring of trade journals, internal databases, and other facilities. Best practices shared and implemented.		
Set Performance Goals					
Goals/Potential	Energy reduction goals not established.	Loosely defined. Little awareness of energy goals by others outside of site energy team.	Potential defined by experience or assessments. Goals roll up to unit/site/ organization and status posted prominently.		
Career Development	No career development. No opportunities available.	Exposure to other energy programs. Some temporary or project assignments available elsewhere.	Energy professionals have established career paths that are reviewed annually. Opportunities for growth encouraged.		
Energy Team Incentives	No ties between energy efficiency improvement and compensation.	Spot awards or luncheons for employees on a project.	Accountability tied to performance reviews, compensation, and personal and plant bonuses.		

Create Action Plan					
Improvement Planning	No upgrade plan.	Upgrades implemented sporadically. Some compliance with organizational goals and standards.	Upgrade plans established; reflect assessments. Full compliance with organizational EE design guidelines and goals.		
Roles and Resources	Not addressed, or addressed on ad hoc basis only.	Informal interested person competes for funding. Little support from organizational program.	Internal/external roles defined and funding identified. Organizational or corporate program support secured.		
Site Planning Integration	Impact on energy from changes not considered.	Decisions impacting energy considered on first-cost basis only.	Projects/contracts include energy analysis. Energy projects evaluated with other investments. Lifecycle costing applied.		
Implement Action Plan					
Communication Plan	Site plan not developed.	Periodic communications for projects. Some reporting of energy use information.	All stakeholders are addressed on regular basis.		
Energy Awareness	None conducted.	Occasional energy efficiency awareness campaigns. Some communication of energy costs.	Planned outreach and communications. Support organizational initiatives. Employees aware of site energy costs.		
Building Staff Capacity	No training offered.	Some vendor training for key individuals and operators.	Broad training/certification in technology and best practices. Networking opportunities actively pursued.		
Contract Management	Contracts are renewed automatically without review.	Occasional review of supplier contracts.	Energy-efficient procurement policy in place. Vendors for replacements on standby. Regular review of suppliers.		
Incentives and Rebates	Not researched or pursued.	Occasional communication with utility representatives. Limited knowledge of incentive programs.	Researches rebates and incentives offered regionally and nationally. Communicates often with utility representatives.		

Evaluate Progress					
Measuring Results	No reviews.	Historical comparisons. Some reporting of results.	Compare usage & costs vs. goals, plans, other sites. Results reported to site and organizational or corporate management.		
Reviewing Action Plan	No reviews.	Informal check on progress.	Revise plan based on results, feedback and business factors. Best practices shared with other sites / organization or corporate program.		
Recognize Achievements					
Site Recognition	Not addressed.	Occasional recognition of projects and people.	Recognition system in place. Awards for projects pursued by operators.		
Organizational Recognition	Not sought.	Occasionally when prompted by senior management.	Senior management acknowledges site successes.		
External Recognition	Not sought.	Occasional trade magazine and vendor recognition.	Government and third-party recognition highlighting achievements sought. ENERGY STAR label for facility awarded annually.		

Appendix C: Basic Energy Efficiency Actions for Plant Personnel

Personnel at all levels should be aware of energy use and organizational goals for energy efficiency. Staff should be trained in both skills and general approaches to energy efficiency in day-to-day practices. In addition, performance results should be regularly evaluated and communicated to all personnel, recognizing high achievement. Some examples of simple tasks employees can do are outlined below (Caffal 1995).

- Eliminate unnecessary energy consumption by equipment. Switch off motors, fans, and machines when they are not being used, especially at the end of the working day or shift, and during breaks, when it does not affect production, quality, or safety. Similarly, turn on equipment no earlier than needed to reach the correct settings (temperature, pressure) at the start time.

- Switch off unnecessary lights; rely on daylighting whenever possible.

- Use weekend and night setbacks on HVAC in offices or air conditioned buildings.

- Report leaks of water (both process water and dripping taps), steam, and compressed air. Ensure they are repaired quickly. The best time to check for leaks is a quiet time like the weekend.

- Look for unoccupied areas being heated or cooled, and switch off heating or cooling.

- Check that heating controls are not set too high or cooling controls set too low. In this situation, windows and doors are often left open to lower temperatures instead of lowering the heating.

- Check to make sure the pressure and temperature of equipment is not set too high.

- Prevent drafts from badly fitting seals, windows and doors, and hence, leakage of cool or warm air.

- Carry out regular maintenance of energy-consuming equipment.

- Ensure that the insulation on process heating equipment is effective.

Reference

Caffal, C. 1995. Energy Management in Industry. Centre for the Analysis and Dissemination of Demonstrated Energy Technologies (CADDET), The Netherlands. Analysis Series 17, December.

Appendix D: Support Programs for Industrial Energy Efficiency Improvement

This appendix provides a list of energy efficiency support available to industry. A brief description of the program or tool is given, as well as information on its target audience and the URL for the program. Included are federal and state programs. Use the URL to obtain more information from each of these sources. An attempt was made to provide as complete a list as possible; however, information in this listing may change with the passage of time.

Tools for Self-Assessment

Steam System Assessment Tool

Description:	Software package to evaluate energy-efficiency improvement projects for steam systems. It includes an economic analysis capability.
Target Group:	Any industry operating a steam system
Format:	Downloadable software package (13.6 MB)
Contact:	U.S. Department of Energy
URL:	http://www1.eere.energy.gov/industry/bestpractices/software.html

Steam System Scoping Tool

Description:	Spreadsheet tool for plant managers to identify energy efficiency opportunities in industrial steam systems.
Target Group:	Any industrial steam system operator
Format:	Downloadable software (Excel)
Contact:	U.S. Department of Energy
URL:	http://www1.eere.energy.gov/industry/bestpractices/software.html

3E Plus: Optimization of Insulation of Boiler Steam Lines

Description:	Downloadable software to determine whether boiler systems can be optimized through the insulation of boiler steam lines. The program calculates the most economical thickness of industrial insulation for a variety of operating conditions. It makes calculations using thermal performance relationships of generic insulation materials included in the software.
Target Group:	Energy and plant managers
Format:	Downloadable software
Contact:	U.S. Department of Energy
URL:	http://www1.eere.energy.gov/industry/bestpractices/software.html

MotorMaster+

Description:	Energy-efficient motor selection and management tool, including a catalog of over 20,000 AC motors. It contains motor inventory management tools, maintenance log tracking, efficiency analysis, savings evaluation, energy accounting, and environmental reporting capabilities.
Target Group:	Any industry
Format:	Downloadable software (can also be ordered on CD)
Contact:	U.S. Department of Energy
URL:	http://www1.eere.energy.gov/industry/bestpractices/software.html

ASDMaster: Adjustable Speed Drive Evaluation Methodology and Application

Description:	Software program helps to determine the economic feasibility of an adjustable speed drive application, predict how much electrical energy may be saved by using an ASD, and search a database of standard drives.
Target Group:	Any industry
Format:	Software package (not free)
Contact:	Electric Power Research Institute (EPRI), (800) 832-7322
URL:	http://www.epri-peac.com/products/asdmaster/asdmaster.html

The 1-2-3 Approach to Motor Management

Description:	A step-by-step motor management guide and spreadsheet tool that can help motor service centers, vendors, utilities, energy-efficiency organizations, and others convey the financial benefits of sound motor management.
Target Group:	Any industry
Format:	Downloadable Microsoft Excel spreadsheet
Contact:	Consortium for Energy Efficiency (CEE), (617) 589-3949
URL:	http://www.motorsmatter.org/tools/123approach.html

AirMaster+: Compressed Air System Assessment and Analysis Software

Description:	Modeling tool that maximizes the efficiency and performance of compressed air systems through improved operations and maintenance practices
Target Group:	Any industry operating a compressed air system
Format:	Downloadable software
Contact:	U.S. Department of Energy
URL:	http://www1.eere.energy.gov/industry/bestpractices/software.html

Fan System Assessment Tool (FSAT)

Description:	The Fan System Assessment Tool (FSAT) helps to quantify the potential benefits of optimizing a fan system. FSAT calculates the amount of energy used by a fan system, determines system efficiency, and quantifies the savings potential of an upgraded system.
Target Group:	Any user of fans
Format:	Downloadable software
Contact:	U.S. Department of Energy
URL:	http://www1.eere.energy.gov/industry/bestpractices/software.html

Combined Heat and Power Application tool (CHP)

Description:	The Combined Heat and Power Application Tool (CHP) helps industrial users evaluate the feasibility of CHP for heating systems such as fuel-fired furnaces, boilers, ovens, heaters, and heat exchangers.
Target Group:	Any industrial heat and electricity user
Format:	Downloadable software
Contact:	U.S. Department of Energy
URL:	http://www1.eere.energy.gov/industry/bestpractices/software.html

Pump System Assessment Tool 2004 (PSAT)

Description:	The tool helps industrial users assess the efficiency of pumping system operations. PSAT uses achievable pump performance data from Hydraulic Institute standards and motor performance data from the MotorMaster+ database to calculate potential energy and associated cost savings.
Target Group:	Any industrial pump user
Format:	Downloadable software
Contact:	U.S. Department of Energy
URL:	http://www1.eere.energy.gov/industry/bestpractices/software.html

Quick Plant Energy Profiler

Description:	The Quick Plant Energy Profiler, or Quick PEP, is an online software tool provided by the U.S. Department of Energy to help industrial plant managers in the United States identify how energy is being purchased and consumed at their plant and also identify potential energy and cost savings. Quick PEP is designed so that the user can complete a plant profile in about an hour. The Quick PEP online tutorial explains what plant information is needed to complete a Quick PEP case.
Target Group:	Any industrial plant
Format:	Online software tool
Contact:	U.S. Department of Energy
URL:	http://www1.eere.energy.gov/industry/bestpractices/software.html

ENERGY STAR Portfolio Manager

Description:	Online software tool helps to assess the energy performance of buildings by providing a 1 to 100 ranking of a building's energy performance relative to the national building market. Measured energy consumption forms the basis of the ranking of performance.
Target Group:	Any building user or owner
Format:	Online software tool
Contact:	U.S. Environmental Protection Agency
URL:	http://www.energystar.gov/index.cfm?c=evaluate_performance.bus_portfoliomanager

Assessment and Technical Assistance

Industrial Assessment Centers

Description:	Small- to medium-sized manufacturing facilities can obtain a free energy and waste assessment. The audit is performed by a team of engineering faculty and students from 30 participating universities in the U.S. and assesses the plant's performance and recommends ways to improve efficiency.
Target Group:	Small- to medium-sized manufacturing facilities with gross annual sales below $75 million and fewer than 500 employees at the plant site.
Format:	A team of engineering faculty and students visits the plant and prepares a written report with energy efficiency, waste reduction and productivity recommendations.
Contact:	U.S. Department of Energy
URL:	http://www1.eere.energy.gov/industry/bestpractices/iacs.html

Save Energy Now Assessments

Description:	The U.S. DOE conducts plant energy assessments to help manufacturing facilities across the nation identify immediate opportunities to save energy and money, primarily by focusing on energy-intensive systems, including process heating, steam, pumps, fans, and compressed air.
Target Group:	Large plants
Format:	Online request
Contact:	U.S. Department of Energy
URL:	http://www1.eere.energy.gov/industry/saveenergynow/

Manufacturing Extension Partnership (MEP)

Description:	MEP is a nationwide network of not-for-profit centers in over 400 locations providing small- and medium-sized manufacturers with technical assistance. A center provides expertise and services tailored to the plant, including a focus on clean production and energy-efficient technology.
Target Group:	Small- and medium-sized plants
Format:	Direct contact with local MEP Office
Contact:	National Institute of Standards and Technology, (301) 975-5020
URL:	http://www.mep.nist.gov/

Small Business Development Center (SBDC)

Description:	The U.S. Small Business Administration (SBA) administers the Small Business Development Center Program to provide management assistance to small businesses through 58 local centers. The SBDC Program provides counseling, training and technical assistance in the areas of financial, marketing, production, organization, engineering and technical problems and feasibility studies, if a small business cannot afford consultants.
Target Group:	Small businesses
Format:	Direct contact with local SBDC
Contact:	Small Business Administration, (800) 8-ASK-SBA
URL:	http://www.sba.gov/sbdc/

ENERGY STAR – Selection and Procurement of Energy-Efficient Products for Business

Description:	ENERGY STAR identifies and labels energy-efficient office equipment. Look for products that have earned the ENERGY STAR. They meet strict energy efficiency guidelines set by the EPA. Office equipment included such items as computers, copiers, faxes, monitors, multifunction devices, printers, scanners, transformers and water coolers.
Target Group:	Any user of labeled equipment.
Format:	Website
Contact:	U.S. Environmental Protection Agency
URL:	http://www.energystar.gov/index.cfm?c=business.bus_index

Training

ENERGY STAR

Description:	As part of ENERGY STAR's work to promote superior energy management systems, energy managers for the companies that participate in ENERGY STAR are offered the opportunity to network with other energy managers in the partnership. The networking meetings are held monthly and focus on a specific strategic energy management topic to train and strengthen energy managers in the development and implementation of corporate energy management programs.
Target Group:	Corporate and plant energy managers
Format:	Web-based teleconference
Contact:	Climate Protection Partnerships Division, U.S. Environmental Protection Agency
URL:	http://www.energystar.gov/

Best Practices Program

Description:	The U.S. DOE Best Practices Program provides training and training materials to support the efforts of the program in efficiency improvement of utilities (compressed air, steam) and motor systems (including pumps). Training is provided regularly in different regions. One-day or multi-day trainings are provided for specific elements of the above systems. The Best Practices program also provides training on other industrial energy equipment, often in coordination with conferences.
Target Group:	Technical support staff, energy and plant managers
Format:	Various training workshops (one-day and multi-day workshops)
Contact:	Office of Industrial Technologies, U.S. Department of Energy
URL:	http://www1.eere.energy.gov/industry/bestpractices/training.html

Compressed Air Challenge®

Description:	The not-for-profit Compressed Air Challenge® develops and provides training on compressed air system energy efficiency via a network of sponsoring organizations in the United States and Canada. Three levels of training are available: (1) Fundamentals (1 day); (2) Advanced (2 days); and (3) Qualified Specialist (3-1/2 days plus an exam). Training is oriented to support implementation of an action plan at an industrial facility.
Target Group:	Compressed air system managers, plant engineers
Format:	Training workshops
Contact:	Compressed Air Challenge: Info@compressedairchallenge.org
URL:	http://www.compressedairchallenge.org/

Financial Assistance

The listings below summarize major federal programs that provide assistance for energy-efficiency investments. Many states also offer funds or tax benefits to assist with energy-efficiency projects (see below for State Programs). However, these programs can change over time, so it is recommended to review current policies when making any financial investment decisions.

Industries of the Future - U.S. Department of Energy

Description:	Collaborative R&D partnerships in nine vital industries. The partnership consists of the development of a technology roadmap for the specific sector and key technologies, and cost-shared funding of research and development projects in these sectors.
Target Group:	Nine selected industries: agriculture, aluminum, chemicals, forest products, glass, metal casting, mining, petroleum, and steel.
Format:	Solicitations (by sector or technology)
Contact:	U.S. Department of Energy – Office of Industrial Technologies
URL:	http://www.eere.energy.gov/industry/technologies/industries.html

Inventions & Innovations (I&I)

Description:	The program provides financial assistance through cost-sharing of (1) early development and establishing technical performance of innovative energy-saving ideas and inventions (up to $75,000), and (2) prototype development or commercialization of a technology (up to $250,000). Projects are performed by collaborative partnerships and must address industry-specified priorities.
Target Group:	Any industry (with a focus on energy-intensive industries)
Format:	Solicitation
Contact:	U.S. Department of Energy – Office of Industrial Technologies
URL:	http://www.eere.energy.gov/inventions/

Small Business Administration (SBA)

Description:	The Small Business Administration provides several loan and loan guarantee programs for investments (including energy-efficient process technology) for small businesses.
Target Group:	Small businesses
Format:	Direct contact with SBA
Contact:	Small Business Administration
URL:	http://www.sba.gov/

State and Local Programs

Many state and local governments have general industry and business development programs that can be used to help businesses assess or finance energy-efficient process technology or buildings. Please contact your state and local government to determine what tax benefits, funding grants, or other assistance they may be able to provide to your organization. This list should not be considered comprehensive, but merely a short list of places to start your project funding search. These programs can change over time, so it is recommended to review current policies when making any financial investment decisions.

Summary of Motor and Drive Efficiency Programs by State

Description:	A report that provides an overview of state-level programs that support the use of NEMA Premium® motors, ASDs, motor management services, system optimization, and other energy management strategies.
Target Group:	Any industry
Contact:	Consortium for Energy Efficiency (CEE), (617) 589-3949
URL:	http://www.motorsmatter.org/tools/123approach.html

California – Public Interest Energy Research (PIER)

Description:	PIER provides funding for energy efficiency, environmental, and renewable energy projects in the State of California. Although there is a focus on electricity, fossil fuel projects are also eligible.
Target Group:	Targeted industries (e.g., food industries) located in California
Format:	Solicitation
Contact:	California Energy Commission, (916) 654-4637
URL:	http://www.energy.ca.gov/pier/funding.html

California – Energy Innovations Small Grant Program (EISG)

Description:	EISG provides small grants for development of innovative energy technologies in California. Grants are limited to $75,000.
Target Group:	All businesses in California
Format:	Solicitation
Contact:	California Energy Commission, (619) 594-1049
URL:	http://www.energy.ca.gov/research/innovations/index.html/

California – Savings By Design

Description:	Design assistance is available to building owners and to their design teams for energy-efficient building design. Financial incentives are available to owners when the efficiency of the new building exceeds minimum thresholds, generally 10% better than California's Title 24 standards. The maximum owner incentive is $150,000 per free-standing building or individual meter. Design team incentives are offered when a building design saves at least 15%. The maximum design team incentive per project is $50,000.
Target Group:	Nonresidential new construction or major renovation projects
Format:	Open year round
URL:	http://www.savingsbydesign.com/

Indiana – Industrial Programs

Description:	The Energy Policy Division of the Indiana Department of Commerce operates two industrial programs. The Industrial Energy Efficiency Fund (IEEF) is a zero-interest loan program (up to $250,000) to help Indiana manufacturers increase the energy efficiency of manufacturing processes. The fund is used to replace or convert existing equipment, or to purchase new equipment as part of a process/plant expansion that will lower energy use. The Distributed Generation Grant Program (DGGP) offers grants of up to $30,000 or up to 30% of eligible costs for distributed generation with an efficiency over 50% to install and study distributed generation technologies such as fuel cells, micro turbines, co-generation, combined heat and power, and renewable energy sources. Other programs support can support companies in the use of biomass for energy, research, or building efficiency.
Target Group:	Any industry located in Indiana
Format:	Application year-round for IEEF and in direct contact for DGGP
Contact:	Energy Policy Division, (317) 232-8970.
URL:	http://www.iedc.in.gov/Grants/index.asp

Iowa – Alternate Energy Revolving Loan Program

Description:	The Alternate Energy Revolving Loan Program (AERLP) was created to promote the development of renewable energy production facilities in the state.
Target Group:	Any potential user of renewable energy
Format:	Proposals under $50,000 are accepted year-round. Larger proposals are accepted on a quarterly basis.
Contact:	Iowa Energy Center, (515) 294-3832
URL:	http://www.energy.iastate.edu/funding/aerlp-index.html

New York – Industry Research and Development Programs

Description:	The New York State Energy Research & Development Agency (NYSERDA) operates various financial assistance programs for New York businesses. Different programs focus on specific topics, including process technology, combined heat and power, peak load reduction, and control systems.
Target Group:	Industries located in New York
Format:	Solicitation
Contact:	NYSERDA, (866) NYSERDA
URL:	http://www.nyserda.org/programs/Commercial_Industrial/default.asp?i=2

Wisconsin – Focus on Energy

Description:	Energy advisors offer free services to identify and evaluate energy-saving opportunities, recommend energy-efficiency actions, develop an energy management plan for business, and integrate elements from national and state programs. It can also provide training.
Target Group:	Industries in Wisconsin
Format:	Open year round
Contact:	Wisconsin Department of Administration, (800) 762-7077
URL:	http://focusonenergy.com/portal.jsp?pageId=4

Appendix E: Teaming Up to Save Energy Checklist

The following checklist can be used as a handy reference to key tasks for establishing and sustaining an effective energy team. For more detailed information on energy teams, consult the U.S. EPA's *Teaming Up to Save Energy* guide.[23]

ORGANIZE YOUR ENERGY TEAM		√
Energy Director	Able to work with all staff levels from maintenance to engineers to financial officers. Senior-level person empowered by top management support	
Senior Management	Energy director reports to senior executive or to a senior management council. Senior champion or council provides guidance and support	
Energy Team	Members from business units, operations/engineering, facilities, and regions. Energy networks formed. Support services (PR, IT, HR).	
Facility Involvement	Facility managers, electrical personnel. Two-way information flow on goals and opportunities. Facility-based energy teams with technical person as site champion.	
Partner Involvement	Consultants, vendors, customers, and joint venture partners. Energy savings passed on through lower prices.	
Energy Team Structure	Separate division and/or centralized leadership. Integrated into organization's structure and networks established.	
Resources & Responsibilities	Energy projects incorporated into normal budget cycle as line item. Energy director is empowered to make decisions on projects affecting energy use. Energy team members have dedicated time for the energy program.	
STARTING YOUR ENERGY TEAM		**√**
Management Briefing	Senior management briefed on benefits, proposed approach, and potential energy team members.	
Planning	Energy team met initially to prepare for official launch.	
Strategy	Energy team met initially to prepare for official launch.	
Program Launch	Organizational kickoff announced energy network, introduced energy director, unveiled energy policy, and showcased real-world proof.	
Energy Team Plans	Work plans, responsibilities, and annual action plan established.	
Facility Engagement	Facility audits and reports conducted. Energy efficiency opportunities identified.	

[23] See www.energystar.gov.

BUILDING CAPACITY		√
Tracking and Monitoring	Systems established for tracking energy performance and best practices implementation.	
Transferring Knowledge	Events for informal knowledge transfer, such as energy summits and energy fairs, implemented.	
Raising Awareness	Awareness of energy efficiency created through posters, intranet, surveys, and competitions.	
Formal Training	Participants identified, needs determined, training held. Involvement in ENERGY STAR Web conferences and meetings encouraged. Professional development objectives for key team members.	
Outsourcing	Use of outside help has been evaluated and policies established.	
Cross-Company Networking	Outside company successes sought and internal successes shared. Information exchanged to learn from experiences of others.	
SUSTAINING THE TEAM		√
Effective Communications	Awareness of energy efficiency created throughout company. Energy performance information is published in company reports and communications.	
Recognition and Rewards	Internal awards created and implemented. Senior management is involved in providing recognition.	
External Recognition	Credibility for your organization's energy program achieved. Awards from other organizations have added to your company's competitive advantage.	
MAINTAINING MOMENTUM		√
Succession	Built-in plan for continuity established. Energy efficiency integrated into organizational culture.	
Measures of Success	Sustainability of program and personnel achieved. Continuous improvement of your organization's energy performance attained.	