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IMPROVING ENERGY EFFICIENCY AND REDUCING COSTS IN THE DRINKING WATER SUPPLY INDUSTRY

An ENERGY STAR Resource Guide for Energy and Plant Managers

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ABSTRACT

As American drinking water agencies face higher production costs, demand, and energy prices, they seek opportunities to reduce costs without negatively affecting the quality of the water they deliver. This guide describes resources for cost-effectively improving the energy efficiency of U.S. public drinking water facilities. The guide (1) describes areas of opportunity for improving energy efficiency in drinking water facilities; (2) provides detailed descriptions of resources to consult for each area of opportunity; (3) offers supplementary suggestions and information for the area; and (4) presents illustrative case studies, including analysis of cost-effectiveness.

DISCLAIMER

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1. Introduction

Energy and water use are linked inextricably. Not only is water used in producing electrical power, but significant amounts of energy are consumed in supplying potable water (collecting, treating, distributing) and providing sanitation (collecting, treating, and disposing or recycling wastewater). Although the Nation's population continues to grow, our supply of freshwater is finite, making it ever more difficult and expensive to supply water that is adequate in both quantity and quality. In order to sustain our environment, quality of life, and level of economic activity, it is necessary to conserve both energy and freshwater resources.

As U.S. drinking water agencies face higher production costs, more demanding standards for water quality, and increasingly volatile energy prices, they seek opportunities to reduce costs without negatively affecting the quality of the water they deliver. One way to maintain water quality while reducing production costs is to invest in energy efficient technologies and energy efficiency practices. Energy efficient technologies often offer additional benefits, such as quality improvement, increased production, and lower operation and maintenance costs, which can lead to further economic savings. In short, investment in energy efficiency is a sound business strategy for public utilities.

ENERGY STAR, a voluntary program operated by the U.S. Environmental Protection Agency (EPA) in coordination with the U.S. Department of Energy (DOE), aims to help all industries improve their competitive vigor through increased energy efficiency and reduced environmental impacts. ENERGY STAR stresses the need for strong and strategic corporate energy management programs. It provides a host of energy management tools and strategies, discussed throughout this guide, to support the successful implementation of such programs.

This ENERGY STAR guide is intended for water utility owners, operators, and managers. After briefly describing the drinking water supply industry and its primary end uses for energy, the guide directs the reader to resources regarding energy efficiency measures applicable to the operation of drinking water systems. The guide focuses on measures and resources that are used throughout a facility, such as motors, pumps, and lighting. The emphasis is on technologies and practices that are commercially available and have been demonstrated successfully in facilities in the United States or abroad. As well as providing detailed descriptions of resources to consult for each energy efficiency measure, this guide presents case studies in each area of efficiency improvement and, where feasible, an analysis of the cost-effectiveness of each measure. The guide also identifies potential sources of funding for developing and enacting energy efficiency programs.

2. Drinking Water Supply Industry

Drinking water systems serve the vital purpose of providing adequate, high-quality water for U.S. residences, commercial buildings, and industries. The percentage of the U.S. population that obtains drinking water from suppliers increased steadily from 62 percent in 1950 to 86 percent in 2005 (Kenny et al., 2005). In 2005, public water supply was the third largest use for water withdrawals (behind thermoelectric and irrigation), accounting for 13 percent of all freshwater withdrawals in the Nation.

Per capita water withdrawals for public supply increased steadily through 1980, then declined by about 5 percent through 2005 (Kenny et al., 2005). Although the U.S. population increased by more than 5 percent between 2000 and 2005, water withdrawals for public supply increased only 2 percent during that period. Even though per-person use has stabilized, the growth in population has resulted in an increase of 27 percent in the total withdrawals for public supply since 1980 (ICF Consulting, 2008). If the trend continues, population growth will continue to be the primary driver of increases in withdrawals for drinking water supply. Many community water systems are faced with additional pressures, including declining quality of new water supplies, increased demand from economic growth, costly maintenance, significant need for capital to replace aging infrastructure, and increased costs of obtaining additional supplies (ICF Consulting, 2008).

The processes of both supplying water and providing sanitation are highly disaggregated and localized. Although there are about the same number of publicly and privately held supply systems, most people obtain drinking water from publicly owned drinking water suppliers. The largest domestic deliveries from public supply occur in states having the largest populations: California, Texas, New York, Florida, and Illinois. Roughly 80 percent of the U.S. population (221 of 273 million) is served by 3,900 large to very large drinking water systems (those serving more than 10,000 people). Those larger systems typically depend on surface water, so more U.S. drinking water is supplied from surface water than from groundwater sources (ICF Consulting, 2008). On the other hand, water systems that use groundwater sources (i.e., wells) outnumber those that use surface water by a ratio of about 4 to 1.

Annual water sales by community water systems were about $33 billion in 2000, making the drinking water supply industry economically significant. Capital spending by those same systems is approximately $10 billion annually (ICF Consulting, 2008). Capital spending is driven by several factors: (1) aging infrastructure; (2) population increase and shift to areas that have fewer water resources (e.g., the Southwest); and (3) increasing treatment requirements to meet more stringent water quality regulations. Some of those factors also increase the energy consumed by drinking water treatment systems. Electricity costs can compose anywhere between 20 percent and 80 percent of a water utility’s total operating budget (ICF Consulting, 2008). Below we describe where energy is used in the public drinking water supply industry.

2.1 Steps in Supplying Drinking Water

Energy is used in every part of a drinking water supply system, from collection and conveyance through treatment, storage, and distribution. Regardless of the end use, the service remains the same—the provision of clean, safe drinking water. Water supply utilities use energy to (see Figure 1):

- extract groundwater and/or divert and collect surface water to send to a treatment facility;
- treat source water to achieve a potable water quality; and
- store and distribute drinking water to homes, businesses, and/or industries within the utility's service area.

Appendix A provides a brief history of drinking water treatment.

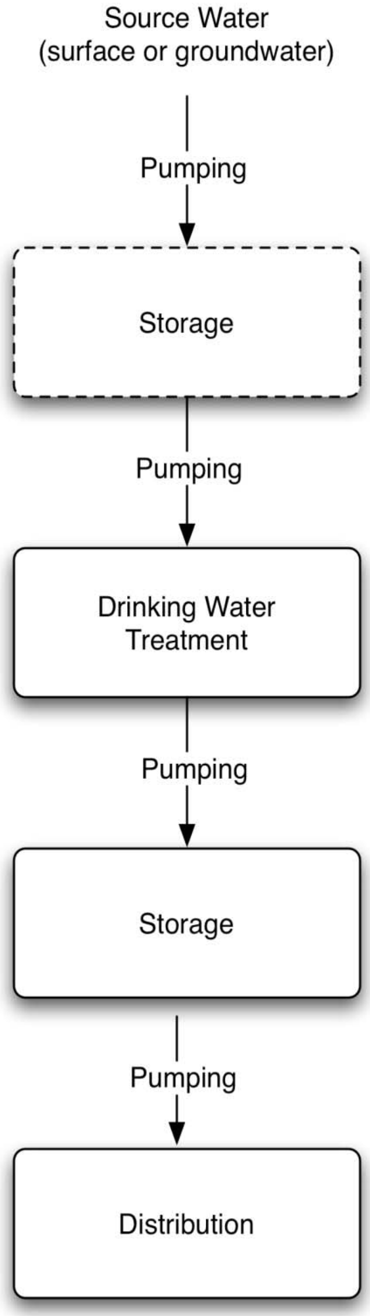


Figure 1. Steps in a typical drinking water supply system

Pumping is the most ubiquitous and greatest energy-consuming process in the overall structure of most water supply utilities. Indeed, the same raw-to-potable water may be pumped several times, especially in larger systems that incorporate storage both before and after treatment. Because pumping is the largest consumer of electrical energy, improving the efficiency of pumps and the motor control systems by which they are driven offers one of the greatest opportunities for reducing energy use at drinking water supply utilities large and small.

With the possible exception of a gravity outfall into the sanitary sewer, energy also is used in the handling, conveyance, and disposal of residuals from the treatment process. Historically, most residuals comprised the sludge produced by metal hydroxide coagulation, lime softening, and iron and manganese removal. Increased use of granular activated carbon, membrane filtration, and ion exchange processes in drinking water treatment have generated new types of residuals.

Solid and liquid residuals from drinking water treatment may be disposed by application to land or discharge to surface water, evaporation ponds or lagoons, or wastewater collection systems. The energy uses that occur off site of a drinking water treatment plant may not be counted in the overall water supply energy budget, yet occur as a result of drinking water treatment and the water supply enterprise.

2.2 Energy Use in the Public Drinking Water Industry

As many water utility owners, operators, and managers well know, energy use is often the second or third highest operational cost for a drinking water system after employee costs, after staffing and supplies. The following are some facts and figures for the nation as a whole. These numbers are averages; the ranges can be broad depending on the circumstances of the service territory.

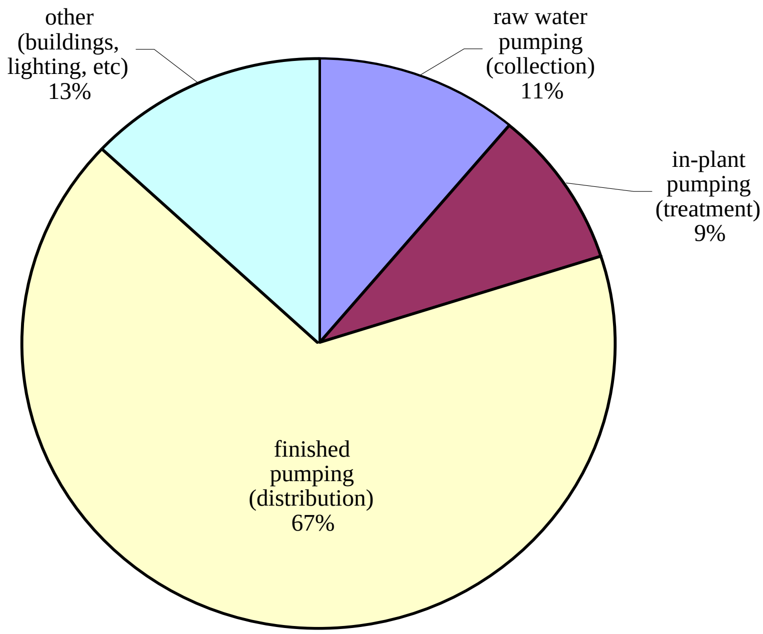
- Four percent of the Nation's electricity goes toward moving and treating water and wastewater (EPRI, 2002).
- Approximately 80 percent of municipal water processing and distribution costs are for electricity (EPRI, 2002).
- Groundwater systems use an average of 1,824 kilowatt-hours per million gallons (kWh/MG) (Burton, 1996).
- A 10 million-gallon-per-day surface water treatment facility would have an estimated total electricity consumption of about 14,057 kWh per day, which is equivalent to a unit energy consumption of 1,400 kWh/MG (EPRI, 2002).
- Nationally, in 2000 annual electricity consumption required for water supply and treatment totaled about 30 billion and 7 billion kWh, respectively, or nearly one percent of total electricity generation, at a cost of about $3 billion (ICF Consulting, 2008).
- In 2003, the drinking water sector accounted for about 0.5 percent of U.S. greenhouse gas emissions (U.S. DOE, 2004).
- Water and wastewater utility energy consumption is generally on the order of 30 percent to 60 percent of a city's energy bill, based on data from Energy Information Administration (U.S. DOE, Energy Information Administration, 2010).

Typical energy usage for an urban drinking water system comprises the following.

- Conveyance accounts for about 100 kWh/MG (range: 0 to 10,000 kWh/MG).
- Treatment uses about 250 kWh/MG (range: 100 to 5,000 kWh/MG).
- Distribution accounts for about 1,150 kWh/MG (range: 0 to 1,200 kWh/MG) (American Water Works Association Research Foundation [AwwaRF], 2008).

For groundwater-based systems, as much as 99 percent of electricity use goes to pumping. The energy required to treat groundwater usually is minor compared to that required for the pumping attributable to collection and distribution (ICF Consulting, 2008).

Williams and Culp (1986) estimated that, of the total energy used in water treatment processes in a 10-million-gallon-per-day (MGD) surface water system, 67 percent is used for pumping finished water (distribution), 11 percent for pumping raw water (collection), and 9 percent for pumping within the treatment plant. Altogether, 87 percent of drinking water system energy is consumed for pumping, as illustrated in Figure 2.



Source: Williams and Culp, 1986.

Figure 2. Typical allocation of energy use in a 10-MGD surface water treatment system

3 Increasing Energy Efficiency in the Drinking Water Industry

Numerous opportunities exist within the U.S. drinking water supply industry to reduce energy consumption while maintaining quality and maintaining, or even or enhancing, productivity. Where and how much energy can be saved varies by facility, however, and cannot be predicted by formula or generalization, because every facility functions within different constraints. Energy consumption varies among systems depending on many factors, among them the age of the facility and components; the type of treatment being used; the topography; whether the utility uses a surface or ground water source; and the size of the system (the geographic area as well as population size). Table 1 lists factors, organized into functional categories, that affect energy consumption in water supply systems. The degree to which the owner/operator can control factors and systems varies.

Table 1. Factors Affecting Energy Consumption in Public Drinking Water Systems

Category	**Factor**
Technical Requirements	Pre-plant pumping requirements Design criteria based on plant size, capacity, peak production In-plant pumping requirements
Source of Water	Number and type: ground and/or surface water For groundwater sources, depth of water table Reliability of source (aquifer, snowmelt, etc.) Rate of withdrawal Distance and elevation from source to plant
Population Served	Number and types of commercial and industrial customers Number and types of residential/institutional customers Number of golf courses, swimming pools, etc.
Water Treatment	Quality of source water (total dissolved solids, organics, etc.) Drinking water quality standards Degree of solids removal, chemical addition Method of disinfection
Potable Water Storage	Number, capacity, and location of storage facilities Distance and elevation from plant to storage Plant-to-storage pumping requirements
Distribution System	Number, size, and location of pumping stations Age, size, and configuration of piping system Storage-to-customer pumping requirements Pressure requirements
Source of Electricity	Fuel source (coal, gas, hydro, nuclear) Cost of electricity (per kilowatt-hour) Billing rate structure from provider (e.g., time-of-use)

Category	Factor
Plant Building Energy Use	Space cooling, heating, lighting, ventilation In-house laboratory Outdoor lighting
Unaccounted-for Water	Number, location, and accuracy of water meters Leak detection, access, and repair Authorized unmetered uses (e.g., fire fighting) Unauthorized use—breaches in supply, metering, billing processes
Demand Management	Conservation Population growth, development Drought/emergency conditions

3.1 First Steps

Numerous organizations offer tips on evaluating ways to reduce energy consumption in businesses and plants. The following six steps describe the types of information you need to assemble before beginning efforts to reduce energy.

(1) *Baseline*: determine your monthly baseline energy consumption—for about a year, if possible.
(2) *Utility Rate Structure*: learn to understand your electric bill. Contact your local utility to determine whether the current pricing structure is the most appropriate one for the facility based on peak demand and overall energy consumption.
(3) *Energy Audit*: perform an energy audit yourself or by hiring a third-party auditor to quantify energy end uses facility-wide.
(4) *Peak Demand*: contact your local utility to find out whether your utility charges more during peak usage hours. Shifting to off-peak hours or shaving peak power usage can lower energy costs substantially.
(5) *Real-Time Monitoring*: conduct real-time monitoring yourself or by hire a third-party. Systems for real-time energy monitoring enable the collection and analysis of periodic energy data for each treatment process and major piece of equipment (e.g., pump). Real-time monitoring can, among other purposes, help in managing peak demand.
(6) *Leak Detection*: review the annual water report from the Public Service (or Utility) Commission or Utility Regulatory Commission for your facility to determine whether its unaccounted-for losses exceed typical losses for similar facilities. If so, implement programs for leak detection and repair, pipe inspection and maintenance, and meter inspection and replacement. Automatic meter reading (AMR) technology and computerized maintenance management software (CMMS) can be useful tools for identifying leaks.

Appendix B contains the market profile used in ENERGY STAR's Portfolio Manager tool for water utilities. The profile conveys the range in treatment types and electricity use for the industry. Portfolio Manager is an interactive energy management tool that enables the user to track and assess energy and water consumption in all facilities. Portfolio Manager can be used to track key energy consumption, performance, and cost information portfolio-wide, regardless of the types of facilities in a portfolio. The tool, which also covers wastewater, can be accessed at: http://www.energystar.gov/index.cfm?c=evaluate_performance.bus_portfoliomanager.

3.2 Value of Increasing Efficiency

The U.S. EPA's ENERGY STAR program estimates that the energy required to operate drinking water and wastewater utilities costs about $4 billion annually. If the sector could reduce energy use by just 10 percent through energy efficiency, collectively it would save about $400 million annually (http://www.epa.gov/waterinfrastructure/bettermanagement_energy.html). The changes made to improve energy efficiency can streamline production and thereby reduce overall operating costs. Saving energy also reduces emissions of the greenhouse gases that result from the generation and distribution of electrical power. Because every utility is unique, there rarely is a way to measure energy improvements against an external benchmark: the most appropriate benchmark against which progress can be evaluated is a facility's baseline energy consumption.

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The State of Massachusetts has initiated individualized energy management programs for some of its drinking water and wastewater treatment facilities. In 2007, the Massachusetts Department of Environmental Protection launched a pilot program that comprises seven wastewater and seven drinking water treatment facilities. So far, the project has guided each facility through an assessment of their current energy performance, conducted energy audits, and assessed the potential for generating renewable energy. More than $3.7 million of potential annual energy savings, through energy efficiency and renewables, were identified at the 14 facilities. Each facility varied in estimated potential savings, from 5 percent to 106 percent of annual energy costs, with an average of 33 percent. Project implementation is expected to save the water sector more than 20 million kWh and 17,000 tons of carbon dioxide (CO_2) annually, which is equivalent to powering 2,400 average-sized homes for a year. The pilot is described at: http://www.mass.gov/dep/water/wastewater/empilot.htm.

3.3 Behavioral Changes

Although technological changes in equipment and processes conserve energy, changes in staff behavior and attitude also can have a great impact. Focused training can help a facility's staff incorporate energy efficiency practices into their daily work routines. Although a single instance of turning off un-used lights or equipment may save only a small amount of energy, such behaviors, enacted continuously over long periods, can have a greater effect than more costly technological improvements. Personnel at all levels should be aware of energy use and overall objectives for improving energy efficiency. Otherwise, information acquired by lower-level managers may neither be passed up to higher-level management nor passed down to staff (Caffal, 1995).

3.4 Water Conservation

Beyond optimizing the efficiency and performance of equipment and processes as described throughout this guide, the most effective way to minimize the energy used to collect, transfer, treat, and distribute potable water is through energy efficiency on the supply side and water efficiency and conservation on the demand side. Any amount of water not collected and distributed represents energy saved. A utility can increase water efficiency through universal metering, water accounting, water audits, and implementing leak detection and repair/replacement programs. It is also effective to apply a multi-tiered residential rate structure that charges a higher rate for high water consumption (also known as an “inclined block” or “inverted” rate structure).

Customers can lower their water consumption through utility programs such as rebates on water-efficient appliances or free home water audits and retrofits. A utility should assess water-conserving plumbing fixtures and appliances and promote them within the community, targeting all customer sectors: residential, commercial, institutional, and industrial. To learn quickly about water efficient fixtures, visit the websites of some of the large public water supply utilities. It can be useful to offer commercial and industrial customers water use audits and perhaps financial incentives for using more efficient systems, especially for high water-use applications such as cooling towers, ice making, laundry processing, or landscape irrigation.

The U.S. EPA has a website for sustainable infrastructure for water facilities. Among the associated webpages are *Water Conservation & Efficiency*, which presents both supply- and demand-side strategies for reducing costs and water withdrawals. The webpage has links to (1) information on issues such as pricing, rate structures, and leak detection; (2) technical support in areas such as controlling water loss; (3) training and tools for efficiency programs and resource management; and (4) case studies on effective efficiency and pricing practices. The webpage also has links to free water audit software from the American Water Works Association (AWWA) and to a downloadable Water Loss Audit Manual developed by the Texas Water Development Board. The *Water Conservation & Efficiency* webpage is at: http://water.epa.gov/infrastructure/sustain/wec_wp.cfm, and the audit manual is available at: http://www.twdb.state.tx.us/assistance/conservation/Municipal/Water_Audit/Leak_Detection/WaterLossManual_2008.pdf.

The American Water Works Association (AWWA) offers several manuals pertinent to controlling water loss and costs.

- *Water Audits and Loss Control Program, 3rd ed.* (AWWA, 2009).
- *Principles of Water Rates, Fees, and Charges, 5th ed.* (AWWA, 2000).
- *Water Conservation Programs—A Planning Manual* (AWWA, 2006).

These and other resources are available through the AWWA bookstore at: http://www.awwa.org/Resources/Waterwiser.cfm?&navItemNumber=1561.

3.5 Cross-Cutting Efficiency Measures

Cross-cutting measures, such as efficiency improvements to pumps, motors, compressed air systems, heating, cooling, and lighting may apply to many areas and processes in a facility. Efficiency measures for heating and lighting, for instance, are ubiquitous throughout commercial and industrial enterprises, and the tools and techniques for applying them are readily available. Because pumping accounts for 80 percent to 99 percent of energy consumption in drinking water systems, installing energy-efficient motors and optimizing pumping systems represents obvious (and well-documented) opportunities for saving energy. Ensuring that processes are optimized and the most productive technology is in place also are key to realizing energy savings in operations. Finally, many processes operate simultaneously throughout a facility. Coordinating improvements to efficiency in processes and equipment will enhance energy savings.

The following are general areas for incorporating cross-cutting energy efficiency measures, characterized by system. Also given is the section of this guide that provides resources and information about improving the efficiency of each system.

- Energy management systems and programs (section 4)
- Motors (section 5)
- Pumps (section 6)
- Variable controls (section 7)
- Compressed air (section 8)
- Lighting (section 9)
- Heating, ventilating, and air conditioning (HVAC) (section 10)

Although lighting is not a major consumer of electricity in most drinking water plants, generally consuming 2 percent or more of a plant's total electricity load (Elliott et al., 2003), it is an area where efficiency improvements can be made quickly and cost-effectively. As with lighting, the provision of HVAC consumes only a small part of the energy used at a water facility. Some simple measures are available to reduce HVAC energy consumption, however.

Resources are divided into two sections: *Primary Resources*, and *Additional Assistance*. We list one or two resources in the first section to offer targeted support regarding the subject. The resources listed in *Additional Assistance* may be equally relevant to the needs of a particular utility, however. The additional resources are listed in alphabetical order.

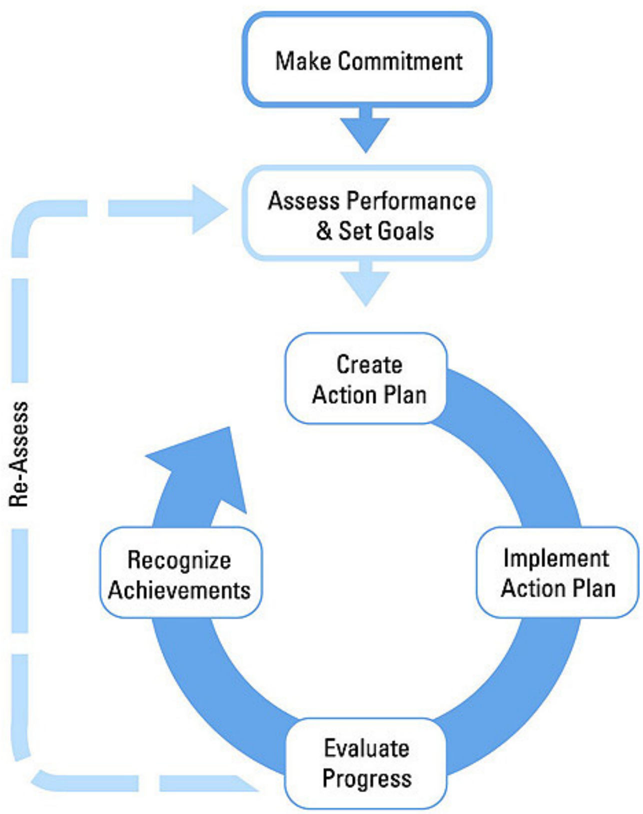
As well as describing resources related to energy efficiency measures for each cross-cutting area, the following sections provide practical notes and case studies, including payback periods where possible. When available, we provide case studies for U.S. drinking water supply facilities, including specific energy and cost savings data. For other measures, we provide comparable data from similar facilities, such as wastewater treatment plants, or from plants in other countries. This analysis excludes the cost of down time for replacing equipment and ancillary benefits, such as increased production or decreased future maintenance costs. We present only those case studies for which we could find impact data (that is, data regarding savings and payback)—especially measured impacts. We excluded studies for which there were no impact data or which only estimated impacts for recommended (as opposed to completed) actions. When data exist, we calculated simple payback period as a first measure of profitability. Although there are more refined methods for determining profitability, such as return on investment or life-cycle cost, those methods require more data than our research uncovered. The reader should use payback period as a first criterion to determine whether to conduct further research on a measure's profitability.

For drinking water supply facilities in the United States, actual payback and savings for any measure depend on plant configuration and size, location, regulations, topography, and customer base, as discussed above. The values presented here are intended as guidelines; only a detailed study of a specific location can produce reliable estimates for that plant. Our goal is to provide resources and guidance for selecting and prioritizing energy improvement projects appropriate for a specific plant.

4 Energy Management Systems and Programs

Energy efficiency does not happen on its own. Implementing an organization-wide energy management program is one of the most successful and cost-effective ways to improve energy efficiency. Focus on Energy (2006) reports that many energy efficiency projects provide a 100-percent return on investment and involve little risk. They report that an enterprise "typically can achieve 10 to 30 percent energy cost savings in the first year by implementing a systematic energy management program." A strong program creates a foundation for positive change and provides guidance for managing energy throughout an organization. Energy management programs also help ensure that improvements do not happen just once, but are identified and implemented through an ongoing process. Furthermore, a management program provides a systems perspective, proper maintenance, and follow-up so that energy efficiency improvements reach their full potential.

For larger enterprises, an energy management program ideally involves facility, operations, environmental, health and safety, and management personnel. The U.S. EPA, through its ENERGY STAR program, worked with leading industrial manufacturers to identify the basic aspects of an effective energy management program. The major elements in a strategic energy management program are depicted in Figure 3.



Source: http://www.energystar.gov/index.cfm?c=guidelines.guidelines_index.

Figure 3. Major elements of a strategic energy management program

A successful program begins with a strong organizational commitment to continuous improvement of energy efficiency. The commitment involves assigning oversight and management duties to an energy director, establishing an energy policy, and perhaps creating a cross-functional energy team (see section 4.3). Then steps and procedures are put in place to assess performance through reviewing energy data regularly, performing technical assessments, and benchmarking. From this assessment, an organization is able to develop a baseline of energy use and set goals for improvement. Performance goals help shape the development and implementation of an action plan.

Ensuring the success of an action plan calls for making all personnel aware of energy use and goals for efficiency. Staff should be trained in both the skills and general approach to energy efficiency in day-to-day practices. Some straightforward tasks that all employees can undertake are outlined in Appendix C to this guide. Results of employee efforts should be evaluated regularly and communicated to all personnel, recognizing high achievement. Strong communication and recognition help build support and momentum for future activities.

Evaluating progress involves regularly reviewing both data on energy use and the activities carried out as part of the action plan. Information gathered during the review helps in setting new performance goals and action plans and in revealing best practices. After best practices are established, the goal becomes to replicate those practices throughout the organization.

An organization's efforts to manage energy can be assessed quickly by comparing its current energy management program against the table contained in Appendix D to this guide. Appendix E duplicates the ENERGY STAR Energy Program Assessment Matrix, which is helpful in evaluating energy management practices.

4.1 Primary Resources

Almost every reference manual for implementing energy efficiency improvements at any type of facility discusses establishing an energy management program. A helpful web-based plan of action is presented on the ENERGY STAR webpage titled *Guidelines for Energy Management Overview*. This webpage outlines a plan of action for improving a facility's energy and financial performance.

- Make a commitment.
- Assess current energy performance.
- Set goals.
- Create an action plan.
- Implement the action plan.
- Evaluate progress.
- Recognize achievements.

On the website, each step in the list is a link to a more detailed discussion of ways to enact that step. Each link takes the reader to more detailed steps designed to achieve specific

accomplishments. The website address is:
http://www.energystar.gov/index.cfm?c=guidelines.guidelines_index.[1]

The U.S. EPA created another guide that focuses on the energy management process and provides numerous support tools specifically for water and wastewater treatment facilities, as described below.

Ensuring a Sustainable Future: An Energy Management Guidebook for Wastewater and Water Utilities. 2008. U.S. EPA. The forward states: "This *Guidebook* was specifically written to provide water and wastewater utility managers with a step-by-step method, based on a Plan-Do-Check-Act management system approach, to identify, implement, measure, and improve energy efficiency and renewable opportunities at their utilities." The guidebook walks the reader through sessions and modules, organized around the plan/do/check/act structure, for creating an energy management program. The steps involve:

1. identifying and prioritizing energy operations and issues that can increase efficiency;
2. identifying energy efficiency objectives and targets;
3. defining the performance indicator(s) to use to measure progress toward identified energy targets;
4. establishing energy management programs (i.e., action plans to meet established goals);
5. monitoring and measuring the performance of established target(s);
6. documenting and communicating success; and
7. reviewing progress periodically and making adjustments as necessary.

The guidebook contains several valuable appendixes. Among them are worksheets for recording:

1. baseline energy data;
2. an equipment inventory;
3. plant activities and operations;
4. a means to prioritize improvements and activities;
5. objectives and targets;
6. performance indicators;
7. appropriate staff, timeline, and costs; and
8. progress.

Other appendixes briefly summarize opportunities for saving energy in cross-cutting areas (motors, pumps, aeration systems, lighting, and HVAC); provide case studies; and provide examples of using operating controls for energy operations. Available at:
http://www.epa.gov/owm/waterinfrastructure/pdfs/guidebook_si_energymanagement.pdf.

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[1] This website served as the source for Figure 3 and Appendix D of this guide.

4.2 Additional Assistance

The following resources offer additional helpful information and resources about establishing an energy management plan.

Best Practices for Energy Management. 2003. Water Research Foundation. This report "develops a documented consortium benchmarking process for water utility application. Reports on applying the process in an energy management benchmarking study." The 24 utilities surveyed for the study averaged 11 percent (water) and 7 percent (wastewater) of their operating costs in energy costs, which totaled more than $100 million for those surveyed. Case studies demonstrate that energy costs can be reduced by as much as half by applying best practices. Available at: http://www.waterrf.org/Search/Detail.aspx?Type=3&PID=2621&OID=2621.

Effective Energy Management Guide. 2000, 2010. P. Harding, UK Government Office for the South West. This report describes "5 steps to effective energy management":

Step 1. Commitment
Step 2. Understand (establish the facts)
Step 3. Plan and organize
Step 4. Act
Step 5. Control, monitor & review

Clicking on any one of the steps moves the user to more detailed guidance for taking the desired step. Available at: http://www.oursouthwest.com/SusBus/susbus9/eemguide.htm.

Energy Conservation in Water and Wastewater Facilities. 2010. Water Environment Federation. Manual of Practice No. 32. Chapter 1 summarizes the importance of management's role in conserving energy. Chapter 2 gives a thorough description of utility billing, and Chapter 11 discusses energy management, including computer modeling and using renewable resources. Published by McGrawHill and available from the Water Environment Federation, Alexandria, VA.

Energy Index Development for Benchmarking Water and Wastewater Utilities. 2007. Water Research Foundation. This report presents metrics that provide feedback to utilities on the effects of implementing practices for reducing energy costs. The metrics help utilities measure operational performance relative to internal and external benchmarks, establish performance targets and budgets, identify key drivers and practices that produce high performance, and assess operational progress over time. Available at: http://www.waterrf.org/ProjectsReports/PublicReportLibrary/91201.pdf.

Fifteen O&M Best Practices for Energy-Efficient Buildings. 1999. Portland Energy Conservation, Inc. Although not specific to the water supply industry, the 15 best practices delineate how to establish, assess, and maintain an effective energy management program for buildings. The document discusses management (goals, planning, energy accounting); teamwork (staffing, training, outsourcing, and partnerships); resources (documentation, tools, and assessments); and operating and maintenance. Available at: http://www.energystar.gov/ia/business/15best.pdf.

Navigating Energy Management: A Roadmap for Business. 2005. C.J. Bennett and M.A. Whiting. The Conference Board Executive Action Series. No. 160. Business & Energy in the 21st Century. Research Report R 1365-05-RR. This 6-page roadmap to corporate energy management "is intended to guide companies in identifying energy-related business opportunities and developing the strategic framework for realizing them; it is not intended be a 'cookbook' approach for implementation." It provides an overview for management consisting of:

- Step 1: Initial Assessment
- Step 2: Design the Process
- Step 3: Evaluate Opportunities
- Step 4: Implementation

Available at: http://www.energystar.gov/ia/business/guidelines/Navigating_Energy_Management.pdf.

Water & Wastewater Energy Management: Best Practices Handbook. 2010. New York State Energy Research & Development Authority. The centerpiece of this handbook is a series of one-page descriptions of best practices (general, water, wastewater, and buildings). Chapter 2 describes the step-by-step development of an energy management program specific to water and wastewater utilities. Topics include developing a baseline of energy use and defining resource needs. Also included is a discussion of constraints on implementing such a program. Available at: http://www.nyserda.org/programs/Environment/best_practice_handbook.pdf.

Water & Wastewater Treatment Energy Use Self-Audit Tool. No date. Iowa Association of Municipal Utilities (IAMU) & The Energy Group, Inc. The IAMU website offers this free software tool and instruction manual, which develops estimates of energy and cost savings for upgrades based on user-input values. This tool is especially helpful because it pertains directly to water treatment facilities and utilizes specific data the user provides. It covers:

- cooling and heating equipment;
- scheduling equipment around peak/off-peak hours;
- night setback;
- windows, doors, roof, and walls;
- variable speed drives;
- motors; and
- lighting equipment.

Ancillary information includes a lighting chart, R-values for insulation, heating system efficiencies, and an explanation of how to calculate annual heating hours. Available under the heading *Tools* at: http://www.iamu.org/services/water/resources.htm. The webpage contains links to additional resources, including a cost analysis tool and a planning tool.

Water and Wastewater: Energy Best Practice Guidebook. 2006. Focus on Energy, Wisconsin, and Science Applications International Corporation. The user can obtain a CD that accompanies the guidebook. The guide has a helpful overview chapter called *Management Best Practices*, pages 17-25, and a few case studies. Focus on Energy also has developed a set of tools (called *Practical Energy Management*), which are available free to Wisconsin facilities by calling 608-277-2946. Available at: http://www.focusonenergy.com/files/Document_Management_System/Business_Programs/waterandwastewater_guidebook.pdf.

Water/Wastewater Guide 1: Reduce Energy Use in Water and Wastewater Facilities Through Conservation and Efficiency Measures. No date. Flex Your Power. Flex Your Power was created to be "California's statewide energy efficiency marketing and outreach campaign" representing "a partnership of California's utilities, residents, businesses, institutions, government agencies, and nonprofit organizations working to save energy." This 24-page guide summarizes the establishment of an energy management process and presents case studies for nine utilities that applied various measures. It evaluates the effectiveness and cost-effectiveness of measures. They report overall savings of 15 percent for water and wastewater utilities. Available at: http://www.fypower.org/pdf/BPG_Water1_Con&Eff.pdf.

WATERGY: Energy and Water Efficiency in Municipal Water Supply and Wastewater Treatment (Cost-Effective Savings of Water and Energy). 2007. The Alliance to Save Energy (Judith A. Barry). The Alliance coined the term *Watergy* to describe the strong link between water and energy in municipal water systems. The Watergy approach aims to realize energy, water, and monetary savings through technical and managerial improvements in systems related to water supply and wastewater treatment. They examine efficiency measures such as leak management, automated controls, metering, and monitoring. In addition to the manual is a Watergy toolkit that provides multi-media resources to help users achieve results. The toolkit includes training videos (for example on conducting audits and detecting leaks); manuals; case studies; and best practice guides. Available at: http://www.watergy.net/resources/publications/watergy.pdf.

Among the resources available to those having a strong technical bent is the **Handbook of Energy Audits, Eighth Edition.** 2009. A. Thumann, W.J. Younger, and T. Niehus. Published by the Association of Energy Engineers, this handbook is described as a comprehensive and practical reference on energy auditing in buildings and industry. The description says the handbook will "guide you through accounting procedures, rate of return, and life cycle cost analysis. Also covered is information on understanding your utility bill and using that knowledge to trim your energy costs. Loaded with forms, checklists, and handy working aids." ISBN: 0-88173-621-X. They also have a book titled, *Investment Grade Energy Audit.* Available at bookstores or: https://www.aeeprograms.com/store/detail.cfm?id=673&category_id=6.

4.3 Energy Teams

Depending on the size and structure of the specific utility, establishing an energy team, although not required, can be an important part of solidifying the commitment to making and continuing improvements. Forming an energy team requires establishing an organizational structure, designating team members, and specifying roles and responsibilities. Because senior management must perceive energy management as part of the organization's core business activities, the leader of the energy team ideally is high-level and empowered by senior-level management. The energy team should include members from each key operational area within a utility and be as multi-disciplinary as possible to provide a diversity of perspectives. The team should be responsible primarily for planning, implementing, benchmarking, monitoring, and evaluating the organization's energy management program, but its duties also can include delivering training, communicating results, and providing employee recognition. It is crucial to provide adequate organizational funding for the energy team's activities, preferably as a line item in the annual budget rather than as a special project.

The energy team should perform audits with key plant personnel at each facility to identify opportunities for improving energy efficiency. As part of the facility audits, the team should look for current best practices that can serve as success stories and provide inter-plant knowledge transfer. A key function of the energy team is to develop mechanisms and tools for tracking and communicating the progress, results, and lessons learned throughout the organization. Examples of mechanisms and tools include best practice databases, facility benchmarking tools, intranet sites, performance scorecards, and case studies of successful projects. A recognition and rewards program should be established. Energy summits and employee energy fairs also are effective means of information exchange and technology transfer.

4.3.1 Primary Resources

The following resource provides a comprehensive overview of establishing, operating, and sustaining an effective energy management team.

Teaming Up to Save Energy. 2005. U.S. EPA Climate Protection Division. Report 430-K-05-007. This 35-page document serves as a how-to guide on building an energy management team. The guide discusses how to structure, launch, and maintain an energy team. It includes a checklist that illustrates effective practices and supports implementation. It also presents examples from companies that have applied the team approach to energy management. This guide complements ENERGY STAR's *Guidelines for Energy Management Overview*, described in section 4.1. Available at: http://www.energystar.gov/ia/business/guidelines/continuous_improvement/Teaming_Up_To_Save_Energy.pdf.

Appendix F to the current guide provides a checklist of key steps for forming, operating, and sustaining an effective energy management team, taken from *Teaming Up to Save Energy*.

4.3.2 Additional Assistance

Continuous Energy Improvement for Industry. 2009. The Northwest Energy Efficiency Alliance (NEEA) offers an energy management system known as Continuous Energy Improvement (CEI). They say, "NEEA's CEI system helps industrial facilities permanently integrate energy management into their business and manufacturing operations, leading to reduced costs and increased profitability. NEEA's CEI system focuses on helping companies adopt best practices in operational efficiency as well as energy management." Their website provides resources helpful to an energy team or team leader within separate modules titled Engage, Plan, Commit, Practice, and Sustain. Among the offerings are fill-in-the blank templates, for example, for statements of corporate and facility energy policies or for meeting agendas and minutes. One document specifies roles and responsibilities for members of an energy management team. There is a Microsoft PowerPoint presentation on energy awareness and Excel files for tracking projects, training, and action plans. These and other resources, along with links to other websites, are available at: http://www.energyimprovement.org/getstarted_6.html.

Among the seven steps ENERGY STAR outlines on its website, *Guidelines for Energy Management Overview*, is "STEP 1: Commit to Continuous Improvement." Step 1 comprises appointing an energy director and establishing an energy team, as well as instituting an energy policy. Further links provide detailed guidance. Appears at: http://www.energystar.gov/index.cfm?c=continuous_improvement.continuous_improvement_index.

4.4 Energy Monitoring Systems

Energy monitoring and process control systems are key tools in energy management and reduction. Metering systems collect data; monitor load profiles, track daily and monthly trends in energy consumption or volume of water treated, or calculates results such as kWh expended per MG treated. Monitoring systems can reduce the time required to perform tasks, improve product and data quality and consistency, and optimize operations. Monitoring and metering play a key role in alerting energy personnel to problem areas and in assigning accountability for energy use. Additionally, such systems can be useful in initiatives to account for corporate greenhouse gas emissions. They are also helpful in profiling energy use for ENERGY STAR partners. Submetering is vital to determining how much energy each process and piece of equipment consumes. The Alliance to Save Energy (2002) asserts that installing metering and monitoring systems can save 10 percent of energy costs through behavioral changes and improved maintenance. Those savings apply to plants without updated process control systems; actual savings depend on current systems in place.

4.4.1 Primary Resources

Effective Energy Management Guide. 2000, 2010. P. Harding, (UK) Government Office for the South West. http://www.oursouthwest.com/SusBus/susbus9/eemguide.htm. (First described in section 4.2.) As part of a five-step process of energy management, this website recommends continuous recording and monitoring of energy use for comparison against consumption targets, known as monitoring and targeting (M&T), and, in particular, automated M&T (aM&T): "aM&T is a management system that automatically collects energy consumption data and analyses this data to ensure energy use is in line with targets set by the user. aM&T includes the meters, automatic data collection, database collation, analysis and presentation. aM&T automatically delivers useable energy management information to the person(s) who can make changes." A six-page *Quick Start Guide to Energy Monitoring & Targeting* is available at: http://www.oursouthwest.com/SusBus/susbus9/m&tguide.pdf. The guide is a helpful introduction but is not specific to the drinking water industry and does not include aM&T.

Energy Conservation in Water and Wastewater Facilities. 2010. Water Environment Federation. Manual of Practice No. 32. Chapter 11, section 2.4 (*Gathering Data*), discusses the importance of submetering for developing both baseline and benchmark energy consumption for a facility. Published by McGrawHill and available from the Water Environment Federation, Alexandria, VA.

4.4.2 Additional Assistance

Among the seven steps ENERGY STAR outlines on its website *Guidelines for Energy Management Overview* is "STEP 2: Assess Performance." This step, which ENERGY STAR advises be conducted periodically, comprises subtasks that links to additional information related to subtasks such as: gather and track data, establish baselines, benchmark, analyze, and perform technical assessments and audits. Available at: http://www.energystar.gov/index.cfm?c=assess_performance.gather_data.

4.4.3 Case Studies

Table 2 lists case studies specific to energy management programs. Empty cells indicate no data were available.

Table 2. Case Studies for Energy Management Programs[2]

Site/Utility	Actions	Cost/Savings	Payback Period
Ann Arbor water treatment plant, MI[*]	Energy audit led to improved maintenance.		2 years
Groundwater and surface water treatment plant, Ann Arbor Water Utilities Dept., MI, capable of processing 50 MGD[*]	Examined provider's rate structure; installed energy monitoring devices; developed load profiles; energy team assessed, implemented, and monitored recommendations.	Saved $1,500 to $2,000 per month from January 1999–May 2001.	
Columbus Water Works, Columbus, GA[†]	Created energy management program and worked together to re-engineer and automate the plant, retrofit older equipment, and install adjustable-speed drives and automated speed controls for pumps.	Saved $1 million in 5 years	
Dublin San Ramon Services District, CA, which expanded wastewater treatment capacity from 11.5 to 17 MGD[‡]	Worked with utility-sponsored energy efficiency program: installed premium efficiency motors on pumps, redesigned the system to reduce head loss, and bought high efficiency ultraviolet (UV) lamp system.	Processing 48% more wastewater more efficiently: annual energy savings estimated at 2.2 million kWh and annual energy cost savings estimated at $290,000	6.6 years, accounting for incentives from utility
East Bay Municipal Utility District, CA, capable of meeting average demand of 220 MGD and peak of 341 MGD[§]	Developed an energy and water quality management system (EWQMS) software program to generate an optimized pump schedule.	During the first 11 months of operation, savings were estimated at about $300,000, or 11% of energy bills; 9% in winter.	
City of Fairfield,	Proactive energy management:	Reduced average daily use	

[2] Empty cells indicate no data were available.

Site/Utility	Actions	Cost/Savings	Payback Period
OH[#]	• Used a system approach to evaluate energy saving opportunities. • Motivated the teamwork of operators and management to obtain system data and develop solutions. • Performed energy assessments and coordinated services of electric contractors, consultants, and electricity provider.	from more than 10,000 kWh in 1986 to about 8,650 kWh in 1999, despite an increase in treatment capacity	
City of Indore, India[**]	Analyzed operations to identify immediate opportunities for savings; developed well-funded and well-staffed water efficiency management team; and developed an energy and water metering and monitoring infrastructure. Data collection and analysis revealed major ongoing overcharge from electric utility.	Discovered overcharges by the utility company, saving more than $70,000 US (3.1 million rupes). Saved US $35,000 (1.6 millions rupes) with other no-cost efforts	
Lachine water filtration plant, Quebec, which has a capacity of 127,300 m^3 of water daily[††]	Installed continuous recording equipment to optimize operating sequences and minimize the demand for electricity.	Cost: CAD 4,000; Savings: CAD 4,200 annually	Less than 1 year
Las Vegas Valley Water District[‡‡]	Applied an energy and water quality management system, replaced pump motors, monitored and improved pump and motor efficiency, and reviewed power bills.	From 1999 to 2003, reduced energy use by more than half, saving 0.87 MWh per MG of water pumped (58%)	
City of Pune, India[§§]	Performed energy audit and staff training.	Annual energy savings of 3.78 million kWh and cost savings of more than $336,000 (148 lakhs Rupees)	Nearly 70% of measures had payback periods of less than 1 year
U.S. Steel (USS), Edgar Thomson Plant, Braddock, PA[##]	Staff formed an Energy Optimization Business Unit Team comprising members who work in various areas of the plant. Team members identify and implement potential opportunities for saving energy and improving operations. A spreadsheet of completed projects, active projects, and	Estimated total annual savings of $2 million	

Site/Utility	Actions	Cost/Savings	Payback Period
	"reminders" is used as a framework for biweekly meetings. 40 projects have been completed; 18 are underway. Most have been successful and resulted in quick paybacks. USS plans to form energy teams at other plants.		
City of Vishakhapatnam, India, water utility[***]	Waste at points in the system meant 340 MLD had to be pumped from the source, but only 190 MLD reached the city. Performed energy audit, then followed all energy efficiency suggestions: retrofitted pumps and motors, and trimmed impellers.	Cost: US$24,500. Annual energy savings of 1.4 million kWh (5.4%). Annual cost savings of about US$60,400, and reduced CO_2 emissions by about 2,400 metric tonnes	
Water and wastewater company for the state of Ceará, Brazil, comprising 8,000 reservoirs having a total capacity of more than 10 million m^3[†††]	Managers of each department—with leadership from engineering staff—work together to develop new procedures. Developed proactive training and efficiency program to improve operations and reduce costs, instructing employees on how to identify and implement savings opportunities and helping implement approximately 50 companywide projects. Automated energy management system gathers electricity billing information directly from the database of the electric company. Analyzing the data garners energy efficiency opportunities and investments. Also developed database of historical information to be integrated with its electromechanical management (monitoring) system to incorporate real-time data (e.g., pressure, flow, system demand, and energy consumption), which are processed through the operational control center.	Achieved a 7.9-percent energy reduction in the first year of the program	
Cedar Rapids Water Utility, IA, which has two treatment plants[‡‡‡]	Implemented extensive program to monitor, analyze, and evaluate energy consumption throughout its systems, including electrical usage records, peak demand, and real-time power monitoring	Formerly spent $1.15 million annually on electricity; now saving $150,000 annually (est.)	

Notes:
KWH = kilowatt-hours.
MG = million gallons.
MGD = million gallons per day.
MWh = megawatt-hours.
m^3 = cubic meters.
CAD = Canadian dollars.
SCADA = supervisory control and data acquisition.

Sources:

[*] Steglitz and Alford, 2001, as reported in Elliott et al., 2003, pp. 79-81. Available at: http://www.ecw.org/prod/222-1.pdf. (Last accessed March 20, 2011.)

[†] Alliance to Save Energy, 2002, pp. 13 & 89-90. Available at: http://pdf.usaid.gov/pdf_docs/PNACT993.pdf. (Last accessed August 31, 2010.) Also written up as a Water Research Foundation case study, *Taking Action on Energy Costs.* Available at: http://www.waterresearchfoundation.org/research/TopicsandProjects/Resources/caseStudies/caseStudyColumbusWaterWorks.aspx. (Last accessed August 30, 2010.)

[‡] Energy Design Resources. *Wastewater Treatment Plant Achieves Energy and Resource Savings with Efficient Design.* Available at: http://www.energydesignresources.com/Portals/0/documents/CaseStudies/EDR_CaseStudies_dsrsd.pdf. (Last accessed August 31, 2010.)

[§] Water Research Foundation. *Case Study: Energy and Water Quality Management System (EWQMS) Saves Electricity Dollars.* Available at: http://www.waterresearchfoundation.org/research/TopicsAndProjects/Resources/caseStudies/caseStudyEWQMS.aspx. (Last accessed August 31, 2010.)

[#] U.S. DOE Energy Efficiency & Renewable Energy (EERE), Office of Industrial Technologies. 2000. *Best Practices Management Case Study: Performance Improvements at Wastewater Treatment Plants.* DOE/ORNL–010. Available at: http://www1.eere.energy.gov/industry/bestpractices/pdfs/fairf.pdf. (Last accessed August 31, 2010.)

[**] Alliance to Save Energy, 2002, pp. 96-97. Available at: http://pdf.usaid.gov/pdf_docs/PNACT993.pdf. (Last accessed August 31, 2010.)

[††] Caddett. 1998. *Energy Savings in a Water Filtration Plant.* Available at: http://www.oee.nrcan.gc.ca/publications/infosource/pub/ici/caddet/english/pdf/R321.pdf. (Last accessed March 20, 2011.)

[‡‡] Water Research Foundation. *Case Study: The Las Vegas Valley Water District Energy Management Program.* Available at: http://www.waterresearchfoundation.org/research/TopicsandProjects/Resources/caseStudies/caseStudyLasVegas.aspx. (Last accessed August 30, 2010.)

[§§] Alliance for Energy. *Watergy Case Study: Pune, India*. Available at: http://www.watergy.net/resources/casestudies/pune_india.pdf. (Last accessed August 31, 2010.)

[##] U.S. DOE EERE, Office of Industrial Technologies. 2000. *Best Practices Project Case Study: Energy Team Pursues a Wide Range of Projects to Improve Operations at a Steel Plant.* DOE/ORNL-016. Available at: http://www1.eere.energy.gov/industry/bestpractices/pdfs/usssucce.pdf. (Last accessed September 8, 2010.)

[***] Alliance for Energy. *Watergy Case Study: Vishakhapatnam, India.* Available at: http://www.watergy.net/resources/casestudies/vishakhapatnam_india.pdf. (Last accessed August 31, 2010.)

[†††] Alliance to Save Energy, 2002, pp. 93-95. Available at: http://pdf.usaid.gov/pdf_docs/PNACT993.pdf. (Last accessed August 31, 2010.)

‡‡‡ Iowa Association of Municipal Utilities. *Cedar Rapids Water Utility: Energy Efficiency Management Program—Meeting the Demands of Industrial and Residential/Commercial Customers.* http://www.iamu.org/services/electric/resources/appa_deed/CR_Water_Department.pdf. (Last accessed March 23, 2011.)

5 Motors

Electric motors represent one of the largest end uses of electricity in the United States. In industrial applications, electric motors account for roughly 60 percent of electricity consumption; in the process industries, they account for more than 70 percent (U.S. DOE Energy Efficiency & Renewable Energy [EERE], 2008). In a drinking water treatment plant, the motors devoted to various pumping processes account for the majority of energy consumption. The following section applies to motors in all systems.

As part of its Showcase Demonstration component, the U.S. DOE reviewed the results of 13 motor systems efficiency projects supported and documented by its Motor Challenge (an energy efficiency program run by DOE). Most projects involved assessing and adjusting fluid systems such as pumps, fans, and compressors, often accompanied by the addition of adjustable speed drives for speed control. The projects achieved energy savings of 38.6 million kWh per year at an average payback of 1.5 years (U.S. DOE EERE, 2002).

Bear in mind that electricity costs represent as much as 96 percent of the total life-cycle cost of a motor; the initial capital outlay only makes up 3 percent of the total; and maintenance accounts for a mere 1 percent (U.S. DOE EERE, 2008). Clearly, reducing energy consumption without reducing reliability or productivity has long-term and significant positive benefits. It may sound inconsequential that high-efficiency motors generally are 3 percent to 8 percent more efficient than standard ones (DOE EERE, 2006), but the savings accumulate significantly throughout the lifetime of a motor.

Taking a system approach that examines the entire motor system often yields the most savings. A system approach analyzes both the supply and demand of energy services and how they interact, shifting the focus from individual components to overall performance.

A system approach typically involves the following steps (Southern California Edison, 2003).

1. First, locate and identify all applications of motors and their end uses (pumps, compressors, fans, etc.) in the facility.
2. Second, document the conditions and specifications of the equipment to develop a current systems inventory.
3. Third, assess the needs and functions of the motor systems to determine whether motors are sized properly and how well each motor meets the needs of its driven equipment.
4. Fourth, support the decision-making process by collecting information on potential upgrades to motor systems, including the economic costs and benefits of implementing upgrades.
5. Finally, if upgrades are pursued, monitor the performance of the upgraded motor systems to determine the actual cost savings

For optimal savings and performance, we recommend the system approach. Pumps and compressors are discussed in more detail in sections 6 and 7, respectively.

5.1 Primary Resources

Best Practices: Motors, Pumps, and Fans. This website, developed by DOE's Industrial Technologies Program (ITP), offers a range of tips, tools, technical publications, and industrial case studies on motor and pump efficiency. The following tip sheets are among those offered for motors.

- Avoid nuisance tripping [a momentary current transient that can occur during startup] with premium efficiency motors.
- Eliminate excessive in-plant distribution system voltage drops.
- Eliminate voltage unbalance.
- Estimate motor efficiency in the field.
- Extend your motor's operating life.
- Improve motor operation at off-design voltages.
- Is it cost effective to replace old eddy-current drives [magnetically coupled]?
- Replace V-belts with cogged [slotted] or synchronous [toothed; also called timing, positive-drive, or high-torque] belt drives.
- The importance of motor shaft alignment.
- Turn motors off when not in use.
- When to purchase NEMA Premium efficiency motors [a labeling program; section 5.2].

The ITP website also describes the U.S. DOE's free MotorMaster+ 4.0 software, which is designed to help users make the most effective and cost-effective decisions regarding motor repair or purchase issues. The tool includes a catalog of more than 20,000 low-voltage induction motors and features tools for managing a motor inventory, maintenance log tracking, efficiency analysis, savings evaluation, energy accounting, and environmental reporting capabilities. All resources available at: http://www1.eere.energy.gov/industry/bestpractices/motors.html.

Improving Motor and Drive System Performance: A Sourcebook for Industry. 2008. U.S. DOE, Energy Efficiency & Renewable Energy, Industrial Technologies Program (ITP). This sourcebook covers the basics of motor and drive systems and highlights opportunities for improving efficiency. Among other topics, it discusses:

- the system approach,
- indications of poor system design,
- motor operating characteristics and load characteristics,
- matching motors and drives to their applications, and
- motor selection problems.

The sourcebook presents a "performance opportunity roadmap" that outlines the following steps to improving motor system performance.

- Establish current conditions and operating parameters.
- Determine present process production needs and estimate future ones.
- Gather and analyze operating data and develop load duty cycles.

- Assess alternative system designs and improvements.
- Determine the most technically and economically sound options, taking all subsystems into consideration.
- Implement the best option.
- Assess energy consumption with respect to performance.
- Continue to monitor and optimize the system.
- Continue to operate and maintain the system for peak performance.

Importantly, the sourcebook devotes an entire section to the economics of motor system choices, including measuring the dollar impact of efficiency and relating efficiency to corporate priorities. Available at: http://www1.eere.energy.gov/industry/bestpractices/pdfs/motor.pdf.

5.2 Additional Information

American Council for an Energy Efficient Economy (ACEEE). *Energy-Efficient Motor Systems: A Handbook on Technology, Program, and Policy Opportunities.* Selected parts of the book are available for download at http://www.aceee.org/topics/motors. An ACEEE 1995 report discusses motor system efficiency measures and the proper sizing, high-efficiency motors, and ASDs.
http://www.aceee.org/sites/default/files/publications/researchreports/IE952.pdf.

Consortium for Energy Efficiency (CEE). The CEE maintains a website that describes initiatives to promote the manufacture and purchase of energy efficient products and services. Their website provides guidance on motors and motor systems, including the following.

- Efficiency specifications for motors of 1 to 200 horsepower.
- List of premium efficiency motors (a Microsoft Excel worksheet).
- Guidance specification for motors of 250 to 500 horsepower.
- Summary of efficiency programs for motors and motor systems (updated May 2009; Microsoft Excel workbook).

These resources are available at: http://www.cee1.org/ind/mot-sys/mtr-ms-main.php3.

Energy Conservation in Water and Wastewater Facilities. 2010. Water Environment Federation. Manual of Practice No. 32. Chapter 3, *Electric Motors and Transformers*, provides technical information on motors, including their electrical characteristics (e.g., power factor and slip); types (three-phase, single-phase, and direct current); and standards for energy-efficient motors. Published by McGrawHill and available from the Water Environment Federation, Alexandria, VA.

Motor Decisions Matter. This website is maintained by CEE, industry trade associations and others. The user can download motor management and planning software that contains advice on developing an in-plant motor inventory, decision rules, critical planning tips, and guidance on motor replacement. The website also offers *1*2*3 Approach to Motor Management*, an Excel spreadsheet and user's guide intended to serve as "an easy-to-use resource to assist your motor repair/replace decision making. 1*2*3 also provides a framework for educating industrial customers about other best practice motor management strategies." With it, the user can develop a “comparative financial analysis for future decisions based on life-cycle costing methods….” The site also has case studies pertinent to water and wastewater treatment plants. All resources available at: http://www.motorsmatter.org/.

Motor Maintenance. U.S. DOE, EERE, Federal Energy Management Program (FEMP). Webpage describes the importance of preventative and predictive motor maintenance. The page has a link to a step-by-step maintenance checklist, including how often each step should be taken. Available at: http://www1.eere.energy.gov/femp/operations_maintenance/om_motormaintenance.html.

National Electrical Manufacturers Association (NEMA). NEMA has developed a labeling program for high-efficiency motors. NEMA Premium labeled electric motors are designed to “optimize motor systems efficiency, reduce electrical power consumption and costs, and improve system reliability.” The website provides product specifications for labeled motors and a list of participating manufacturers: http://www.nema.org/gov/energy/efficiency/premium/. The following table comes from the NEMA website.

Annual Savings from NEMA Premium Motors				
Horsepower	Full-load Motor Efficiency (%)		Annual Savings from Use of a NEMA Premium Motor	
	Energy Efficient Motor	NEMA Premium Efficiency Motor	Annual Energy Savings (kWh)	Monetary Savings ($/year)
10	89.5	91.7	1,200	60
25	92.4	93.6	1,553	78
50	93.0	94.5	3,820	191
100	94.5	95.4	4,470	223
200	95.0	96.2	11,755	588

Small Water Supply Facilities: A Profile of Motor Energy Efficiency Opportunities. 2001. This 29-page document addresses opportunities specific to small facilities, which are defined as those employing 100 or fewer persons and having an annual electricity consumption of 250 to 1,299 MWh. XENERGY, Inc. Available through the CEE at: http://www.cee1.org/ind/mot-sys/Water_Supply_Pro.pdf.

Table 3 summarizes case studies specific to energy-saving measures for motors. Empty cells indicate no data were available.

Table 3. Case Studies of Energy-Saving Measures for Motors

Site/Utility	Action	Cost	Annual Savings	Payback Period
Columbus Water Works, Columbus GA*	Upgraded a 750-hp motor.		$200,000	1 year
East Bay Municipal Utility District Special District 1 Wastewater Treatment Plant, which processes about 415 MGD†	Replaced five 700-hp pumps and motors and four 1,000-hp pumps and motors with high efficiency units that incorporate VFDs.		Decreased electrical use required to run influent and effluent pumps by 50% annually, equaling $273,000	
Ellensburg Wastewater Treatment Plant, WA, which processes an average of 3.5 MGD‡	Used MotorMaster+ 3.0 software to decide whether to replace or to rewind two 50-hp aerator motors, and if to replace, which motor to purchase.		New standard efficiency motors offered lifetime savings of $1,650 per motor	Immediate
Encina Wastewater Authority, which processes about 36 MGD§	Installed energy efficient motors.		$15,000, or almost 10% of electrical costs annually	
Frank E. VanLare Wastewater Treatment Facility, Monroe County, NY#	In 2004 replaced 30 motors (out of about 1,000), ranging from 25 to 100 hp, with NEMA Premium motors.		Estimated 4% to 6% percent energy savings	
Inland Empire Utilities Agency, regional wastewater treatment plant, Ontario, CA**	Removed 14 eddy-current clutches and installed more efficient, direct-drive pumps.	$188,000, with a $15,000 grant	10%, equal to $57,000 and 475,000 kWh	A little more than 26 months
Kennewick (secondary) Wastewater Treatment	Used MotorMaster+ software to create database of all motors to facilitate		Avoided 2% efficiency loss of the rewound motors, which	

Site/Utility	Action	Cost	Annual Savings	Payback Period
Plant, WA, which processes an average of 5.5 MGD[††]	comparisons, parts inventory, and purchase decisions. Used motor repair purchasing specifications to ensure that rewound 40- and 150-hp motors retained efficiency.		would have increased annual operating costs by $242 for the 40-hp pump motor and $907 for the 150- hp motor.	
Kentucky Wastewater Pump Station[‡‡]	Installed energy efficient motors and VFDs in 2004.	$150,000: (two 125-hp Premium Efficiency Motors @ $8,945). Partly offset by a grant.	Savings for the first year exceeded $12,000. Average monthly reduction in energy use for the first 10 months was 6,595 kWh.	
Lachine water filtration plant, Quebec, which has a capacity of 127,300 m^3 of water per day[§§]	Installed two high-efficiency motors.	CAD 24,000	CAD 7,962 annually	A little more than 3 years
Madera Valley Water Company, which processes about 8.21 MGD[##]	Upgraded motors at 3 wells; installed energy-efficient motor in new well.		2% increase in efficiency in 3 wells. Total savings about $2,000.	
Madison Water Utility[***]	Rehabilitated a 300-hp pump motor.	$29,500	Increased efficiency from 89.2% to 95.9% for annual energy savings of 81,000 kWh.	About 4 years
Moulton Niguel Water District (capacity for water treatment = 48 MGD; for wastewater = 17 MGD)[†††]	Replaced standard efficiency motors with energy efficient units.		$5,000	

Site/Utility	Action	Cost	Annual Savings	Payback Period
Outokumpu Copper Products, Buffalo, NY, a 1 million ft^2 brass mill having many 5- to 100-hp AC motors[‡‡‡]	If a 50-hp or smaller motor fails, they replace with a NEMA Premium motor rather than rewind it. If a larger motor fails, and if the cost of repair/rewind exceeds 50% of the cost of a new motor, they buy the new motor.	For two 100-hp lubricant pump motors: $3,425, compared to $1,775 to rewind standard efficiency motor.	$1,002 annually	1.47 years
Pierce Union Batavia Water Treatment Plant, New Richmond, OH[§§§]	Installing capacitors estimated to increase power factor to 0.95.			Less than 1 year
San Juan Water District, Sidney N. Peterson Water Treatment Plant, which processes 120 MGD[###]	Replaced 40- to 100-hp motors with more energy efficient ones.		$5,000 while reducing maintenance costs and increasing equipment life.	
Vallejo Sanitation and Flood Control District (wastewater agency)[****]	Replaced a motor.	$21,000	450,000 kWh, equaling $54,000	5 months because of $12,000 rebate
Vallejo Sanitation and Flood Control District (wastewater agency)[****]	Replaced a throttling value operation and two 15-hp motors with two 50-hp motors and VFDs.		450,000 kWh and $54,000 per year	
Veracruz, Mexico, water utility[††††]	For pilot project for part of the system that serves 25,000 people, installed automatic control system with VFD		Pump system efficiency increased from 45% to 72%, reducing energy consumption	

Site/Utility	Action	Cost	Annual Savings	Payback Period
	controlled at constant pressure.		by 24%, saving 24 million kWh/year, equal to US$394,000/year.	
Wastewater Treatment Plant‡‡	Replaced aeration system blower in 2005: installed two high-efficiency blowers and premium efficiency motors.	$750,000 (cost of 2 blowers & motors = $454,000, partly offset by a grant).	Energy use reduced by 752,000 kWh (for about $26,000 in cost savings) per year.	
Wastewater Treatment Plant‡‡	Replaced influent pump station motor in 2006: installed two premium efficiency motors with VFDs.	$170,000 (including two 200-hp Premium efficiency motors @ $22,882, Partly offset by a grant).	Energy use reduced by 157,000 kWh (for more than $5,300 in cost savings) per year.	

Notes:
hp = horsepower.
MGD = million gallons per day.
CAD = Canadian dollars.
VFD = variable frequency drive.

Sources:
* Alliance to Save Energy, 2002, p. 89-90 and throughout. Available at: http://pdf.usaid.gov/pdf_docs/PNACT993.pdf. (Last accessed September 4, 2010.)
† CEC. *Success Story: East Bay Municipal Utility District Special District 1, Wastewater Treatment.* Available at: http://www.energy.ca.gov/process/pubs/ebmud.pdf. (Last accessed March 20, 2011.)
‡ Northwest Energy Efficiency Alliance, Electric Motor Management. 2001. *Making Good Motor Decisions: The Ellensburg Wastewater Treatment Plant*. Available on the website of the Consortium for Energy Efficiency (CEE): http://www.cee1.org/ind/mot-sys/ww/Ellensburg_case.pdf. (Last accessed September 3, 2010.)
§ CEC. *Success Story: Encina Wastewater Authority*. Available at: http://www.energy.ca.gov/process/pubs/encina.pdf. (Last accessed September 3, 2010.)

[#] New York State Energy Research and Development Authority. *Premium-Efficiency Motors Program: Frank E. VanLare Wastewater Treatment Facility*. Case Available at: http://www.nyserda.org/programs/Environment/Monroe%20County%20WWTF.pdf. (Last accessed September 3, 2010.)

[**] CEC and the U.S. DOE Office of Industrial Technologies Best Practices. 2002. *Case study: Pump System Upgrade Saves Energy and Increases Efficiency at a Wastewater Treatment Plant.* Available at: http://www.motorsmatter.org/case_studies/Inland_Empire.pdf. (Last accessed September 3, 2010.)

[††] Northwest Energy Efficiency Alliance, Electric Motor Management. 2001. Motor Management Success: *Repair Specifications Save Money and Energy—Kennewick Wastewater Treatment Plant*. August. Available on the website of CEE: http://www.cee1.org/ind/mot-sys/ww/Kennewick_case.pdf. (Last accessed September 7, 2010.)

[‡‡] Focus on Energy. 2006. pp. 24-25. Available at: http://www.werf.org/AM/Template.cfm?Section=Home&TEMPLATE=/CM/ContentDisplay.cfm&CONTENTID=10245. (Last accessed September 3, 2010.)

[§§] Caddett. 1998. *Energy Savings in a Water Filtration Plant.* Available at: http://www.oee.nrcan.gc.ca/publications/infosource/pub/ici/caddet/english/pdf/R321.pdf. (Last accessed September 4, 2010.)

[##] CEC. *Success Story: Madera Valley Water Company*. Available at: http://www.energy.ca.gov/process/pubs/madera.pdf. (Last accessed September 3, 2010.)

[***] Olsen and Larson. 2003, *Opportunities and Barriers in Madison, Wisconsin: Understanding Process Energy Use in a Large Municipal Water Utility*. Available at http://www.cee1.org/ind/mot-sys/ww/mge2.pdf. (Last accessed September 24, 2010.)

[†††] California Energy Commission (CEC). *Success Story: Moulton Niguel Water District*. Available at: http://www.energy.ca.gov/process/pubs/moulton.pdf. (Last accessed September 3, 2010.)

[‡‡‡] Copper Development Association. Case Study. *Brass Mill Cuts Costs with NEMA Premium Motors.* Available at: http://www.copper.org/applications/electrical/energy/casestudy/brass_mill_cuts_cost_a6089.html. (Last accessed September 6, 2010.)

[§§§] Steglitz and Alford, 2001, as reported in Elliott et al.,2003, pp. 79-81. Available at: http://www.ecw.org/prod/222-1.pdf. (Last accessed September 4, 2010.)

[###] CEC. *Success Story: San Juan Water District Sidney N. Peterson Water Treatment Plant*. Available at: http://www.energy.ca.gov/process/pubs/sanjuan.pdf. (Last accessed September 3, 2010.)

[****] Flex Your Power. *Water/Wastewater Case Study*: *Vallejo Sanitation and Flood Control District.* Available at: http://www.fypower.org/pdf/CS_Water_VallejoSan.pdf. (Last accessed September 3, 2010.)

[††††] Alliance to Save Energy. *Watergy Case Study: Veracruz, Mexico*. Available at: http://www.watergy.net/resources/casestudies/veracruz_mexico.pdf. (Last update, March 2005; last accessed September 3, 2010.)

6. Pumps

Pumping systems, which consist of a pump, a driver, pipe installation, and controls (such as adjustable speed drives or throttles), are a part of the overall motor system, discussed in section 5. Taking a system approach to motors also is discussed in section 5. Higher-efficiency motors can increase the efficiency of the associated pump by 2 to 5 percent (Tutterow, 1999). On top of that, the installation of newer, higher-efficiency pumps typically achieves pump system energy savings of 2 percent to 10 percent (Elliott, 1994).

Higher-efficiency motors can increase the efficiency of the associated pump by 2 to 5 percent (Tutterow, 1999).

This section of the guide applies to pumps in all areas of a water supply operation.

Pumping systems account for about 20 percent of the world's electrical energy demand (U.S. DOE EERE, 2001, 2002). In the United States, pumping systems account for about 24.8 percent of the electricity used in manufacturing and, depending on configuration, can reach 90 percent in the drinking water supply industry (U.S. DOE EERE, 2002; Williams and Culp, 1986; Alliance to Save Energy, 2002). For typical surface water facilities, 85 percent of the cost of energy is related to pumping raw or treated water, and 9 percent to pumping concentrated waste streams (Elliott et al., 2003). For groundwater systems, almost all energy costs go to pumping, unless advanced treatment such as ozone disinfection, ultraviolet (UV) radiation, or membrane treatment is required (Elliot et al., 2002). An obvious target for reducing electricity is increasing pumping efficiency. The Confederation of Indian Industry estimates that energy savings as high as 25 percent are possible using a systematic approach (Alliance to Save Energy, 2002).

A system approach for pumps typically involves the following steps.

1. First, locate and identify all applications of pumps in the facility.
2. Second, document the conditions and specifications of the equipment to develop a current systems inventory.
3. Third, assess the needs and functions of the pump systems to determine whether pumps are sized properly.
4. Fourth, support the decision-making process by collecting information on potential upgrades to pump systems, including the economic costs and benefits of implementing upgrades.
5. Finally, if upgrades are pursued, monitor the performance of the upgraded pump systems to determine the actual cost savings.

Energy costs make up about 90 percent of the cost of owning a pump (U.S. DOE, 2001a), with maintenance costs composing about 2.5 percent. As with motors, selection and design of pumping systems should

Selection and design of a pumping system should depend on life-cycle rather than initial costs.

depend on life-cycle rather than initial costs. Hodgson and Walters (2002) discuss software developed for this purpose (OPSOP), describing several case studies in which they show large reductions in energy use and lifetime costs for a complete pumping system. Typically, focusing on life-cycle costs when designing a pumping system will lead to energy savings of 10 percent to17 percent (Hodgson and Walters, 2002). For new installations, Jacobs et al. (2003) stress the importance of a quality check at the 80-percent completion mark to determine if installation is on track.

Studies have shown that more than 20 percent of the energy consumed by pump systems could be saved through changes to equipment or control systems, for instance, using holding tanks to equalize flow over production cycle (energy savings of 10 percent to 20 percent); eliminating bypass loops and other unnecessary flows (energy savings of 10 percent to 20 percent); and increasing piping diameter to reduce friction (energy savings of 5 percent to 20 percent) (U.S. DOE EERE, 2002). Efficiency improvements include replacing inefficient motors on pumps; installing variable-speed drives on pumps; and implementing operational controls, such as those provided through supervisory control and data acquisition (SCADA) systems. SCADA systems save energy by matching equipment performance to the demands of the system. Although the capital investment required to implement a SCADA system can be cost-prohibitive for smaller utilities, installation of a SCADA system for central equipment control benefits the entire plant (New York State Energy Research & Development Authority [NYSERDA], 2010).

6.1 Primary Resources

Best Practices: Motors, Pumps, and Fans. This website, developed by DOE’s Industrial Technologies Program (ITP), supplements the sourcebook described directly below. The website offers a range of tips, tools, and industrial case studies on motor and pump efficiency. Resources include a guide to calculating life-cycle costs for pumping systems and a guide to variable speed pumping. Pumping tip sheets cover many of the topics in the ITP sourcebook, along with the following.

- Conduct an in-plant pumping system survey.
- Energy savings opportunities in control valves.
- Maintain pumping systems effectively.
- Optimize parallel pumping systems.
- Pump selection considerations.
- Select an energy-efficient centrifugal pump.
- Test for pumping system efficiency.

The website offers technical fact sheets as well, for instance, *Reducing Power Factor Cost* and *Determining Electric Motor Load and Efficiency*. Among the software offered for free on the ITP website is a pump system assessment tool, which uses achievable pump performance data from Hydraulic Institute standards and motor performance data to assess the efficiency of pump system operations. All resources available at: http://www1.eere.energy.gov/industry/bestpractices/motors.html.

Improving Pumping System Performance: A Sourcebook for Industry. 2006. Second edition. U.S. DOE EERE, ITP. This detailed, practical sourcebook covers all aspects of pumping systems, including:

1. assessing system needs,
2. properly sizing pumps,
3. piping configurations to improve system efficiency,
4. basic pump maintenance,
5. multiple pump arrangements,
6. impeller trimming, and
7. using adjustable speed drives.

Comparable to the DOE sourcebook for motors, the sourcebook provides an overview of pumping systems and their components, an outline for improving performance, and tools for calculating the economic advantages of improving a pumping system. References are provided for assessment tools, training, and software. Appendixes include some of the tip sheets offered on the ITP website (described above). Others were in development at the time the sourcebook was printed, and are available only on the ITP website. Sourcebook at: http://www1.eere.energy.gov/industry/bestpractices/pdfs/pump.pdf.

6.2 Additional Assistance

Energy Conservation in Water and Wastewater Facilities. 2010. Water Environment Federation. Manual of Practice No. 32. Chapter 4 provides a detailed technical discussion of pumping, complete with charts, graphs, and equations. Among the topics discussed are: pumping principles (e.g., best efficiency point and system head curve); energy principles; and pump head (e.g., measuring pump head and determining head loss). Published by McGrawHill and available from the Water Environment Federation, Alexandria, VA.

How to Buy an Energy-Efficient Centrifugal Pumping System. U.S. DOE EERE, Federal Energy Management Program (FEMP). This webpage presents advice for purchasing centrifugal pumps. Although the guidelines pertain only to Federal agencies, the information applies to all centrifugal pumps. The webpage, which can be downloaded as a four-page PDF, briefly reviews pump basics, such as pump sizing and impeller and motor selection. Two helpful tables are: *Operating Cost Comparison: Two Pump Sizes for a 100-hp Application*, and *Operating Cost Comparison: Two Flow Control Options for a 100-hp Application.* Available at: http://www1.eere.energy.gov/femp/procurement/eep_centrifugal_pump.html.

Pump Life Cycle Costs: A Guide to LCC Analysis for Pumping Systems, Executive Summary. 2001. U.S. DOE EERE Technical publication DOE/GO-102001-1190. This document explains what life-cycle cost is, the equation for calculating it, and the elements of the equation. Available at: http://www1.eere.energy.gov/industry/bestpractices/pdfs/pumplcc_1001.pdf.

Pump Systems Matter. An educational web resource conceived by the Hydraulic Institute, This resource promotes "educated decision-making based on life cycle costs and systems optimization concepts….” They offer a training course titled, *Pumping System Optimization: Opportunities to Improve Life Cycle Performance.* Associated with the training course is their Pump System Basic Assessment Guide, which “identifies a few pump systems that could be investigated further for cost-effective system improvements. It uses a spreadsheet (pre-screening form) to gather the needed data on the pumping systems.” They offer a free pump system improvement modeling (PSIM) tool, which “makes it easy to calculate the pressure drop and flow distribution in both straight-path and simple branching or looped pumping systems. PSIM calculates pump energy usage and energy cost over time using net present value concepts.” Available at: http://www.pumpsystemsmatter.org/.

6.3 Case Studies

Table 4 summarizes case studies specific to improving the energy efficiency of pumps and pumping systems. Empty cells indicate no data were available.

Table 4. Case Studies of Energy-Saving Measures for Pumps

Site/Utility	**Action**	**Cost**	**Annual Savings**	**Payback Period**
Ahmedabad Municipal Corporation, India, a system that collects both surface and ground water*	Installed capacitors on bore wells, draining pumps, and water pumps.		US $137,000 annually	1.5 to 3 years
Ahmedabad Municipal Corporation, India, a system that collects both surface and ground water*	Replaced steel piping in its French wells with a wider, durable plastic pipe to prevent friction loss.		Estimated US $102,000 annually	
Bexar Metropolitan Water District, TX, which has 54 groundwater pumping facilities†	Converted all check valves to tilting-disc or double-door check valves.		Estimated to reduce head loss by 50%	
Ghana Water Company‡	Installed two 300-kilovolt-ampere reactive (kVAR; 1,000 volt-ampere) capacitors, reducing maximum demand and improving power factor to 0.91	Approximately US $7,000	US $5,000; when additional capacitors are installed: $25,000 US	1.37 years; less than 2 years for all 13 planned capacitors
Inland Empire Utilities Agency, Southern CA§	Retrofitted 15 pump drives.	$188,000	Reduced energy use by 10%, equal to 475,000 kWh or $71,000 annually	2.7 years
Kolhapur, India#	Redesigned system to match pumps to loads.		$180,000 US (8 million rupes)	
Madison Water Utility, WI**	Reprioritized pumps at two wells having different efficiencies.		214,476 kWh, or $10,724	
Pune Municipal System, India††	Turned off unnecessary pumps.	None	$35,000 US	

Site/Utility	Action	Cost	Annual Savings	Payback Period
South Tahoe Public Utility District, CA[‡‡]	Installed variable frequency drive (VFD) on one plant effluent pump; installed VFDs on filter influent pumps; and replaced one pump.	$136,900	498,600 kW and $33,100	
South Tahoe Public Utility District, CA[‡‡]	Stopped using three unneeded pumps.	$10,000	$68,300	Less than 2 months
Town of Trumbull, CT wastewater pumping station, which handles about 0.34 MGD[§§]	Modified control scheme, added a smaller pump, and reduced unnecessary lighting.	Total cost of $12,000, including bubbler and lighting retrofits	44%, equal to 31,900 kWh, for more than $2,600 annually	4.6 years
Welches Point Pump Station, Milford, CT, which processes about 750 MGD of wastewater[##]	Replaced one of three 75-hp pumps with a 35-hp booster pump, reserving the other 2 pumps for peak flows.	$16,000	Save 37,000 kWh per year, more than 15% of the system's energy use of about 240,000 kWh per year, equal to $2,960	5.4 years; 1.7 years including savings in labor and materials

Notes:
ft^2 = square feet.
hp = horsepower.
kWh = kilowatt-hours.
MGD = million gallons per day.
MWh = megawatt-hours.

Sources:
[*] Alliance to Save Energy. 2002, p.85-86. Available at: http://pdf.usaid.gov/pdf_docs/PNACT993.pdf. (Last accessed September 4, 2010.)
[†] Phillips et al. 2001, as reported in Elliott et al. 2002, pp. 81-81. Available at: http://www.ecw.org/prod/222-1.pdf. (Last accessed September 4, 2010.)
[‡] Alliance to Save Energy. 2002, pp. 83-84. Available at: http://pdf.usaid.gov/pdf_docs/PNACT993.pdf. (Last accessed September 4, 2010.)
[§] Flex Your Power. *Water/Wastewater Case Study*: *Inland Empire Utilities Agency.* Available at: http://www.fypower.org/pdf/CS_Water_IEUA.pdf. (Last accessed September 4, 2010.)
[#] Alliance to Save Energy. 2002, p. 37. Available at: http://pdf.usaid.gov/pdf_docs/PNACT993.pdf. (Last accessed September 4, 2010.)
[**] Olsen and Larson, 2003, p. 4-425. Available at http://www.cee1.org/ind/mot-sys/ww/mge2.pdf. (Last accessed September 24, 2010.)
[††] Alliance to Save Energy. *Watergy Case Study: Pune, India*. Available at: http://www.watergy.net/resources/casestudies/pune_india.pdf. (Last accessed September 3, 2010.)

‡‡ Flex Your Power. *Water/Wastewater Case Study*: *South Tahoe Public Utility District.* Available at: http://www.fypower.org/pdf/CS_Water_South_Tahoe.pdf. (Last accessed September 4, 2010.)

§§ U.S. DOE EERE. Industrial Technologies Program: BestPractices. *Case Study: The Challenge: Improving Sewage Pump System Performance.* Available at: http://www1.eere.energy.gov/industry/bestpractices/case_study_sewage_pump.html. (Last accessed September 4, 2010.)

U.S. DOE EERE. 1999. *Motor Challenge Project Fact Sheet: City of Milford Pump Optimization Project Yields $96,000 Net Present Value*. Available at: http://www1.eere.energy.gov/industry/bestpractices/pdfs/milford.pdf. (Last accessed September 4, 2010.)

7 Variable Controls

Although not always appropriate, variable or adjustable controls can have numerous applications in a water treatment facility. Variable or adjustable controls better match speed-to-load requirements for pumps and motors where energy use is approximately proportional to the cube of the flow rate.[3] In centrifugal applications involving no static lift, for instance, small reductions in flow that are proportional to pump speed can yield large energy savings. Reducing the speed (flow) by 20 percent can reduce input power requirements by approximately 50 percent (U.S. DOE EERE, Industrial Technologies Program [ITP], 2007).

Because pump speed adjustments are the most efficient means of controlling pump flow, pumping, the greatest energy consumer in the drinking water industry, often can benefit from adjustable speed drives (ASDs). The most popular type of ASD is a variable frequency drive (VFD). ASDs enable pump speed adjustments to be made over a continuous range. ASDs improve overall productivity, control, and product quality and reduce wear on equipment, thereby reducing long-term maintenance costs. ASDs also can reduce labor needs compared to manual controls (Burton, 1996). Burton (1996) estimates typical energy savings to be between 15 percent and 50 percent, with a payback period of 1 to 8 years based on energy savings alone. Focus on Energy (2006) estimates savings of 10 percent to 40 percent. First costs range can be $3,000 for a 5-hp motor, almost $45,000 for a custom-engineered 300-hp motor, or more for larger motors (CEC, 2005a). Payback periods range from a few months to less than three years for 25- to 250-horsepower models (CEC, 2005a).

A system approach to variable and adjustable controls typically involves the following steps.

1. First, locate and identify all applications of variable or adjustable controls in the facility.
2. Second, document the conditions and specifications of the equipment, developing a current systems inventory.
3. Third, assess the needs and functions of the variable or adjustable control applications to determine how well each control meets the needs of its equipment.
4. Fourth, support the decision-making process by collecting information on potential upgrades to the control systems, including the economic costs and benefits of implementing upgrades.
5. Finally, if upgrades are pursued, monitor the performance of the upgraded control systems to determine actual cost savings.

[3] This equation applies to dynamic systems only. Systems that consist solely of lifting (static head systems) will accrue no benefits (indeed, often become more inefficient) from adjustable speed drives (ASDs) because ASDs are independent of flow rate. Similarly, systems having more static head will accrue fewer benefits than systems that are largely dynamic (friction) (U.S. DOE EERE, 2006). Additional calculations must be performed to determine actual benefits, if any, for those systems.

According to inventory data collected by the U.S. DOE EERE (2002), 96 percent of motors in U.S. industrial facilities have no load modulation feature (e.g., ASD). Including modulation features with circulating pumps has been estimated to save between 30 percent and 80 percent of pump energy consumption at relatively short payback periods, depending on pump size, load, and load variation (U.S. DOE EERE, 2002). Although it generally is not economical to retrofit ASDs, paybacks for installing new ASD motors in new systems or plants can be as short as 1.1 years (Martin et al., 2000).

VFDs,, the most common type of electronic ASD, "efficiently meet varying process requirements by adjusting the frequency and voltage of the power supplied to an AC motor to enable it to operate over a wide speed range" (U.S. DOE EERE, 2008). Depending on the pump, benefits beyond energy savings include increased curtailable service on generator pumps, increased control of pressures and flows, increased tank storage life, and eliminating some pumps altogether. Although savings vary with application and technology, many VSD retrofits have saved 15 percent to 35 percent. In some installations, particularly where throttling is used to control flow, savings may reach 10 percent to 40 percent (Focus on Energy, 2006).

But VFDs do not always improve efficiency as described in the list below. "VFDs need to be evaluated on a case-by-case basis to determine actual savings. Such evaluations should include a life cycle cost analysis because the savings can be impacted by several system factors" (Water Environment Foundation, 2010). The following factors affect energy savings.

> ***"VFDs need to be evaluated on a case-by-case basis to determine actual savings. Such evaluations should include a life cycle cost analysis because the savings can be impacted by several system factors" (Water Environment Foundation, 2010).***

- Generally, the higher the horsepower, the more likely it is that ASDs will be cost-effective.
- Generally, ASDs will be cost-effective only on motor systems that are used 2,000 hours per year or more.
- Centrifugal loads, such as pumps and fans, offer the best potential savings; reciprocating machines offer fewer opportunities.
- Loads that vary by 30 percent of full load offer the best opportunities for cost-effective application.
- In pumping, ASDs are applicable primarily to circulating systems as opposed to systems having significant static head. In the latter situation, slowing the pump may increase energy use under certain conditions and lead to severe maintenance problems (U.S. DOE EERE, 2002).

Obviously, ASDs should be weighed against other efficiency opportunities; in some cases, for example, sequenced multiple pumps might be a more economical option (EPRI, 1997). A study on performance and energy efficiency opportunities at the Madison Water Utility suggested that adding a high-efficiency motor as well as a ASD would yield only marginal improvements over the ASD alone (Olsen and Larson, 2003).

7.1 Primary Resource

Variable Speed Pumping: A Guide to Successful Applications—Executive Summary. 2004. U.S. DOE EERE ITP. This 22-page guide describes how to select variable speed pumps and when their application is—and is not—appropriate. It also describes how to estimate pumping costs and calculate life-cycle costs. Available at: http://www1.eere.energy.gov/industry/bestpractices/pdfs/variable_speed_pumping.pdf.

7.2 Additional Assistance

The website for *Pump Systems Matter* offers a 45-minute video briefing titled *Variable Speed Drives make "cents."* The briefing describes VSDs and discusses their common applications and when not to install them. Pump Systems Matter is an educational initiative to assist North American pump system users in gaining a competitive advantage through strategic, broad-based optimization of energy management and pump system performance. The briefing can be downloaded for free at: http://www.pumpsystemsmatter.org/.

The U.S. DOE's ITP website offers tip sheets for adjustable or variable controls, including the following from among the tip sheets for pumps and motors.

- Adjustable Speed Pumping Applications. 2007. Pumping Systems Tip Sheet #11. DOE/GO-102007-2229. This two-page summary shows how to estimate the performance of centrifugal pumps at any speed given little or no static head. http://www1.eere.energy.gov/industry/bestpractices/pdfs/38947.pdf.
- Minimize Adverse Motor and Adjustable Speed Drive Interactions. 2008. Motor Tip Sheet #15. DOE/GO-102008-2621. This two-page sheet describes the characteristic of electronic ASDs and design considerations for installing them. http://www.nrel.gov/docs/fy08osti/43270.pdf.
- Control Strategies for Centrifugal Pumps with Variable Flow Rate Requirements. 2007. Pumping Systems Tip Sheet #12. DOE/GO-102007-2230. This two-page sheet presents calculations and considerations related to deciding whether to install ASDs. http://www1.eere.energy.gov/industry/bestpractices/pdfs/38949.pdf.
- Magnetically Coupled Adjustable Speed Motor Drives. 2008. Motor Tip Sheet #13. DOE/GO-102008-2619. This two-page sheet describes both electronic and magnetically coupled ASDs. http://www.nrel.gov/docs/fy08osti/43268.pdf.
- Adjustable Speed Drive Part-Load Efficiency. 2008. Motor Tip Sheet #11. This two-page summary shows how to calculate the power requirement for centrifugal loads and determine energy savings from an ASD. http://www1.eere.energy.gov/industry/bestpractices/pdfs/motor_tip_sheet11.pdf.

7.3 Case Studies

Table 5 summarizes case studies specific to ASDs and VFDs. Empty cells indicate no data were available.

Table 5. Case Studies of Energy Savings from Adjustable Speed Drives and Variable Frequency Drives

Site/Company	Action	Cost	Savings	Payback Period
Albany County Sewage District's North Plant in Menands, NY*	Installed new ultra-NEMA Premium 20-hp pump motor, but found increased motor speed increased electrical consumption. Installed VFD to control speed/flow and reduce electrical consumption.		By leaving throttle valve fully open and using VFD alone to control flow: $6,535 annually.	For both new motor and VFD, less than 1 year
Bexar Metropolitan Water District, TX, which comprises 54 groundwater-pumping facilities†	Installed VFDs at all facilities.	$85,000	$12,600 per year	6.7 years
Encina Wastewater Authority, which processes about 36 MGD‡	Installed VFDs.		$21,000 annually, about 12% of annual electricity costs	
Town of Falmouth, MA, Long Pond surface water treatment plant§	Installed 4 VSDs on three 250-hp high-lift pumps and one pump station.	$123,068	34%: $49,000 and 260,200 kWh annually.	
General Motors#	Replaced five 60- to 100-hp pumps with three 15-hp pumps having adjustable speeds.	$44,966	Reduced pumping energy consumption by 80% (225,100 kWh), saving $11,255.	4.0 years
Lachine water filtration plant, Quebec, which has a capacity of 127,300 m^3 per day**	Installed a variable frequency drive for high-pressure pump.	CAD 200,000	CAD 50,000 annually	4 years
Lowell Water Works, Lowell MA, which treats 18 MGD raw water††	Installed VSDs on 3 of 4 pumps and adjusted the system so that 2 pumps are operated at higher speeds instead of operating 3 to achieve the desired flow.		40%	

Site/Company	**Action**	**Cost**	**Savings**	**Payback Period**
Madera Valley Water Company, which has a capacity of 8.21 MGD[‡‡]	Installed VFDs and programmable logic controllers on motors that drive deep well turbine pumps.		$17,000 annually, or almost 14% of electricity costs	
Madison Water Utility, WI[§§]	Added VFDs to two distribution pumps.	About $50,000 per pump station	One pump showed savings of $5,400 per year; the second $8,800.	5.7 and 9.3 years
Moulton Niguel Water District, which has a capacity of 17 MGD wastewater[##]	Installed VFDs on the wastewater system to control pump speed in coordination with a proportional, integral, and derivative system.		$3,000 per year (reduced pumping energy use by 4%)	
Patterson Irrigation District, CA' Pumping Plant No. 1, which serves 625 agricultural users[***]	Installed a plant control system in 1997 that utilized a VFD and pump staging by order of efficiency.		23% increase in pumping efficiency	
Patterson Irrigation District, CA, which serves 625 agricultural users[***]	Installed two additional VFDs.		Reduced energy use by approximately 45,000 kWh per month	
San Juan Water District, Sidney N. Peterson Water Treatment Plant, which has a capacity of 120 MGD[†††]	Installed four VFDs to control pumps and motors.		$11,000	
South Tahoe Public Utility District, CA[‡‡‡]	Installed VFDs on plant effluent pump and filter influent pumps (and replaced one pump).	Installation of VFDs and pump replacement: $136,900.	VFDs on pump and pump replacement: 498,600 kW and $33,100.	

Site/Company	Action	Cost	Savings	Payback Period
South Tahoe Public Utility District Wastewater Plant‡‡‡	VFD installed at sewage lift system.	$37,500	Annual savings of 78,800 kW, equal to $4,700.	
Vallejo Sanitation and Flood Control District, CA, wastewater treatment system§§§	Installed four VFDs.		625,000 kWh and $75,000/year.	

Notes:
m^3 = cubic meters.
CAD = Canadian dollars.

Sources:

* Copper Development Association, Inc. Case Study: *Copper-Rotor Motors + Variable Frequency Drives Maximize Savings at Water Treatment Plant*. The write-up examines payback periods and 10-year savings for various motor replacement scenarios. Available at: http://www.copper.org/applications/electrical/energy/casestudy/a1357/a1357.html#b6. (Last accessed September 6, 2010.)

† Elliott et al. 2003.Available at: http://www.ecw.org/prod/222-1.pdf.

‡ CEC. *Success Story: Encina Wastewater Authority*. Available at: http://www.energy.ca.gov/process/pubs/encina.pdf. (Last accessed August 31, 2010.)

§ Massachusetts DEP, Massachusetts Energy Management Pilot: *Falmouth Wastewater Treatment Facility*. Available at: http://www.mass.gov/dep/water/wastewater/empilot.htm#cr. (Last accessed August 31, 2010.)

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*** Flex Your Power, *Water/Wastewater Case Study: Patterson Irrigation District*. Available at: http://www.fypower.org/pdf/CS_Water_Patterson.pdf. (Last accessed August 31, 2010.)

††† California Energy Commission (CEC), *Success Story: San Juan Water District Sidney N. Peterson Water Treatment Plant*. Available at: http://www.energy.ca.gov/process/pubs/sanjuan.pdf. (Last accessed August 31, 2010.)

‡‡‡ Flex Your Power, *Water/Wastewater Case Study: South Tahoe Public Utility District*. Available at: http://www.fypower.org/pdf/CS_Water_South_Tahoe.pdf. (Last accessed August 31, 2010.)

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8 Compressed Air

When air is reduced in volume and held under greater than atmospheric pressure, it can be used as a source of power for operating a mechanical device or machine. The poor efficiency associated with compressing air generally makes compressed air the most expensive form of energy in any industrial or municipal facility. From start to end use, the efficiency of compressed air systems typically is about 10 percent (U.S. DOE, 2003a). If compressed air must be used, it should be the minimum needed for the shortest possible time, constantly monitored, and reweighed against alternatives. In addition to measures specific to compressed air, other measures (see sections on motors and HVAC) may apply to compressors. High efficiency motors and speed controls are two major possible efficiency improvements.

A system approach to compressed air systems typically involves the following steps.

1. First, locate and identify all compressed air use in the facility.
2. Second, document the conditions and specifications of the equipment to develop a current systems inventory.
3. Third, assess the needs and functions of compressed air applications.
4. Fourth, support the decision-making process by collecting information on potential upgrades or changes to compressed air use, including the economic costs and benefits of implementing upgrades or changes.
5. Finally, if upgrades are pursued, monitor the performance of the upgraded compressed air to determine the actual cost savings.

Many opportunities to reduce energy use for compressed air systems are quite cost-effective; payback periods for some are less than one year. Energy savings from making improvements to a compressed air system can range from 20 percent to 50 percent of total system electricity consumption (U.S. DOE, 2003a). The most effective measure is to reduce air leaks throughout the system: 42 percent of potential energy savings derive from this measure alone (Radgen and Blaustein, 2001).

8.1 Primary Resource

Compressed Air Tip Sheets. 2004. U.S. DOE EERE, ITP Best Practices website. Associated with the sourcebook described directly below, the tip sheets cover many topics, including the following.

- Alternative strategies for low-pressure end uses.
- Compressed air storage strategies.
- Compressed air system control strategies.
- Determine the cost of compressed air for your plant.
- Effect of intake air on compressor performance.
- Engineer end uses for maximum efficiency.
- Remove condensate with minimal air loss.

- Stabilizing system pressure.

Tip sheets are available at:
http://www1.eere.energy.gov/industry/bestpractices/tip_sheets_compressed_air.html.

Improving Compressed Air System Performance: A Sourcebook for Industry. 2003a. U.S. DOE EERE, ITP. DOE/GO-102003-1822. Comparable to the sourcebooks for pumps and motors, this resource describes in detail compressed air systems and components, along with opportunities for improving their energy efficiency. The sourcebook is a product of the Compressed Air Challenge, a national collaborative formed in 1997 to assemble state-of-the-art information on compressed air system design, performance, and assessment. The sourcebook presents a performance opportunity roadmap that comprises the following 12 features.

1. Analyzing compressed air needs.
2. Potentially inappropriate uses of compressed air.
3. Compressed air system leaks.
4. Pressure drop and controlling system pressure.
5. Compressed air system controls.
6. Compressed air storage.
7. Proven opportunities at the component level.
8. Maintenance of compressed air systems for peak performance.
9. Heat recovery and compressed air systems.
10. Baselining compressed air systems.
11. Determining your compressed air system analysis needs.
12. Compressed air system economics and selling projects to management.

The sourcebook offers resources, contacts, and references, including information about workshops. It contains several appendixes, including *Packaged Compressor Efficiency Ratings* and *Guidelines for Selecting a Compressed Air System Provider*. This sourcebook is available on the ITP website:
http://www1.eere.energy.gov/industry/bestpractices/techpubs_compressed_air.html.

8.2 Additional Resources

AirMaster+ software. Developed by the U.S. DOE EERE ITP for help in assessing industrial compressed air systems. AIRMaster+ enables the user to model existing systems and future upgrades and to evaluate the savings and effectiveness of energy efficiency measures. The software tool is available free for download. A description of the software, a fact sheet, and user's guide are available at:
http://www1.eere.energy.gov/industry/bestpractices/software_airmaster.html.

Best Practices: Compressed Air Systems. 2004. Focus on Energy. This two-page document summarizes 10 simple and effective best practices for air compressors. Available at:
http://www.focusonenergy.com/files/Document_Management_System/Business_Programs/compressedair_bestpracticessheet.pdf.

For anyone interested in receiving ongoing information about compressed air systems, Bantra Publishing offers *Compressed Air Systems Solution Series*. S. Foss. A comprehensive discussion of ways to improve the performance of compressed air systems, covering topics such as design issues, troubleshooting, instrumentation, storage, piping, controls, demand issues, and supply issues. It is published as a two-year, bi-monthly subscription series. Phone contact for Bantra: (704) 372-3400.

Compressed Air Challenge (CAC). The website for this organization provides an alternative source for the U.S. DOE sourcebook, tip sheets, and software described above. It also has links to articles, fact sheets, and case studies, although none specific to water treatment facilities. The group offers workshops and trainings, as well as a best practices manual. They also provide free web-based guidance for selecting the most appropriate integrated service provider. They define walk-through evaluations, system assessments, and fully instrumented system audits (CAC, 2002). Their website: http://www.compressedairchallenge.org/. A direct link to their guidelines for selecting a service provider is available at: http://www.compressedairchallenge.org/library/guidelines.pdf.

Table 6 presents case studies about the energy savings that can be achieved for air compressors. Empty cells indicate no data were available.

Table 6. Data Related to Improvements to Air Compressor Efficiency

Company/Utility	Actions	Savings	Payback Period
Agilent Technologies, Fort Collins, CO, manufacture of semiconductor chips[*]	Had 3 plant air compressors, 2 operating at full capacity in one building, and a third underutilized in a second building. To even out the load across the three systems and maximize their efficiency, the systems were connected across the buildings.	Energy savings of 250,000 kWh and more than $20,000 per year.	
Alcoa North American Extrusions Plant, Spanish Fork, UT[†]	Reduced compressed air leaks for an implementation cost of $1,000.	171,900 kWh per year, equal to $4,980.	0.2 years
BD Medical, Sandy, UT, manufacturing facility[‡]	Installed compressor sequencer and modified piping that connected two compressor systems, enabling the main compressed air system to meet system loads without excessive pressure drops.	177,652 kWh/year for $5,330 at $0.03/kWh. Before upgrades, they usually ran 5 compressors and 4 dryers. Now, despite increased production and air demand, they run 3 compressors and 3 dryers.	Cost was $6,066 after utility incentive, for simple payback of 1.1 years.
BD Medical, Sandy, UT, manufacturing facility[‡]	Replaced air-drying system with new externally heated atmospheric blower dryers. Also installed air loss valves at receiver and cooler drains.	1,137,008 kWh/year for $34,110 at $0.03/kWh. Reduces dryer energy consumption and increases capacity of the compressed air system.	Cost was $134,658 after utility incentive, for simple payback of 3.9 years.
East Bay Municipal Utility District, Special District 1 Wastewater Treatment Plant, 415 MGD capacity[§]	Replaced 2 small compressors with 1 large unit at the pure oxygen plant.	$77,000 per year.	

Company/Utility	Actions	Savings	Payback Period
Mead-Johnson Nutritionals, Evansville, IN[#]	Took a systemwide approach to improvements to see if an air compressor system was needed: reconfigured system; centralized control system; increased storage capacity; repaired leaks.	Save $102,000 (2.5 million kWh) in energy costs annually, equal to a little more than 4% of annual electricity costs	Total cost: $264,000 after rebate. Payback of 2.6 years. Avoided purchase of new compressor and increased system reliability.
San Jose Mercury News, San Jose, CA[**]	Ineffective control scheme for system (six 100-hp compressors) and not enough air storage to satisfy temporary demand spikes. Installed multiple compressor control system, pressure/flow controller with 3,800 gallons of additional storage, and mist eliminator filters. Also repaired leaks and lowered system pressure.	Energy savings of 800,000 kWh and an annual energy cost savings of $96,000. System now satisfies production under all demand conditions with 5 or fewer compressors.	Total project cost of $129,000 resulted in simple payback of 1.3 years.
Abitibi Consolidated Sales Corporation, West Tacoma Division, WA, manufacturer of recycled newsprint[††]	Took a system approach to auditing, analyzing, and upgrading compressed air system, including design, operational, and maintenance issues. Got new air compressors, premium pfficiency motors, and controller. Increased diameter of distribution pipe and moved filtered air intake to outdoors.	Investment of about $0.75 million for energy savings of 2,935,000 kWh/year and non-energy benefits, including a utility grant, increased production, and lowered maintenance, which justified the project.	

Sources:

[*] Energy Efficiency Guide for Colorado Businesses. *Energy Efficiency Case Studies: Agilent Technologies.* Available at: http://www.coloradoefficiencyguide.com/casestudies/agilent.htm. (Last accessed September 2, 2010.)

[†] Energy Efficiency Guide for Utah Businesses. *Energy Efficiency Case Studies: Alcoa North American Extrusions Plant.* Available at: http://www.utahefficiencyguide.com/casestudies/alcoa.htm. (Last accessed September 2, 2010.)

[‡] Utah Power: Making it happen. *Case study: BD Medical*. Available at: http://www.utahefficiencyguide.com/casestudies/bd_medical.pdf. (Last accessed September 2, 2010.)

[§] California Energy Commission. *Success Story: East Bay Municipal Utility District Special District 1, Wastewater Treatment.* Available at: http://www.energy.ca.gov/process/pubs/ebmud.pdf. (Last accessed September 2, 2010.)

[#] U.S. DOE, EERE. 2001. *Best Practices Project Case Study: Compressed Air System Renovation Project Improves Production at a Food Processing Facility*. Available at: http://www1.eere.energy.gov/industry/bestpractices/pdfs/bristolmyers.pdf. (Last accessed September 2, 2010.)

[**] Energy Design Resources. *Newspaper Increases Production and Saves Energy with a Compressed Air System Retrofit*. Available at: http://www.energydesignresources.com/Portals/0/documents/CaseStudies/EDR_CaseStudies_sjmn.pdf. (Last accessed September 2, 2010.)

[††] Parekh, P.S. 2000. *Investment Grade Compressed Air System Audit, Analysis and Upgrade.* 22nd National Industrial Energy Technology Conference Proceedings. Houston, TX. April 5-6, pp. 270-279. Available at: http://repository.tamu.edu/handle/1969.1/90905. (Last accessed March 25, 2011.)

9 Lighting

Only 10 percent of the energy consumed by an incandescent bulb is emitted in the form of light (U.S. DOE EERE, FEMP, 2007). In facilities that treat drinking water, lighting is used either to provide overall ambient light throughout processing, storage, operations and maintenance, and office spaces or to provide low bay and task lighting in areas such as laboratories.

A system approach to improving lighting efficiency typically involves the following steps.

1. First, locate and identify all lighting applications in the facility.
2. Second, document the conditions and specifications of the equipment to develop a current inventory.
3. Third, assess the needs and functions of the lighting applications to determine how well the lighting equipment meets the needs of that area of the facility.
4. Fourth, support the decision-making process by collecting information on potential upgrades to the lighting systems, including the economic costs and benefits of implementing upgrades.
5. Finally, if upgrades are pursued, monitor the performance of the upgraded lighting systems to determine the actual cost savings.

High-intensity discharge (HID) sources, including metal halide, high-pressure sodium, and mercury vapor lamps, can provide overall ambient light. Fluorescent, compact fluorescent (CFL), and incandescent lights typically are used for task lighting and offices. Because lighting is a cross-cutting feature present in most kinds of facilities, little of the information on energy efficient lighting is specific to water treatment plants. And because lighting retrofits often are done using a system approach, case study data on specific measures are not always available, particularly for a specific industry. Hence, in this section we include case study data from outside the drinking water industry.

9.1 Primary Resources

Building Upgrade Manual, Chapter 6, Lighting. 2006. U.S. Environmental Protection Agency, ENERGY STAR, offers a thorough, practical, and informative guide to energy efficient lighting. The following key guidelines are presented.

- Design the system to get the appropriate amount of light for the tasks to be performed in the space in question.
- Distribute that light to prevent glare.
- Use daylight whenever possible, but avoid direct sunlight, and install controls to reduce the use of electric lights in response to daylight.
- Use the most efficient light source for the application: high-performance fluorescent systems as the primary light source for most commercial spaces; compact

fluorescent lamps in place of incandescent bulbs in most cases; and high-intensity discharge lamps where appropriate.
- Use automatic controls to turn lights off or dim them as appropriate.
- Plan for and carry out the commissioning of all lighting systems to ensure that they are performing as required, and create a schedule to retro-commission systems periodically.
- Design lighting systems with ongoing maintenance in mind, and include a comprehensive plan for group re-lamping, fixture cleaning, and proper disposal of old lamps and ballasts.

Chapter 6 discusses the following specific topics, among others:
- Applying a whole-system approach (using a comprehensive lighting upgrade strategy).
- Lighting design, including:
  - the right quantity of light,
  - the right quality of light, and
  - outdoor lighting.
- Using efficient light sources, including:
  - daylight,
  - linear fluorescent lamps (and ballasts),
  - CFLs,
  - HIDs lamps (including metal halide), and
  - other light sources (light-emitting diodes [LEDs] and induction lamps).
- Using efficient luminaires, including
  - direct lighting (including reflectors, lenses and diffusers, and louvers) and
  - indirect lighting.
- Automatically controlling lighting, for instance via:
  - occupancy sensing;
  - scheduling;
  - tuning, in which light output is reduced to meet current user needs;
  - daylight harvesting, in which electric lights are dimmed or turned off in response to the presence of daylight;
  - demand response, in which power to electric lights is reduced in response to utility curtailment signals or to reduce peak power charges; and
  - adaptive compensation, in which light levels are lowered at night to take advantage of the fact that people need and prefer less light at night than they do during the day.
- Building in an operations and maintenance (O&M) plan, including
  - developing an O&M manual that incorporates correct operation and maintenance into job descriptions.

Chapter 6 of the Building Upgrade Manual is available online at:
http://www.energystar.gov/index.cfm?c=business.EPA_BUM_CH6_Lighting.

Chapter 6 also offers a summary comparison of the performance of options for retrofitting with fluorescent lighting. Chapter 6 states, "Packages of lighting-efficiency measures such as high-performance lamps and ballasts, delamping, and controls achieve deep savings with attractive economics." Table 7, taken from Chapter 6, summarizes information regarding several options for increasing the energy efficiency of lighting.

Table 7. Cost and Payback Period for Various Energy Efficiency Lighting Options

Retrofit Option	Base Case: energy-saving T12 lamps with magnetic ballasts	Case 1: T8 lamps with electronic ballasts	Case 2: high-performance T8s with electronic ballasts	Case 3: Case 2 + specular reflector + lens + 50% delamping	Case 4: Case 3 + occupancy sensing and daylighting dimming
Average maintained foot-candles	25	30	28	25	26
Power per fixture (W)	156	116	90	45	49
Annual energy use (kWh)	7,507	5,568	4,320	2,160	1,275
Energy savings (%)	NA	26	42	71	83
Annual operating cost ($)	826	612	475	238	175
Upgrade cost ($)	NA	1,165	1,320	1,560	2,150
Simple payback (years)	NA	5.5	3.8	2.7	3.3

Notes: NA = not applicable; W = watts.
Assumptions:
1. A minimum illumination level of 25 foot-candles is maintained.
2. Lamps are replaced at burnout.
3. Fixture cleaning occurs at the end of the rated base-case life. Assuming 4,000 burn hours per year and a 20,000-hour rated life, 5 years separate cleanings, for a total dirt loss of 30%.
4. The specular reflector retrofit kit is designed to maintain the same spacing ratio.
5. The existing diffuser has yellowed and gathered sufficient adhesive dirt (which isn't easily removed during routine cleaning) to reduce transmittance by another 10%.
6. Energy costs: demand = $10 per kW per month (all 12 months of the year); energy consumption = 7 per kWh (all times of day).

Source: Table 6.1 from Chapter 6 of the Building Upgrade Manual. Courtesy: E Source Lighting Technology Atlas (2005).

Advanced Lighting Guidelines, 2001 ed. New Buildings Institute Inc. For the person who wants to know everything about lighting, lighting systems, luminaires, and controls, this 394-page book has it all, from the effects of lighting on human performance to light distribution. Available at: http://www.planetpdf.com/forumarchive/alg2001.pdf.

9.2 Additional Resources

Energy Smart Lighting: Use in the Water/Wastewater Treatment Process. 2000. This two-page summary from the California Energy Commission is a useful place to start if you want a brief description of efficient lighting alternatives, their benefits, and their costs. Available at: http://www.energy.ca.gov/process/pubs/lighting.pdf.

Federal Energy Management Program (FEMP). U.S. DOE, Energy Efficiency and Renewable Energy. In addition to the guide described below, FEMP describes and discusses specific topics in energy efficient lighting and lighting controls. Some webpages describe requirements that FEMP has established for Federal purchases of designated lighting products; others simply present energy efficient options. The webpages provide specific guidance for anyone purchasing such products. The following webpages can be consulted without reference to the *Federal Lighting Guide* described below.

- **FEMP Designated Product: Industrial Luminaires**. This webpage presents the luminaire efficacy that FEMP requires for fluorescent T5HO lamps, fluorescent high-performance T8 lamps, and metal halide lamps. The page also provides a cost-effectiveness example, buyer tips, and resources for additional information. http://www1.eere.energy.gov/femp/procurement/eep_hid_lumen.html.
- **FEMP Designated Product: Compact Fluorescent Lamp**. This webpage provides performance requirements, by wattage, for bare bulbs and reflector-type bulbs, buyer tips, a cost-effectiveness example, and additional resources. http://www1.eere.energy.gov/femp/procurement/eep_compact_fluor_lamp.html.
- **FEMP Designated Product: Fluorescent Luminaires**. This webpage presents the FEMP performance requirements for fluorescent luminaires (recessed, wraparound, strip, and recessed with U-tube lamps); a cost-effectiveness example; buyer tips; and additional resources. http://www1.eere.energy.gov/femp/procurement/eep_fluor_lum.html.
- **How to Buy an Energy-Efficient Fluorescent Ballast.** This webpage presents recommended efficiencies for various lamp types, a cost-effectiveness example, buyer tips, and additional resources. http://www1.eere.energy.gov/femp/procurement/eep_fluor_ballast.html.
- **How to Buy an Energy-Efficient Fluorescent Tube Lamp.** This webpage provides efficiency recommendations by wattage and lamp length, a cost-effectiveness example, buyer tips, and resources for additional information. http://www1.eere.energy.gov/femp/procurement/eep_fluortube_lamp.html.
- **Maintaining Effective and Efficient Lighting Can Help Save Energy and Reduce Costs.** 2005. A FEMP *O&M First! Fact Sheet*. This four-page fact sheet discusses the importance of operations and maintenance of lighting systems and of relamping. Six opportunities for improving the efficiency and quality of lighted spaces are identified and discussed. http://www1.eere.energy.gov/femp/pdfs/om_lighting.pdf.
- **How to Buy an Energy-Efficient Exit Sign.** This webpage provides an efficiency recommendation, a cost-effectiveness example, buyer tips, and resources for additional information. http://www1.eere.energy.gov/femp/procurement/eep_exit_sign.html.

- **Energy Effective Lighting Checklist.** 2000. A tool for surveying lighting uses and needs. The document notes: "Consideration of the issues below will allow the project team to implement the maximum energy savings feasible without compromising the comfort and effectiveness of the occupants." Issues include surface brightness, overhead glare, and flicker/ballasts. http://www1.eere.energy.gov/femp/pdfs/lighting_checklst.pdf.
- **How to Select Lighting Controls for Offices and Public Buildings.** 2000. A 4-page review of various control options and their cost-effectiveness, along with resources for finding and choosing lighting controls. https://www1.eere.energy.gov/femp/pdfs/light_controls.pdf
- **Tips for Using Compact Fluorescent Lamps.** This webpage provides practical information about using CFLs for recessed downlighting and outdoor lighting. The page provides helpful information regarding when CFLs are not appropriate, for instance, under low-temperature conditions. http://www1.eere.energy.gov/femp/technologies/eep_fluor_tips.html.

Federal Lighting Guide: A Resource for Federal Lighting Improvement Projects. 1998. U.S. DOE, Federal Energy Management Program (FEMP). This thorough, practical guide outlines the following process for undertaking lighting improvement projects.

- Evaluate existing lighting system.
- Identify potential lighting projects.
- Identify funding options.
- Analyze and prioritize potential projects.
- Determine energy use and cost baseline.
- Prepare energy effective lighting design and specifications.
- How to procure and install.
- Commission completed lighting improvements; develop operations & maintenance plan.
- Verify benefits.

Detailed descriptions, references, and resources accompany each step. Additional materials include Appendix C, *Analysis and Design Tools*, and Appendix E, *Energy Effective Lighting Recommendations*. The lighting guide is available at: http://www1.eere.energy.gov/femp/pdfs/fed_light_gde.pdf.

Industrial Lighting: Best Practices. 2007. Focus on Energy. This two-page document lists 13 steps to take to upgrade lighting efficiency. Available at: http://www.focusonenergy.com/files/Document_Management_System/Business_Programs/industriallighting_bestpracticessheet.pdf.

Water & Wastewater Treatment Energy Use Self-Audit Tool. Developed by the Iowa Association of Municipal Utilities (IAMU) & The Energy Group, Inc. The IAMU website offers this free software tool and instruction manual to help the user develop estimates of energy and cost savings for upgrades based on user-input values. This tool is especially helpful because it pertains directly to water treatment facilities and utilizes specific data the user provides. Ancillary information includes a lighting chart. Available under the heading *Tools* at: http://www.iamu.org/services/water/resources.htm.

9.3 Case Studies

Table 9 summarizes case studies for energy efficient lighting projects from various industries. Empty cells indicate no data were available.

Table 9. Case Studies for Energy Efficient Lighting Projects

Site/Utility	Actions	Cost	Savings	Payback Period
BD Medical (manufacturing facility), Sandy, UT[*]	Changed from T12 fixtures to T8 with electronic ballasts (some fixtures also were delamped). Upgraded incandescent exit signs to LED. Changed incandescent lamps to compact fluorescent. Switched mercury vapor fixtures to compact fluorescent fixtures.	$60,322 after utility incentive	533,023 kWh per year, for $15,991 at $0.03/kWh	3.8 years with incentive
Central Contra Costa Sanitary District, CA[†]	Installed 75 motion sensors in offices, restrooms, break rooms, copy rooms, and conference rooms in headquarters building.	$15,000, but received a $3,600 rebate	55,000 kWh and $6,000 annually	2 years
Energy Building, Bangkok, Thailand[‡]	To save energy and improve illumination, replaced old T8 lamps with 148 T5 lamps with reflectors and 145 Master T8 lamps. Replaced fluorescent T8 lamps with compact fluorescents in corridors and bathrooms. Installed occupancy sensor and 3-W LED in one bathroom. Installed individual light switches and rearranged switches to operate groups of lights more appropriately.	243,000 Baht	Saved about 40% of total energy consumption for lighting system. Save 23,530 kWh/year or about $78,840/year. Also mitigate CO_2 emissions by about 17 tons/year.	1.8 years excluding reflectors, which had to be changed anyway.
Inland Empire Utilities Agency, CA[§]	Turned off 50% of non-critical lighting in headquarters, administration, and operations buildings.		15% to 20% percent of lighting energy usage	
Monterey County Jail, CA[#]	Replaced 5,000 of the facility's light bulbs with more energy efficient bulbs.	$100,000	Estimated: 750,000 kWh annually, for approximately $79,000 annually.	
Orange County Water District, CA[**]	Installed automatic light sensors in various offices and restrooms.	$3,000	$200 annually	

Site/Utility	Actions	Cost	Savings	Payback Period
Orange County Water District, CA[**]	Reduced lighting where possible (3% to 5% of total lighting in buildings); also installed energy efficient T8 lights where feasible.	Retrofits cost $4,000.	$700 per year	
Placerville Downtown Association, CA[††]	Replaced more than 5,800 incandescent outdoor lights with LEDs.		117,000 kWh and $17,000 annually	
REMO, Inc., Valencia, CA[‡‡]	Given the goal of retaining employees during a relocation, increased skylighting area to 3% of roof. Combined 250-W metal halide lamps with photocontrols. Washed skylights and dust photosensors.		About $36,000 per year	
San Juan Water District Sidney N. Peterson Water Treatment Plant, CA, which processes 120 MGD[§§]	Installed motion sensors, converted 30 incandescents to fluorescents, eliminated 30 unnecessary lights, and installed task lighting.		$2,400 annually while improving employee comfort and safety	
Sony Pictures, Culver City, CA, building that houses offices and a movie/TV set[##]	Incorporated large central skylight. Used “task/ambient” strategy: recessed deep-cell parabolic fixtures with T-8 lamps and electronic ballasts provide about 70% of the lighting; individually controlled fixtures provide complementary light on tasks. Daylighting controls on ambient lighting, photosensors, and occupancy sensors.		Estimated as-built vs. baseline: 241,000 vs. 486 kWh annually, for $36,916 vs. $63,942 in electricity costs.	
Vallejo Sanitation and Flood Control District, CA[***]	Replaced about 600 fluorescent lamps with more energy efficient lighting; replaced T12s with T8s; and installed electronic ballasts.	$6,000, but received $3,000 in rebates	166,000 kWh ($20,000) annually	4 months

Site/Utility	Actions	Cost	Savings	Payback Period
Vallejo Sanitation and Flood Control District, CA***	Installed 100 motion sensors, including at remote pump stations.	$4,000, but received a rebate of $2,500	125,000 kWh and $15,000 per year	About 3 months (1 month with rebate)
Viscose Rayon Filament Plant, Bulgaria†††	Increased illumination while reducing energy use: installed electronic ballasts and luminaires having an expedient color rendering and high efficiency. Provided optimal positioning of the luminaires dedicated for general illumination.		Reduced energy use from 38.41 \to 13.55 MWh; costs from 3,389.86 BGL to 1,195.57 BGL; GHG emissions from 19 to 7 tons	0.8 year

Notes:
BGL = Bulgarian lev (currency).
Ft^2 = square feet.
GHG = greenhouse gas.
HID = high-intensity discharge.
kWh = kilowatt-hours.
LED = light emitting diode.
M^3 = cubic meters.
W = watts.

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‡ SETatWork (Sustainable Energy Technology at Work) Consortium Members. 2009. *SETatWork Good Practice: Lighting Renovation.* Available at: http://www.setatwork.eu/downloads/SGP12_Lighting_AIT_TH.pdf. (Last accessed September 2, 2010.)
§ Flex Your Power. *Water/Wastewater Case Study: Inland Empire Utilities Agency.* Available at: http://www.fypower.org/pdf/CS_Water_IEUA.pdf (Last accessed September 2, 2010.)
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** Flex Your Power. *Water/Wastewater Case Study: Orange County Water District.* Available at: http://www.fypower.org/pdf/CS_Water_OCWD.pdf. (Last accessed September 2, 2010.)
†† Flex Your Power. *Placerville: Lighting Retrofit.* Available at: http://www.fypower.org/inst/gov/project-detail.html?id=35. (Last accessed September 2, 2010.)

‡‡ Energy Design Resources. *Skylighting Helps a Manufacturing Company Retain Employees*. Available at: http://www.energydesignresources.com/Portals/0/documents/CaseStudies/EDR_CaseStudies_remo.pdf. (Last accessed September 2, 2010.)

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*** Flex Your Power. *Water/Wastewater Case Study: Vallejo Sanitation and Flood Control District.* Available at: http://www.fypower.org/pdf/CS_Water_VallejoSan.pdf. (Last accessed September 2, 2010.)

††† Organisations for the Promotion of Energy Technologies Network. *Energy Efficiency in Industrial Lighting: Bulgaria*. Available at: http://www.managenergy.net/download/opet_gp/summaries/_s024p_gpr-bsrec-energy-efficiency-lighting.htm. (Last accessed September 2, 2010.)

10 Heating, Ventilating, and Air Conditioning

As with lighting measures, there are some simple measures that improve the energy efficiency of heating, ventilating, and air conditioning (HVAC) systems, which apply to any industry and are not specific to water treatment plants.

One way to improve the energy efficiency of HVAC is to purchase a new heater or air conditioner. New air conditioners have high efficiencies—some have energy efficiency ratios as high as 11.5—and can reduce cooling energy use about 30 percent to 40 percent. Air-source heat pumps are also very efficient (10.5 energy efficiency ratio) and can reduce heating energy use by about 20 percent to 35 percent. Moreover, a computerized energy management system for HVAC can manage energy use based on weather conditions, building use patterns, and other variables, potentially reducing building energy use by about 10 percent to 20 percent (CEC, 2005b). Regular cleaning of air filters alone can lower energy use as much as 20 percent and extend equipment life (CEC, 2005b).

In addition to equipment, building shell measures such as building insulation or low-emittance (low-E) windows are useful for improving the indoor environment.

10.1 Primary Resources

Building Upgrade Manual, Chapter 9, Heating and Cooling Upgrades. 2008. U.S. EPA, ENERGY STAR. This chapter addresses:

- central cooling systems,
- central heating systems,
- unitary systems, and
- additional strategies.

The topics are broken down further for detailed discussion. Chapter 9 recommends using an integrated-system approach to address the interactions among HVAC system components. It also notes that if heating and cooling upgrades are performed at the last stage of building upgrades, one can take advantage of the load reductions achieved in earlier stages (e.g., lighting). The chapter contains figures and tables, case studies, resources, and specific actions to take, e.g., regarding chilled-water systems or boiler system upgrades or retrofits. Available at: http://www.energystar.gov/index.cfm?c=business.EPA_BUM_CH9_HVAC.

Online Guide to Energy-Efficient Commercial Equipment: High-Performing HVAC Systems. American Council for an Energy-Efficient Economy (ACEEE). This website gives a thorough overview of various types of HVAC systems and issues, including a table of characteristics and typical applications. The website provides links to further detailed discussion of the following topics.

- HVAC controls for temperature, comfort, and efficiency.
- Air-handling systems: moving heating and cooling energy.
- HVAC for smaller buildings: packaged systems.
- Design and installation considerations.
- Serving larger buildings and facilities: central or “built-up” systems.

- Resources on high-performing HVAC.

Available at: http://www.aceee.org/ogeece/ch3_index.htm.

10.2 Additional Assistance

Building Upgrade Manual, Chapter 8, Air Distribution Systems. 2008. U.S. EPA, ENERGY STAR. This chapter describes air-handling systems (both constant volume [CV] and variable air volume [VAV]) and components (fans, filters, ducts, and dampers). It then discusses in detail opportunities for improving energy efficiency through the following steps.

- Optimize zone-level performance.
- Convert CV systems to VAV.
- Right-size fans.
- Install VSDs.
- Modify controls.
- Choose Premium efficiency motors.
- Use energy efficient belt drives.
- Consider consulting a testing, adjusting, and balancing contractor.

Included in the discussion are figures, tables, and case studies. Available at: http://www.energystar.gov/index.cfm?c=business.EPA_BUM_CH8_AirDistSystems#SS_8_4_8.

Criteria for ENERGY STAR Qualified Light Commercial Air Conditioners and for Light Commercial Heat Pumps. This webpage is a resource for language related to purchasing and procurement of light commercial air conditioners and heat pumps. Available at: http://www.energystar.gov/index.cfm?c=heat_cool.pr_proc_light_commercial.

Energy Efficient Upgrades: HVAC Systems. This *Business.gov* webpage provides tips, advice, and links to additional resources. Guidance includes first reducing loads through insulation and energy efficient windows and lighting systems. The webpage provides helpful suggestions for undertaking an HVAC project and discusses control systems and maintenance. Available at: http://www.business.gov/manage/green-business/energy-efficiency/upgrades/hvac.html.

Energy Efficiency in Industrial HVAC Systems. 2003. North Carolina Division of Pollution Prevention and Environmental Assistance. This document provides guidance in conducting an HVAC audit and provides a step-by-step checklist for assessing opportunities for increasing energy efficiency. Available at: http://www.p2pays.org/ref/26/25985.pdf.

FEMP Designated Product: Commercial Central Air Conditioners. U.S. DOE EERE, FEMP. This webpage provides links to performance requirements, buyer tips, a cost-effectiveness example, and additional resources. Available at: http://www1.eere.energy.gov/femp/technologies/eep_unitary_ac.html.

Improving Fan System Performance: A Sourcebook for Industry. 2003b. U.S. DOE EERE, Industrial Technologies Program. DOE/GO-102003-1294. Like the sourcebooks for motors and pumps, this sourcebook describes fans and fan systems and presents a performance improvement opportunity roadmap. That roadmap covers the following topics.

1. Assessing fan system needs.
2. Fan types.
3. Basic maintenance.
4. Common fan system problems.
5. Indications of oversized fans.
6. System leaks.
7. Configurations to improve fan system efficiency.
8. Controlling fans with variable loads.
9. Fan drive options.
10. Multiple-fan arrangements.
11. Fan system economics.

The sourcebook also provides a list of programs, resources, and contacts. Available at: http://www1.eere.energy.gov/industry/bestpractices/pdfs/fan_sourcebook.pdf.

Life Cycle Cost Estimate for 20 ENERGY STAR Qualified Central Air Conditioners. 2009. The U.S. EPA and U.S. DOE developed this energy savings calculator for estimating costs and savings of energy efficient central air conditioners. The user enters specific details, such as location, price of electricity, and cost of ENERGY STAR and conventional units. The calculator provides annual operating and life cycle costs. The calculator, a Microsoft Excel workbook, can be downloaded at: http://search.energystar.gov/search?q=cache:BP4rmmbBcmMJ:www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_CAC_bulk.xls+commercial+air+conditioners&access=p&output=xml_no_dtd&site=default_collection&ie=UTF-8&client=default_frontend&proxystylesheet=default_frontend&oe=UTF-8.

Water & Wastewater Energy Management Best Practices Handbook. 2010. New York State Energy Research & Development Authority. Among the best practices described in the handbook are the following sheets related to buildings (B).

- B-5: Maintain Boilers and Furnaces.
- B-6: Adjust Burners on Furnaces and Boilers.
- B-7: Check Outside Air Ventilation Devices, Ventilation/Supply Fans & Clean Fan Blades.
- B 8: Replace Ventilation Air Filters.

Each one-page description briefly summarizes the primary, practical steps to take regarding the named issue. Available at: http://www.nyserda.org/programs/Environment/best_practice_handbook.pdf.

Water & Wastewater Treatment Energy Use Self-Audit Tool. Developed by the Iowa Association of Municipal Utilities (IAMU) and The Energy Group, Inc. The IAMU website offers this free software tool and instruction manual to help the user develop estimates of energy and cost savings for upgrades based on user-input values. This tool is especially helpful because it pertains directly to water treatment facilities and utilizes specific data the user provides. It covers:

- cooling and heating equipment;
- night setback; and
- windows, doors, roof, and walls.

Ancillary information includes R-values for insulation, heating system efficiencies, and an explanation of how to calculate annual heating hours. Available under the heading *Tools* at: http://www.iamu.org/services/water/resources.htm.

Water/Wastewater Guide 1: Reduce Energy Use in Water and Wastewater Facilities Through Conservation and Efficiency Measures. Post-2001. Flex Your Power. This guide has a section on HVAC (page 9) that includes some guidance and examples from water and wastewater utilities. In addition to purchasing more efficient equipment and maintaining HVAC systems, the recommendations call for the following.

- Alter settings of HVAC system seasonally.
- Prevent solar entry or air-conditioning loss.
- Install devices, software, or management systems that will regulate and/or track the use of energy by HVAC systems and equipment.
- Alter schedules of HVAC systems to reduce on-peak energy use and/or shift load to off-peak hours. Use programmable control systems and an EMS to regulate schedules.
- Adjust workplace schedules to reduce on-peak HVAC usage.

Although examples are provided, they generally do not include data regarding cost-effectiveness or payback period. Available at: http://www.fypower.org/pdf/BPG_Water1_Con&Eff.pdf .

Appendix D to Water and Wastewater Energy Best Practice Guidebook. 2006. Focus on Energy. This appendix lists measures considered best practices for common systems.

- Area comfort heating
  - Reduce waste heat.
  - De-stratify heated air.
  - Control heating to desired temperature.
  - Use infrared heating.
  - Optimize CFM air exhausted.
  - Automatic temperature control.
  - Minimize heat to storage areas.
- For comfort cooling
  - Install removable insulation.
  - Minimize unnecessary ventilation.
  - Minimize moisture released.
  - Higher efficiency air conditioning.
  - Optimize room air temperature.
- For ventilation

- Direct-fired make-up units.
- Better ventilation management.
- De-stratified air.

10.3 Case Studies

Table 10 describes case studies for improving the energy efficiency of HVAC systems. Empty cells indicate no data were available.

Table 10. Case Studies for Energy Efficiency Improvements to HVAC Systems

Site/Utility	Actions	Cost	Savings	Payback Period
Agilent Technologies, Fort Collins, CO, manufacturer of semiconductor chips[*]	Set temperature levels of HVAC units in interior office spaces higher at night.	$0	Reduces air pumping requirements as well as cooling load, resulting in $2,000 in energy cost savings annually.	
Lachine filtration plant, Quebec, which has a capacity of 127,300 m^3 water per day[†]	Added 10 cm of insulation to permanent walls; 10-cm layer of insulating concrete in pipe gallery; insulated pipes with 5 cm mineral wool; enclosed wash-water recovery pipe along the floor in a wooden box lined with 3.8 cm of Styrofoam; replaced insulation for wall heaters; installed ceiling fans.	40,000 CAD	18,000 CAD	2.2 years
Orange County Water District, CA[‡]	After performing audit of HVAC system, changed thermostat setting to 76° in summer, cleaned coils, and performed other maintenance.	$10,000	$3,000	
Nisshinbo California, Inc., textile plant, Fresno, CA[§]	Improved air flow control and energy efficiency of ventilation system by retrofitting 15 of the system's fan motors with variable frequency drives (VFDs).	$130,000	Reduced energy use by 59% , saving approximately $101,000 per year	1.3 years.
The Aventine, a 252,000 ft^2 multi-use building, La Jolla, CA[#]	To lower HVAC energy consumption and improve the environmental footprint of the complex, converted the chiller plant to a primary-only, all-variable speed system, and retrofitted the two 300-ton chillers with oil-less VFD centrifugal compressors. Installed software to optimize the all-variable-speed components.		Annual cost savings of more than $136,000 (annual electricity savings of more than 637,400 kWh). Reduced peak demand by 37 kW. Reduced annual CO_2 footprint by more than 618,240 lbs.	Less than 3 years

Site/Utility	Actions	Cost	Savings	Payback Period
University of Florida, Gainesville**	Initiated comprehensive retro-commissioning to ensure that air-handling equipment was properly serviced and operating as designed. Monitored, cleaned, repaired, and reconditioned equipment; trained staff; and implemented control strategies.		HVAC comprised more than $28 million of annual utility costs of $48 million. After only partial completion, experienced a 22% return on investment.	
St. Michaels' Hospital, Toronto, Canada††	Replaced two aging centrifugal chillers with a water-to-water heat pump. The heat pump raises the temperature of heat recovered from the air-handling system and water-cooled chillers to warm the incoming ventilation air.		Savings generally range from $2,500 to $6,000 per day, depending on outdoor temperature. Using less steam has provided a 36% reduction in greenhouse-gas emissions.	

Notes:
CAD = Canadian dollars.
ft^2 = square feet.
kWh = kilowatt-hours.
m^3 = cubic meters.
MGD = million gallons per day.

Sources:
[*] Energy Efficiency Guide for Colorado Business. *Energy Efficiency Case Studies: Agilent Technologies*. Available at: http://www.coloradoefficiencyguide.com/casestudies/agilent.htm.
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[§] U.S. DOE EERE ITP, Best Practices. *Case Study–The Challenge: Improving Ventilation System Energy Efficiency in a Textile Plant*. Available at: http://www1.eere.energy.gov/industry/bestpractices/case_study_ventilation_textile.html (Last accessed March 21, 2011.)
[#] Santamaria, C. Next Generation Energy Efficient Technologies: A Case Study Demonstrating Top Operational Performance–The Aventine Chiller Plant Optimization. *Journal of Green Building*. Vol. 4, No. 26/16/09 pp. 44–53. Available at: http://optimumenergyhvac.com/pdf/Journal%20of%20Green%20Building%20-%20Next%20Gen%20Technologies%20-%20JGB%20FINAL.pdf (Last accessed March 21, 2011.).
[**] Johnson Controls. *Case Studies: University of Florida, Gainesville, Florida.* Available at: http://www.johnsoncontrols.com/publish/us/en/products/building_efficiency/case_studies2.html. (Last accessed March 22, 2011.)

†† Johnson Controls. *Case Studies: St. Michaels' Hospital, Toronto, Canada*. Available at: http://www.johnsoncontrols.com/publish/us/en/products/building_efficiency/case_studies2/HVAC-Equipment.html. (Last accessed March 22, 2011.)

11 Financing Energy Efficiency

Although many energy efficiency measures for drinking water facilities have instant payback periods, some improvements require significant capital investment. It is helpful to know how to pay for major improvements and calculate their cost-effectiveness.

Many electric utilities offer free energy audits, rebates on purchases of energy efficiency equipment, or special rates for decreased usage. Audits may examine the end uses of electricity, annual costs, system modifications and their costs, estimated paybacks for recommended changes, and electricity use in relation to rate structure. Electric utilities also may offer financial assistance via incentives such as purchase subsidies/rebates, low- or no-interest loans, guaranteed payback periods, or direct assistance. Special rate programs, which offer time-of-use or interruptible rate structures, are common financial incentives.

When utility rebates or incentives are insufficient to justify a capital investment, a public facility may need to acquire the capital necessary to invest in major infrastructure improvements. Table 11 describes the various options for financing capital improvements.

Table 11. Funding Options for Capital Improvements

	Cash	Bond	Tax-Exempt Lease	Performance Contract
Interest Rate	N/A	Lowest tax-exempt rate.	Low tax-exempt rate.	Can be taxable or tax-exempt.
Financing Term	N/A	May be 20 years or more.	Commonly up to 10 years and up to 12 or 15 years possible for large projects.	Typically up to 10 years, but may be as long as 15 years.
Other Costs	N/A	Underwriting legal opinion, insurance, etc.	None	May have to pay engineering costs if contract not executed.
Approval Process	Internal	May require taxpayers' approval or public referendum. Opinion letter from bond counsel required.	Internal approvals needed; simple attorney letter required.	Request for proposal usually required; internal approvals needed.
Approval Time	Current budget period	May be lengthy; process may take years.	Fast; generally within a week of receiving all requested documentation.	Fast; similar to the tax-exempt lease.
Funding Flexibility	N/A	Very difficult to exceed the dollar ceiling.	Can set up a master lease, which allows funds to be drawn down as needed.	Relatively flexible; an underlying municipal lease often is used.

	Cash	Bond	Tax-Exempt Lease	Performance Contract
Budget Used	Operating or Capital	Capital	Operating	Operating or Capital
Greatest Benefit	Direct access *if* included in budget.	Low interest rate because it is backed by the full faith and credit (taxing powers) of the public entity.	Allows the purchase of capital equipment using operating dollars.	Provides performance guarantees, which facilitate approval process.
Greatest Hurdle	Never seems to be enough money available for projects.	Very time-consuming.	Identifying the project to be financed.	Identifying the project to be financed and selecting the energy service company.

Source: U.S. EPA, ENERGY STAR Program. 2004.

11.1 Primary Resources

Drinking Water State Revolving Fund (DWSRF). Established by the Safe Drinking Water Act, as amended in 1996, the DWSRF makes funds available to drinking water systems to finance both the design and construction of infrastructure improvements. The U.S. EPA allots funds to states based on the 2007 Drinking Water Needs Assessment Survey. Appropriations for 2010 were $1.5 billion. The EPA provides the funds to states in the form of capitalization grants. States, in turn, administer the funds to provide low-interest loans for planning, design, and construction of water treatment facilities. Information available at: http://www.epa.gov/safewater/dwsrf/index.html, but each state serves as the source of funds.

Financing Energy Efficiency Projects. 2003. N. Zobler and K. Hatcher. Reprinted on the ENERGY STAR website with permission from *Government Finance Review*. The concise overview describes using performance contracts and tax-exempt lease-purchase agreements, which may allow repayment to be treated as an operating expense rather than as long-term debt. It also discusses the costs of delay and losses from inefficiency that may exceed financing costs. Available at: http://www.energystar.gov/ia/business/government/Financial_Energy_Efficiency_Projects.pdf.

Sources of Technical and Financial Assistance for Small Drinking Water Systems. 2002. U.S. EPA Office of Ground Water and Drinking Water. Report 816-K-02-005. Summarizes sources for technical as well as financial assistance. This document provides brief descriptions of and contact information for several of the resources described below. Available at: http://www.epa.gov/safewater/smallsystems/pdfs/tfa_sdws.pdf.

11.2 Additional Assistance

Buildings Upgrade Manual. **Chapter 4, Financing**. 2007. ENERGY STAR. Covers methods for purchasing or leasing equipment and services, as well as performance contracting. Available at: http://www.energystar.gov/ia/business/EPA_BUM_CH4_Financing.pdf.

Cash Flow Opportunity Calculator. Version 2.0. 2010. Offered by ENERGY STAR. This Microsoft Excel spreadsheet helps a facility manager answer three critical questions about energy-efficiency investments.

- How much new energy-efficiency equipment can be purchased from the anticipated savings?
- Should this equipment purchase be financed now, or is it better to wait and use cash from a future budget?
- Is money being lost by waiting for a lower interest rate?

Available at: www.energystar.gov/index.cfm?c=business.bus_financing.

The above webpage contains a link to an 11-page document titled, *Innovative Financing Solutions: Finding Money for Your Energy Efficiency Projects*. 2004. Described as "A primer for public sector energy, facility, and financial managers," it also reviews various approaches to securing financing (e.g., tax-exempt lease-purchase agreements). The document was the source for Table 11. Direct link: http://www.energystar.gov/ia/business/COO-CFO_Paper_final.pdf.

The above webpage also contains a link to a two-page document titled, *Easy Access to Energy Improvement Funds in the Public Sector*. The document describes performance contracts and tax-exempt lease-purchase agreements. Direct link: http://www.energystar.gov/ia/business/easyaccess.pdf.

CoBank is a cooperative owned by its customers, which specializes in providing financing for cooperative, agribusiness, rural utility, and farm credit associations. CoBank has financed $1.1 billion in loans to private and municipal water systems since 2005 through its infrastructure lending arm (American Water Intelligence, 2011). CoBank provides assistance to water and wastewater systems in unincorporated areas or systems in incorporated towns having fewer than 20,000 residents. The minimum loan size is $1 million, and the term normally does not exceed 20 years. Website: www.cobank.com. Their national office is in Denver, CO, but they have 13 offices throughout the United States. Regional contact information available at: www.cobank.com/find/cebgoffices.html.

Energy Conservation in Water and Wastewater Facilities. 2010. Manual of Practice No. 32. Water Environment Federation. Section 6.0, Financing Approaches, of Chapter 11, *Energy Management*, focuses on structures for financing construction of electric-generation facilities for wastewater plants. Although the focus is not specific to the needs of drinking water treatment plants, the section discusses revenue bonds, bank financing, various forms of lease financing, privatization, and joint ownership and/or development. Published by McGrawHill and available from the Water Environment Federation, Alexandria, VA.

Financing Alternatives Comparison Tool (FACT). Developed by the U.S. EPA, this financial analysis tool helps identify the most cost-effective method to fund a wastewater or drinking water management project. The webpage provides software, which runs on Microsoft Access 2000 or higher, that incorporates financing, regulatory, and other costs to compare various options. This tool can also create graphical comparisons of annual and total cumulative costs of various financing options. The webpage contains links to (1) a one-page fact sheet on FACT, (2) a download for the FACT software, and (3) a download for the Access program, if needed. Available at: http://www.epa.gov/owm/cwfinance/cwsrf/fact.htm.

Green Project Reserves. In 2009, the U.S. EPA Office of Water established this 20-percent reserve to the state revolving funds through American Recovery and Reinvestment Act (AARA) Guidance. ARRA states: "*Provided further*, that, to the extent there are sufficient eligible project applications, not less than 20 percent of the funds appropriated herein for the Revolving Funds shall be for projects to address green infrastructure, water or energy efficiency improvements, or other environmentally innovative activities." Monies can fund entire projects or components. Again, states administer the funds. See: http://www.epa.gov/water/eparecovery/docs/STIMULUS_Guidance_Green_Reserve.pdf.

India: Manual for Development of Municipal Energy Efficiency Projects. 2008. Alliance to Save Energy. Although written specifically for India, it describes itself as "a practical tool for anyone interested in developing, financing, and implementing municipal energy efficiency projects using performance contracts." Provides guidelines on actions such as procuring services and equipment, performing an investment-grade energy audit, performance contracts, and performance monitoring and verification plans. Available at: http://www.watergy.net/resources/publications/ee_development_manual.pdf.

Rural Utilities Service (RUS) is the federal agency responsible for helping build and support infrastructure related to rural electricity, water, and telecommunications. As a federal credit agency in the U.S. Department of Agriculture, RUS's Water and Environmental Programs provide loans, grants, and loan guarantees for drinking water, sanitary sewer, solid waste, and storm drainage facilities that serve as many as 10,000 persons in rural areas, cities, and towns. RUS also provides funding for on-site technical assistance to help ensure cost-effective operation of rural water systems. Website: www.usda.gov/rus.

U.S. Department of Agriculture (USDA). USDA's Rural Energy for America Program/Renewable Energy Systems/Energy Efficiency Improvement (REAP/RES/EEI) Grants Program makes both matching grants and loans to rural small businesses and agricultural producers for energy efficiency projects, including lighting, heating, cooling, insulation, and pump improvements. Grants for energy efficiency improvements can range from $1,500 to $250,000. Through a national competition, grants also may be made to entities that provide technical assistance to rural businesses, for instance for energy audits. In FY2010, approximately $2.4 million was to be awarded. Again, funds are administered by the states. Information available at: http://www.rurdev.usda.gov/rbs/busp/bprogs.htm.

U.S. Department of Housing and Urban Development (HUD) Community Development Block Grant Program. This HUD program provides small rural water systems with the funds necessary to improve compliance and overall drinking water quality. In the past, utilities have used HUD grants to meet state and federal regulations by developing new water sources; improving treatment techniques; constructing production wells, backup wells, and pump stations; and replacing distribution system pipes. Website: www.hud.gov/offices/cpd/.

U.S. Small Business Administration (SBA) operates an energy loan program. Although SBA itself does not make loans, it guarantees loans made by private and other institutions to small businesses. Most banks and some non-bank lenders participate in the program. SBA's 7(a) Loan Program is the primary program to help start-up and existing small businesses obtain financing when they might not be eligible for business loans through normal lending channels. Information at: http://www.sba.gov/financialassistance/borrowers/guaranteed/index.html.

12 References

Among the following references are documents, whether digital or in print, that are cited in the text, listed as primary resources, or identified as additional assistance. The reference list does not include sources that are simply websites or webpages, for which links are provided in the text. The sources for the case studies listed in the table for each cross-cutting measure appear below the table.

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AWWA. 2009. *Water Audits and Loss Control Programs*. Manual 36, Third Edition. AWWA: Denver, CO. ISBN 978-1-58321-631-6. Described and available at: http://www.awwa.org/Resources/WaterLossControl.cfm?ItemNumber=47957&navItemNumber=48161. (Last accessed September 3, 2010.)

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Appendix A: Historical Overview of Drinking Water Supply

Methods and systems for drinking water collection, treatment, and supply have been enacted since ancient times. All processes related to potable water supply have had the common goal of providing drinking water of the highest possible quality given the constraints of the source water quality and the water supply infrastructure, including any treatment plant. Human consumption of water is one of, if not the, highest and best uses of any particular water resource. A drinking water supply utility's first obligation is to provide the highest quality drinking water in order to safeguard the health and well-being of its customers. Assuring compliance with and staying ahead of regulatory standards and requirements for potable water are easily the most important criteria applied when engineering professionals design a new potable water treatment plant. Until recently, energy use requirements for drinking water facilities were insignificant design criteria compared to public health, regulatory requirements, and safety standards.

Among the earliest methods for drinking water treatment, which was practiced as early as 4,000 B.C., is water filtration using sand, gravel, and/or charcoal as the filter media. Media filtration remains a fundamental process in modern drinking water treatment. Sand filtration has been used to clarify and purify surface water supplies, removing total suspended solids including silt and other colloidal particles; both inorganic and organic solids including microalgae, cyanobacteria, and other bacteria; and other microorganisms. Media filters are distinguished by the level of pressure required: (1) a minimal hydraulic head of several feet in a traditional gravity-pressure slow sand filters; (2) pressured by pumping in more modern pressure filters, such as rapid sand filters and multi-media filters; or (3) more highly pressured filtration processes such as membrane microfilters.

In nineteenth-century England, Europe, and the United States, supplies from surface waters, primarily rivers, were treated first with gravity sedimentation of suspended solids, silts, and colloidal particles, followed by sand filtration. After Dr. John Snow in 1854 discovered that waterborne diseases such as cholera could be spread by contaminated drinking water supplies, disinfection was developed as a final treatment process. Starting in the late 1800s, disinfection after media filtration was used for public drinking water treatment. Chemical disinfection processes using chlorine gas and ozone continued to be developed to kill or inactivate any pathogens that remained in the source water after sedimentation and filtration. In the 1870s Louis Pasteur and Robert Koch developed the germ theory of disease. In 1881 Koch demonstrated in the laboratory that chlorine gas dissolved in water could kill bacterial enteric pathogens. In 1905 continuous chlorination of drinking water was used to stop a typhoid epidemic. Three years later, the first regular use of disinfection in drinking water occurred in Chicago, Illinois, around the time that Dr. Harriette Chick proposed her theory of chemical disinfection.

Along with chemical disinfection, chemical coagulation and flocculation processes were developed and applied. By the middle of the twentieth century, the conventional practice for treating surface water supplies for drinking in Europe and North America had become a sequential process involving (1) coagulation, (2) flocculation, (3) sedimentation, (4) filtration, and finally (5) chemical disinfection (typically some form of chlorination, although in recent decades other methods of disinfection have included ozonation and ultraviolet [UV] light disinfection). The most common sequence of treatment processes for surface water supplies is shown in Figure A-1. The sequence remains the standard practice for drinking water supply utilities around the world.

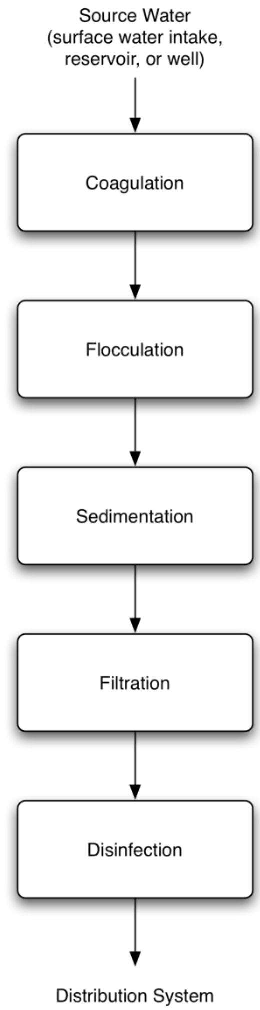


Figure A-1: Common Treatment Processes for Surface Water Sources

Unlike surface water that is seasonally replenished by rainfall and snow melt, groundwater may be quite old. Groundwater also is replenished by the recharge of surface water and precipitation that infiltrates through the soil column into the groundwater basin. Thus, groundwater is subject to filtration as its passes through soil and rock into a porous, water-bearing stratum known as a groundwater reservoir or aquifer. In many parts of the world groundwater is used for drinking water supply, particularly in arid regions where surface water supplies are scarce. The use of groundwater for potable water supply has two implications for energy use. First, groundwater must be lifted to the surface. When groundwater resources are extracted at rates that exceed their replenishment by surface recharge, as happens in many parts of the world, the water table falls, requiring deeper wells and increasing the lift — and resulting energy use — of the well pumps. Second, a different set of drinking water treatment processes may be needed to treat groundwater supplies if they contain dissolved metals such as iron or manganese that require special treatment processes not required in the treatment of surface water supplies. On the other hand, treating groundwater supplies for potable use may not require some of the treatment processes used to treat surface water supplies.

Since the passage of the Clean Water Act in 1972, the number of priority pollutants in drinking water has increased steadily, as have available methods for detecting water contaminants and human pathogens. Today, we are able to detect in parts per billion and parts per trillion contaminants such as natural and synthetic hormones and endocrine disrupting compounds that affect such basic functions as reproduction and metabolism. A multitude of additional drinking water treatment processes have been developed as the list of priority pollutants and pathogens has lengthened. For instance, membrane filtration, also known as microfiltration or nanofiltration, has been developed to remove the oocysts of *Cryptosporidium* sp., a pathogenic protozoan found in dairy runoff and transmitted to humans via contaminated water. These oocysts are quite small—typically five microns in diameter.

Appendix B: Market Profile Used in ENERGY STAR's Portfolio Manager for Drinking Water Utilities

B-1 Introduction

This appendix describes the market profile Lawrence Berkeley National Laboratory developed to describe the energy that public utilities use to convey/produce, treat, and distribute drinking water. First we identified the variables we consider most pertinent to electricity consumption by water utilities. We grouped utilities according to the average volume of source water flow, then developed market profiles based on weighted averages for each variable and its associated energy consumption. In developing the market profiles, we utilized data collected by the American Water Works Association Research Foundation (AwwaRF) through its most recent 2004 survey of water and wastewater utilities. U.S. EPA's ENERGY STAR filtered the data to remove incomplete records.

Currently, water utilities can compare their treatment choices and energy consumption only to national averages for processing drinking water. The weighted averages presented here enable water utilities to compare their processes and energy use with other utilities that treat the same general volume of source water flow. These more relevant comparisons can better assist utilities in evaluating their energy performance and consumption.

B-2 Description of Water Utility Groups

In order to examine parameters that affect energy use by water utilities, we divided the utilities represented in the filtered AwwaRF data set into four groups depending on their total source water flow.

Group 1 water utilities were defined as those averaging less than 3 million gallons per day (MGD) of total source flow. Group 1 utilities used almost 2,000 kilowatt-hours (kWh) per million gallons (MG) for producing/ conveying, treating, and distributing drinking water. Ground water flows represented one-third of overall Group 1 source flows (1.8 MGD out of 5.6 MGD). Surface water (from lakes, rivers, and/or streams) represented 41 percent of total source flows. The weighted average for the turbidity of surface waters was 10.5 nephelometric turbidity units (NTU), higher than the national average of 7.8 NTU. Electricity use associated with treatment (a weighted average of 1 million kWh/year) tended to go toward disinfection (100 percent of Group 1 water utilities), taste and odor control (53 percent), and turbidity removal (43 percent). One-third of Group 1 water utilities treated for total organic carbon, 26 percent to remove manganese, and 30 percent to remove iron. The most prevalent treatment processes were flocculation (used by 43 percent of Group 1 utilities) and rapid-rate filtration (30 percent). Regarding water distribution, Group 1 utilities had a weighted average water main length of 126 miles and a distribution pressure of 67 pounds per square inch (psi).

Group 2 water utilities were defined as averaging at least 3 MGD but less than 5 MGD of total source water flow. Group 2 utilities used a weighted average of slightly more than 1,400 kWh per MG for water conveyance, treatment, and distribution. Ground water flows represented one-third of overall Group 2 source flows (3.5 MGD out of 11.1 MGD). Surface flows accounted for 32 percent, and purchased water for 36 percent, of total source flows. The weighted average for surface water turbidity was 23.1 NTU, higher than the national average of 7.8 NTU. Electricity use associated with treatment (an average of 1.1 million kWh/year) tended to go toward disinfection (91 percent of Group 2 utilities), taste and odor control (41 percent), and turbidity removal (64 percent). Thirty-six percent of Group 2 utilities treated for total organic carbon and for manganese removal; 32 percent treated to remove iron. The most commonly used treatment processes were flocculation (64 percent of Group 2 utilities) and gravity clarification (36 percent). Regarding distribution, Group 2 utilities had a weighted average water main length of 138 miles and a distribution pressure of 69 psi.

Group 3 water utilities were defined as those averaging at least 5 MGD but less than 20 MGD of total source flow. Group 3 utilities used a weighted average of slightly more than 1,600 kWh per MG for water production, treatment, and distribution. Ground water flows represented almost 30 percent of overall Group 3 source flows (7.2 MGD out of 25.8 MGD). Surface flows accounted for 39 percent and purchased water for 33 percent of total flows. The weighted average for surface water turbidity was 9.4 NTU, higher than the national average of 7.8 NTU. Electricity use associated with treatment (a weighted average of almost 3 million kWh/year) tended to go toward disinfection (92 percent of Group 3 utilities), taste and odor control (46 percent), and turbidity removal (64 percent). Forty-two percent of Group 3 utilities treated for total organic carbon, and 34 percent to remove manganese and iron. The most commonly used treatment processes were flocculation (56 percent of Group 3 utilities) and gravity clarification (40 percent). For distribution, Group 3 utilities had a weighted average water main length of 346 miles and a distribution pressure of 72 psi.

Group 4 water utilities were defined as averaging at least 20 MGD but less than 600 MGD of total source flow. They used a weighted average of slightly less than 1,500 kWh per MG for water conveyance/production, treatment, and distribution. Ground water flows represented less than 10 percent of overall Group 4 source flows (21 MGD out of 308 MGD). Surface flows predominated at 68 percent of total source flows; purchased water represented 25 percent of total sources. The weighted average for surface water turbidity was 7.3 NTU, slightly less than the national average of 7.8 NTU. Electricity use associated with treatment (an average of 20 million kWh/year) tended to go toward disinfection (94 percent of Group 4 utilities), taste and odor control (69 percent), and turbidity removal (74 percent). Fifty-four percent of Group 4 utilities treated for total organic carbon, 29 percent for manganese, and 26 percent for iron removal. The most commonly used treatment processes were flocculation (69 percent of Group 4 utilities), gravity clarification (51 percent), and rapid-rate filtration (49 percent). For distribution, the weighted average water main length for Group 4 utilities was 2,700 miles and the distribution pressure 62 psi.

B-3 Market Profile for Water Utilities

AwwaRF surveyed a sample of water utilities nationwide that together serve 118 million people. AwwaRF received responses from 24 percent of the utilities surveyed, or 217 utilities that serve a total of 28 million customers. After filtering the data to exclude incomplete records, AwwaRF condensed the data set to 137 water utilities.

We divided the AwwaRF data set into the four groups described above to examine operating conditions as they relate to total volume of source water. As shown in Table B-1 and Figure B-1, utilities that process 5 million gallons per day (MGD) or less of water represent almost one-third of the data set. When data are weighted by the combined flow of all utilities, however, the smaller utilities constitute only 2 percent of the sample.

The information presented in the following tables is intended to help water utilities compare their operations with those of other utilities operating in the same range of average total source water flow. Total average flow includes ground, surface, and purchased supplies. Summary tables describe treatment purposes, processes, residuals, and electricity use. Each table presents information as weighted averages and percentages assigned to one of four groups depending on average total source water flow.

Table B-1 Water Utilities Grouped by Volume of Average Total Source Water

Number of Utilities	Source Water Greater than or Equal to (MGD)	Source Water Less than or Equal to (MGD)	Weight Given Total Combined Flow	Percent of Sample by Weight (%)
30	0	2.999	59	2
22	3	4.999	88	2
50	5	19.999	483	14
35	20	599.999	2,907	82
137	0	599.999	3,537	100

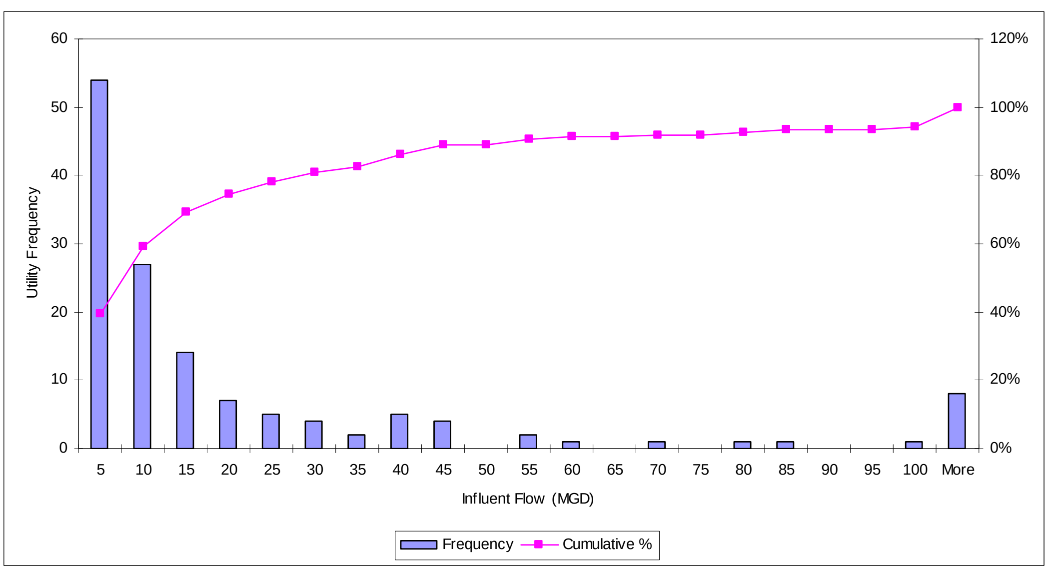


Figure B-1 Distribution of Average Total Source Water Flows for Water Utilities in AwwaRF Filtered Data Set

Table B-2 presents a summary of the general characteristics of water utilities in the four categories of total source water flow. The information is described in greater detail in subsequent tables. The values in Table B-2 (and subsequent tables) are weighted averages based on the sum of the source water flows of utilities within each volume range. The percentage values are based on the numbers of utilities in each source water range.

Table B-2 General Characteristics of Water Utilities by Volume of Source water

Characteristic	Units	Measure of Characteristic (by MGD)—Weighted Average				
		Total	**0–2**	**3–4**	**5–19**	**20–599**
Total average flow	MGD	178.6	2.2	4.1	11.4	215.2
Average raw turbidity	NTU*	7.1	7.9	20.7	6.4	6.9
Peak raw turbidity	NTU	200.4	274.3	798.1	196.7	187.6
Treatment for metals (derived)	%	33.3	36.4	36.0	31.4	34.3
Treatment for contaminates (derived)	%	30.0	31.8	32.0	31.4	31.4
Elevation change (derived)	feet	453.9	267.4	320.7	429.9	465.1
Horsepower (derived)	hp	17,113.4	749.6	1,191.5	3,556.8	20,180.8
Annual electricity use per unit of source water flow	kWh†/MG per year	1,510.4	1,955.5	1,430.1	1,618.4	1,485.9

* Nephelometric turbidity units.
† Kilowatt-hours.

B-4 Characteristics of Source Water

Utilities may obtain water from one or more of three sources: water pumped from the ground; surface water diverted from rivers, streams, or lakes; and water purchased from other utilities. Each source requires a different means of conveyance and different amount of energy use. Additional energy is required to treat the water. Each source has different contaminant characteristics, necessitating different treatment processes that consume different amounts of energy. Turbidity (a measure of suspended particles), for example, tends to be higher in surface water than in ground water. Table B-3 lists the characteristics of the water sources used by utilities in each of the four categories related to source water flow.

Table B-3 Characteristics of Source Waters

Characteristic	Units	Measure of Characteristic (by MGD)—Weighted Average				
		Total	**0–2**	**3–4**	**5–19**	**20–599**
Number of ground water sources	Number	23.4	6.8	10.1	11.5	28.2
Average ground water flow	MGD	17.5	1.8	3.5	7.2	21.0
Design ground water flow	MGD	31.5	3.3	7.9	11.5	38.3

Characteristic	Units	Measure of Characteristic (by MGD)—Weighted Average				
		Total	0–2	3–4	5–19	20–599
Maximum ground water flow	MGD	39.4	5.9	11.5	15.1	50.1
Number of surface water sources	Number	2.2	2.6	2.2	2.2	2.2
Average surface water flow	MGD	186.0	2.3	3.6	10.1	210.7
Design surface water flow	MGD	263.1	3.6	6.1	18.5	298.2
Maximum surface water flow	MGD	523.5	5.4	10.9	27.7	609.1
Number of purchased sources	Number	1.7	1.0	1.0	1.8	1.7
Average purchased water flow	MGD	67.9	1.5	4.0	8.5	76.7
Average well depth	Feet	515.2	549.8	344.0	610.9	492.7
Total pumping horsepower	Hp	6,847.0	383.2	750.4	1,650.3	7,896.3
Total number of pumps	Number	16.0	5.5	8.5	11.1	17.1
Average ground water turbidity	NTU*	1.3	0.3	2.8	0.5	1.5
Peak ground water turbidity	NTU	6.1	0.9	46.3	1.7	5.7
Average surface water turbidity	NTU	7.8	10.5	23.1	9.4	7.3

* NTU = nephelometric turbidity units.

B-4a Source Water Contaminants

AwwaRF survey respondents reported whether they test for various contaminants in their source water and, if so, whether they treat the water for each contaminant. Table B-4 shows the percentages of utilities that measure various contaminants and report treating those contaminants. Almost all utilities that responded to the AwwaRF survey disinfect their source water. As expected, given that the 20–599 MGD group processes the highest average volume of surface water, that group also reports the most frequent measurement and treatment of particulates and turbidity.

Table B-4 Percent of Utilities that Treat Source Water Contaminants

Contaminant Treatment	Percent of Utilities (by MGD) that Treat Each Contaminant (%)				
	Total	0–2	3–4	5–19	20–599
Algae control	23.4	20.0	22.7	16.0	37.1
Disinfection	94.2	100.0	90.9	92.0	94.3
Oxidation	35.0	30.0	31.8	38.0	37.1

Contaminant Treatment	Percent of Utilities (by MGD) that Treat Each Contaminant (%)				
	Total	0–2	3–4	5–19	20–599
Iron removal	30.7	30.0	31.8	34.0	25.7
Manganese removal	31.4	26.7	36.4	34.0	28.6
Taste and odor control	52.6	53.3	40.9	46.0	68.6
Total organic carbon removal	42.3	33.3	36.4	42.0	54.3
Particulate/turbidity removal	62.0	43.3	63.6	64.0	74.3
Softening	13.1	13.3	13.6	16.0	8.6
Recarbonation	10.9	10.0	9.1	14.0	8.6
Organic compound removal	28.5	23.3	27.3	30.0	31.4
Inorganic compound removal	21.9	16.7	18.2	24.0	25.7
Radon treatment	10.9	10.0	22.7	14.0	0.0

B-4b Processes Used to Treat Source Water Contaminants

As shown in Table B-5, flocculation was the most-used treatment process of the utilities that responded to the AwwaRF survey. Flocculation was used most often by utilities in every category of source water: 57.7 percent of the entire data set and, for example, 68.6 percent of the 20–599 MGD group. All utility groups also employ rapid-rate filtration and gravity clarification.

Table B-5 Percent of Utilities That Use Source Water Treatments

Type of Treatment	Percent of Utilities (by MGD) That Use Each Treatment (%)				
	Total	0–2	3–4	5–19	20–599
Aeration	17.5	30.0	18.2	18.0	5.7
Ultraviolet	0.7	0.0	4.5	0.0	0.0
Ozone	8.8	0.0	4.5	12.0	14.3
Upflow clarification	16.8	20.0	27.3	12.0	14.3
Gravity clarification	40.1	30.0	36.4	40.0	51.4
Dissolved air floatation clarification	0.7	0.0	0.0	0.0	2.9
Flocculation	57.7	43.3	63.6	56.0	68.6
Direct filtration	19.0	10.0	27.3	24.0	14.3
Slow sand filtration	5.1	3.3	4.5	6.0	5.7
Dual-stage filtration	24.8	13.3	18.2	26.0	37.1
Rapid-rate filtration	33.6	30.0	27.3	28.0	48.6
Diatomaceous earth filtration	2.2	3.3	4.5	0.0	2.9
Pressure filtration	8.0	6.7	18.2	8.0	2.9

Type of Treatment	Percent of Utilities (by MGD) That Use Each Treatment (%) Total	0–2	3–4	5–19	20–599
Reverse osmosis membrane	2.2	0.0	0.0	2.0	5.7
Microfiltration membrane	1.5	0.0	9.1	0.0	0.0
Ultrafiltration membrane	0.0	0.0	0.0	0.0	0.0
Nanofiltration membrane	1.5	0.0	4.5	0.0	2.9

B-4c Processes Used to Treat Residual Source Water Contaminants

Almost one-third of the water utilities that responded to the AwwaRF survey do not remove water from residual contaminants to reduce the total volume. Two-thirds, therefore, employ one or more residual treatment methods. Table B-6 lists the treatment methods and the percentage of utilities that report using each. As expected, the weight of residual contaminants increases as total average flow increases.

Table B-6 Percent of Utilities That Treat for Residual Contaminants

Type of Treatment	Percent of Utilities (by MGD) That Use Each Treatment (%) Total	0–2	3–4	5–19	20–599
None	27.7	36.7	9.1	20.0	42.9
Gravity thickening	14.6	10.0	9.1	16.0	20.0
Mechanical dewatering	5.1	0.0	0.0	8.0	8.6
Centrifuge	1.5	0.0	0.0	0.0	5.7
Residual pressure filtration	2.9	3.3	9.1	0.0	2.9
Vacuum filtration	0.0	0.0	0.0	0.0	0.0
Belt press	4.4	0.0	0.0	6.0	8.6
Plate and frame press	4.4	3.3	0.0	2.0	11.4
Non-mechanical dewatering	10.2	6.7	13.6	12.0	8.6
Lagoon dewatering/thickening	25.5	23.3	31.8	26.0	22.9
Sand drying bed	9.5	16.7	4.5	8.0	8.6
Freezing and thawing	2.9	3.3	4.5	2.0	2.9
Total average residuals (pounds per day)	1,105,212	18,551	26,542	71,252	1,331,771

B-5 Distribution Characteristics

Utilities use both gravity and pumping to distribute treated water from the plant to the point of use. Table B-7 summarizes the distribution features for each group of utilities. Energy use for each utility depends on the combined effects of all features discussed herein.

Table B-7 Characteristics of Water Distribution Systems

Characteristic	Units	Measure of Characteristic—Weighted Average (by MGD)				
		Total	**0–2**	**3–4**	**5–19**	**20–599**
Size of service area	Square miles	283.5	26.5	34.8	68.6	331.5
Length of water mains	Miles	2276.1	126.4	137.9	345.8	2,705.3
Highest elevation	Feet	1,174.3	1,182.4	1,327.5	1,364.9	1,139.7
Lowest elevation	Feet	729.1	949.8	1,009.4	1,020.1	674.6
Pumping horsepower	hp	11,890.1	405.5	591.3	2,259.2	14,235.9
Number of distribution pumps	Number	40.4	5.3	6.2	15.4	46.2
Total storage volume	MG	4,884.1	81.6	7.0	20.6	5,937.5
Average distribution pressure	psi	64.0	67.3	68.9	71.6	62.5
Number of distribution zones	Number	20.7	3.0	3.8	5.9	23.9
Unaccounted-for treated water	%	9.4	17.0	11.8	9.0	9.3

B-6 Electricity Use

Table B-8 summarizes consumption and cost of electricity required to obtain (produce), treat, and distribute source water. In general, utilities use more electricity for distribution (48 million kWh) than for production (28 million kWh) or treatment (16 million kWh). The largest (20–599 MGD) utilities also consume the most electricity for distribution. For the utilities that handle 3–4 MGD and 5–19 MGD, however, the greatest electricity use is associated with production.

Table B-8 Electricity Use for Water Production, Treatment, and Distribution

Use	Units	Source Water (by MGD)—Weighted Average				
		Total	**0–2**	**3–4**	**5–19**	**20–599**
Production electricity use	kWh	28,255,894	860,423	1,156,003	6,806,462	31,591,377
Peak production electricity use	kW	2,186,828	26,464	174,384	175,111	2,434,298
Production electricity cost	2004$	1,388,792	58,792	105,752	505,753	1,531,155
Treatment electricity use	kWh	16,523,182	944,705	1,144,364	2,298,348	20,250,067
Peak treatment electricity use	kW	19,192	89,812	86,386	25,299	11,856

Use	Units	Source Water (by MGD)—Weighted Average				
		Total	**0–2**	**3–4**	**5–19**	**20–599**
Treatment electricity cost	2004$	1,247,022	57,796	114,641	161,966	1,529,475
Distribution electricity use	kWh	48,711,102	397,029	718,371	1,718,969	56,250,468
Peak Distribution electricity use	kW	954,355	35,321	150,869	99,915	1,077,817
Distribution electricity cost	2004$	2,869,735	29,543	67,496	157,971	3,329,525
Total electricity use	kWh	71,206,945	1,555,044	2,097,419	6,501,010	85,467,356
Total Peak electricity	kW	5,915,104	81,795	577,891	279,688	7,233,725
Total electricity cost	2004$	4,133,334	103,912	194,032	484,055	4,907,305

Appendix C: Basic Energy Efficiency Actions for Plant Personnel

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

- Switch off motors, fans, and machines when not in use, especially at the end of the working day or shift and during breaks, when there is no effect on 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 conditioned buildings.
- Report leaks of water (both process water and dripping taps), steam, and compressed air. The best time to check for leaks is a quiet time such as a weekend.
- Notice whether unoccupied areas that are 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. Windows and doors may be left open to lower temperatures, for instance, instead of lowering the heating set point.
- Check to make sure the pressure and temperature of equipment is not set too high.
- Prevent drafts from badly fitting seals, windows, and doors, which allow leakage of cool or warm air.
- Carry out regular maintenance of energy-consuming equipment.
- Ensure that the insulation on process heating equipment is effective.

Appendix D: Assessing Energy Management Systems for Best Practices[§]

ENERGY STAR® Facility Energy Management Assessment Matrix

Facility 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.		

§ http://www.energystar.gov/index.cfm?c=guidelines.guidelines_index

Facility Name:		Assessment Date:			
	Little or no evidence	**Some elements/degree**	**Fully implemented**		**Next Steps**
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/recommissioning/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.		

Facility Name:		Assessment Date:			
	Little or no evidence	**Some elements/degree**	**Fully implemented**		**Next Steps**
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/corporate/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.		

Facility Name:		Assessment Date:			
	Little or no evidence	**Some elements/degree**	**Fully implemented**		**Next Steps**
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.		

Facility Name:		Assessment Date:			
	Little or no evidence	**Some elements/degree**	**Fully implemented**		**Next Steps**
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 E: Energy Management Assessment Matrix

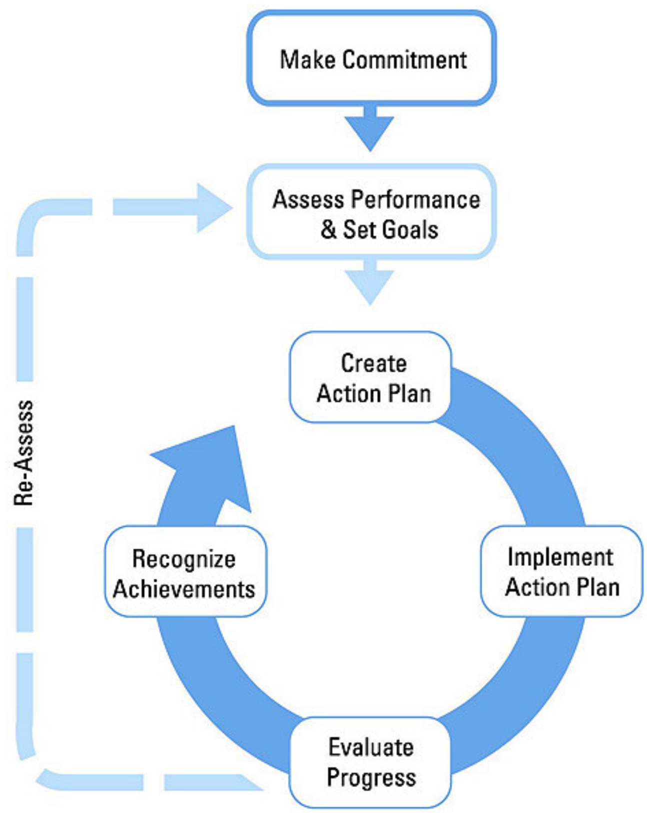
This tool is available online at:
http://www.energystar.gov/index.cfm?c=guidelines.guidelines_index under the heading, *Need help getting started?*

CHANGE FOR THE BETTER WITH ENERGY STAR

Energy Management Assessment Matrix

Introduction
The US 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.



This assessment matrix is designed to help organizations and energy managers compare their energy management practices to those outlined in the guidelines. The full guidelines can be viewed on the ENERGY STAR web site - www.energystar.gov.

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

- No evidence
- Most elements
- Fully Implemented

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.

Energy Management Assessment Matrix				
	Little or no evidence	**Some elements**	**Fully implemented**	**Next Steps**
Make Commitment to Continuous Improvement				
Energy Director	No central corporate resource; decentralized management	Corporate or organizational resource not empowered	Empowered corporate leader with senior management support	
Energy Team	No company energy network	Informal organization	Active cross-functional team guiding energy program	
Energy Policy	No formal policy	Referenced in environmental or other policies	Formal stand-alone EE policy endorsed by senior mgmt.	
Assess Performance and Opportunities				
Gather and Track Data	Little metering/no tracking	Local or partial metering/tracking/reporting	All facilities report for central consolidation/analysis	
Normalize	Not addressed	Some unit measures or weather adjustments	All meaningful adjustments for corporate analysis	
Establish baselines	No baselines	Established for various facilities	Standardized corporate base year and metric established	
Benchmark	Not addressed or only same site historical comparisons	Some internal comparisons among company sites	Regular internal & external comparisons & analyses	
Analyze	Not addressed	Some attempt to identify and correct spikes	Profiles identifying trends, peaks, valleys & causes	
Technical assessments and audits	Not addressed	Internal facility reviews	Reviews by multi-functional team of professionals	
Set Performance Goals				
Determine scope	No quantifiable goals	Short-term facility goals or nominal corporate goals	Short- & long-term facility and corporate goals	
Estimate potential for improvement	No process in place	Specific projects based on limited vendor projections	Facility & corporate defined based on experience	
Establish goals	Not addressed	Loosely defined or sporadically applied	Specific & quantifiable at various organizational levels	
Create Action Plan				
Define technical steps and targets	Not addressed	Facility-level consideration as opportunities occur	Detailed multi-level targets with timelines to close gaps	
Determine roles and resources	Not addressed or done on ad hoc basis	Informal interested person competes for funding	Internal/external roles defined & funding identified	

	Little or no evidence	Some elements	Fully implemented	Next Steps
Implement Action Plan				
Create a communication plan	Not addressed	Tools targeted for some groups used occasionally	All stakeholders are addressed on regular basis	
Raise awareness	No promotion of energy efficiency	Periodic references to energy initiatives	All levels of organization support energy goals	
Build capacity	Indirect training only	Some training for key individuals	Broad training/certification in technology & best practices	
Motivate	No or occasional contact with energy users and staff	Threats for non-performance or periodic reminders	Recognition, financial & performance incentives	
Track and monitor	No system for monitoring progress	Annual reviews by facilities	Regular reviews & updates of centralized system	
Evaluate Progress				
Measure results	No reviews	Historical comparisons	Compare usage & costs vs. goals, plans, competitors	
Review action plan	No reviews	Informal check on progress	Revise plan based on results, feedback & business factors	
Recognize Achievements				
Provide internal recognition	Not addressed	Identify successful projects	Acknowledge contributions of individuals, teams, facilities	
Get external recognition	Not sought	Incidental or vendor acknowledgement	Government/third party highlighting achievements	

Alliance to Save Energy (2002; *Watergy*) provides a similar matrix for efficiency management for energy and water. Their program has three levels: ad hoc, single manager, and team. Details for their system and some actual problems encountered in real water treatment facilities that were not implementing the team approach can be found in Alliance to Save Energy (2002).

Interpreting Your Results
Comparing your program to the level of implementation identified in the Matrix should help you identify the strengths and weaknesses of your program.

The US EPA has observed that organizations fully implementing the practices outlined in the Guidelines achieve the greatest results. Organizations are encouraged to implement the Guidelines as fully as possible.

By highlighting the cells of the matrix, you now can easily tell how well balanced your energy program is across the management elements of the Guidelines. Use this illustration of your energy management program for discussion with staff and management.

Use the "Next Steps" column of the Matrix to develop a plan of action for improving your energy management practices.

Resources and Help
ENERGY STAR offers a variety tools and resources to help organizations strengthen their energy management programs.

Here are some next steps you can take with ENERGY STAR:

1. Read the Guidelines sections for the areas of your program that are not fully implemented.

2. Become an ENERGY STAR Partner, if you are not already.

3. Review ENERGY STAR Tools and Resources.

4. Find more sector-specific energy management information at www.energystar.gov.

5. Contact ENERGY STAR for additional resources.

Appendix F: Teaming Up to Save Energy Checklist

The following checklist can serve 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* (U.S. EPA, 2005), which is available at: http://www.energystar.gov/index.cfm?c=guidelines.teaming_up_to_save_energy.

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.	

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 municipality 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 organization. Energy performance information is published in internal 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.	

Appendix G: Support Programs for Improving Industrial Energy Efficiency

The following is a partial list of sources of support for making energy efficiency improvements. A brief description of the program or tool is given, as well as information on its target audience and the URL for the program. Use the link to obtain more information from each source.

Tools for Performing Assessments

AirMaster+: Compressed Air System Assessment and Analysis Software

Description:	Modelling 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, Office of Industrial Technologies
URL:	http://www1.eere.energy.gov/industry/bestpractices/software_airmaster.html.

ASDMaster: Adjustable Speed Drive Evaluation Methodology and Application

Description:	Software program that helps to (1) determine the economic feasibility of an adjustable speed drive application, (2) predict how much electrical energy may be saved by using an ASD, and (3) search a database of standard drives.
Target Group:	Any industry
Format:	Software package (not free)
Contact:	EPRI at (800) 832-7322
URL:	http://www.epri-peac.com/products/asdmaster/asdmaster.html.

Combined Heat and Power Application Tool

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_chp.html.

ENERGY STAR for Wastewater Plants and Drinking Water Systems

Description:	Provides links to the ENERGY STAR Challenge; ENERGY STAR Partners; and Portfolio Manager, ENERGY STAR's online software tool for measuring and assessing a facility's energy performance.
Target Group:	Managers and owners of drinking water and wastewater facilities
Format:	Online resource with links to support and software
Contact:	U.S. Environmental Protection Agency
URL:	http://www.energystar.gov/index.cfm?c=water.wastewater_drinking_water.

Fan System Assessment Tool

Description:	The Fan System Assessment Tool (FSAT) helps 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, Industry Technologies Program

URL: http://www1.eere.energy.gov/industry/bestpractices/software_fsat.html

MotorMaster+

Description: This toolkit contains tools for managing a motor inventory, a log for tracking maintenance, efficiency analyses, a savings evaluation, energy accounting, and environmental reporting.
Target Group: Any industry
Format: Downloadable software (can also be ordered on CD)
Contact: U.S. Department of Energy, Office of Industrial Technologies
URL: http://www1.eere.energy.gov/industry/bestpractices/software_motormaster.html.

Pump System Assessment Tool

Description: The Pump System Assessment Tool (PSAT) 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 cost savings.
Target Group: Any industrial pump user
Format: Downloadable software
Contact: U.S. Department of Energy, Office of Industrial Technologies
URL: http://www1.eere.energy.gov/industry/bestpractices/software_psat.html.

Steam System Assessment Tool

Description: This software package helps the user evaluate energy efficiency improvement projects for steam systems. It includes the capability to perform an economic analysis.
Target Group: Any industry operating a steam system
Format: Downloadable software package (13.6 MB)
Contact: U.S. Department of Energy, Office of Industrial Technologies
URL: http://www1.eere.energy.gov/industry/bestpractices/software_ssat.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, Office of Industrial Technologies
URL: http://www1.eere.energy.gov/industry/bestpractices/software_ssat.html.

Technical Assistance

ENERGY STAR – Technical Assistance and Support

Description: For further information and assistance with becoming an ENERGY STAR Partner, joining the ENERGY STAR Challenge, or using the Portfolio Manager software.
Target Group: Any manager, operator, or owner of a drinking water or wastewater treatment facility
Format: Email
Contact: U.S. Environmental Protection Agency/ENERGY STAR Program
Email: buildings@energystar.gov

Save Energy Now Assessments

Description: The U.S. DOE conducts plant energy assessments to help industrial plants across the Nation identify immediate opportunities to save energy and money. The assessments focus primarily on energy-intensive systems, including process heating, steam, pumps, fans, and compressed air.

Target Group: Large plants can receive a three-day assessment; small and medium-sized plants a one-day assessment

Format: Online request

Contact: U.S. Department of Energy

URL: http://www1.eere.energy.gov/industry/saveenergynow/assessments.html

Training

Best Practices Program

Description: The Best Practices Program of DOE's Industrial Technologies Program provides training and training materials to support efforts to improve the efficiency of equipment and systems such as compressed air, pumps, fans, and motors. Training sessions are offered regularly throughout the country. The Best Practices program also provides training on other industrial energy equipment, often in coordination with conferences. The website also contains links to various tools and materials.

Target Group: Technical support staff, energy and plant managers

Format: Training workshops (one day and multi-day workshops on various topics)

Contact: U.S. Department of Energy, Office of Industrial Technologies

URL: http://www1.eere.energy.gov/industry/bestpractices/

ENERGY STAR

Description: As part of ENERGY STAR's work to promote superior energy management systems, energy managers for companies that participate as ENERGY STAR Partners can network with other energy managers in the partnership. Networking meetings, which are held monthly, 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: U.S. Environmental Protection Agency, Climate Protection Partnerships Division

URL: http://www.energystar.gov/index.cfm?c=business.bus_index.

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 ½ days plus an exam). Training supports 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/