New York State Energy Research & Development Authority

Water & Wastewater Energy Management

Best Practices Handbook

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Energy. Innovation. Solutions.

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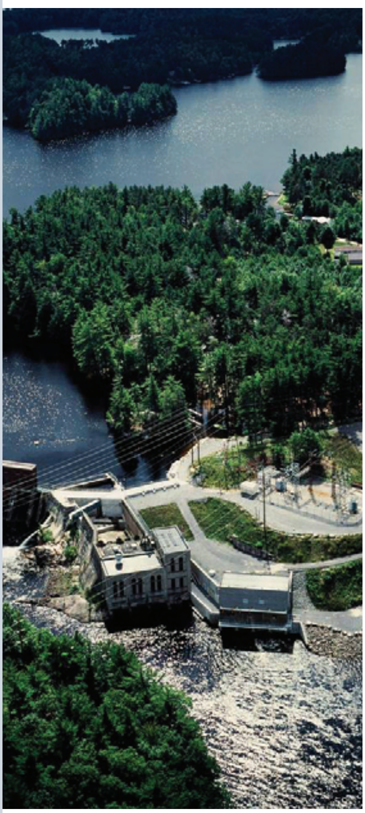
1. INTRODUCTION

The New York State Energy Research & Development Authority (NYSERDA) is a public benefit corporation that was created in 1975. In its current form, NYSERDA is primarily funded through the System Benefits Charge (SBC) established on May 20, 1996. The stated mission of NYSERDA is to:

- Use innovation and technology to solve some of New York's most difficult energy and environmental problems in ways that improve the State's economy.
- Place a premium on objective analysis, as well as collaboration; reaching out to solicit multiple perspectives and share information.
- Be committed to public service, striving to be a model of what taxpayers want their government to be: effective, flexible, responsive, and efficient.

With this charge, NYSERDA has identified the municipal water and wastewater sectors as a target to strategically reduce energy consumption in New York.

1.1 Background



The primary goal of the water and wastewater sectors has been to meet regulatory requirements for the protection of human health and the environment. The sectors have focused on maintaining compliance with discharge requirements regulated by the New York State Department of Environmental Conservation (NYS DEC) through the New York State Pollutant Discharge Elimination System (NY SPDES) program, or water supply requirements as established by the New York State Department of Health (NYS DOH) and several county health departments. Historically, to ensure achievement of this primary objective, many facilities within the water and wastewater sectors were not designed or operated with a goal of reducing or minimizing energy use.

A secondary goal of the water and wastewater sectors is to provide its services for reasonable and fair user fees or rates. These fees are typically developed based on the debt service for capital improvements, operating expenses (labor, energy, chemical, etc.), and reserve accounts. Many water and wastewater utilities treat energy costs simply as a cost of doing business, without significant effort to effectively mitigate cost increases. As a result, capital reserves are often depleted to offset rising operating expenses in an effort to maintain stable user fees. Funding operations in this manner leaves the utility vulnerable to unforeseen capital expenditures and may result in inadequate investment in the upkeep, maintenance and upgrade of process equipment and facilities; or may cause utilities to base all equipment purchases solely on initial capital cost, rather than considering the life-cycle cost of owning and operating the equipment.

1. Introduction

1.2 Description of New York's Water and Wastewater Sectors

In New York, municipal water and wastewater utilities provide services to nearly 95 percent of the state's population. The municipal wastewater sector includes 702 wastewater treatment plants (WWTPs) with a combined design treatment capacity of 3.7 billion gallons per day (NYS DEC, 2004). The drinking water sector includes nearly 2,900 community water supply systems that produce an estimated 3.1 billion gallons of drinking water per day (NYS DOH). Additionally, there are roughly 7,000 non-community public water supply systems within the state (NYS DOH).

NYSERDA conducted a statewide assessment of the New York water and wastewater sectors in 2007. Based on this study, it was estimated that energy use for the water and wastewater sectors is 2.5 to 3.0 billion kilowatt-hours per year, with roughly two-thirds of the electricity being consumed by the wastewater sector (1.75 to 2.0 billion kilowatt hours). The number of treatment plants within each size category and the relative percentage of the statewide treatment capacity and statewide energy use are shown in Table 1 and Table 2.

Table 1. Wastewater Treatment Sector in New York

Design Capacity	Number of WWTPs[1]	Percent of Statewide Design Capacity[1]	Percent of Statewide Wastewater Energy Use[2]
Less than 1 MGD	520	3.8	10.3 (11.0)
1 to 5 MGD	106	7.5	8.3 (8.5)
5 to 20 MGD	43	13.1	14.2 (14.0)
20 to 75 MGD	19	23.8	27.1 (26.8)
Greater than 75 MGD	14	51.8	40.1 (39.7)

[1] Source: NYS DEC 2004 Descriptive Data.

[2] Values shown in parenthesis include collection system usage.

Table 2. Drinking Water Sector in New York State

Population Served	Number of Systems[1]	Percent of Statewide Population Served[1]	Percent of Statewide Water Energy Use[2]
Less than 3,300	2,525	3.8	12.2 (13.1)
3,300 to 50,000	293	21.6	61.1 (70.2)
50,000 to 100,000	11	4.7	11.1 (7.2)
Greater than 100,000	20	69.8	15.6 (9.5)

[1] Source: USEPA Safe Drinking Water Information System.

[2] Values shown in parentheses include estimated distribution system usage.

1.3 Purpose

The water and wastewater sectors' primary objectives remain unchanged – meeting regulatory requirements and protecting public health. Nevertheless, with rising energy costs, a greater financial burden being placed on local governments, and a public sentiment toward sustainability; improving energy efficiency and energy management at WWTPs and WTPs (two of the larger energy users under the control of a typical municipality) are paramount.

Energy efficiency and the protection of public health and the environment are not mutually exclusive. Often, energy conservation programs not only reduce the amount of energy used at a facility, but also provide improved control and operation of unit treatment processes – satisfying both of the water and wastewater sectors' primary and secondary objectives.

The purpose of this Water & Wastewater Energy Management Best Practices Handbook is to provide the water and wastewater sectors with guidance on the development of an energy conservation program, implementation of capital and operational improvements to reduce energy consumption, and methods to track performance and assess program effectiveness.

2. Energy Management Program Development

2.1 Understanding Energy Management Goals

Energy management planning involves more than reducing energy consumption and improving energy efficiency. Most water and wastewater utilities need to evaluate a broad range of energy management goals, including:

- Improving energy efficiency & managing total energy consumption
- Controlling peak demand for energy
- Managing energy cost volatility
- Improving energy reliability

Water and wastewater utilities are tasked with the mission of minimizing the costs associated with protecting water resources while maintaining a high degree of reliability. The goals listed above consider both the costs associated with energy and reliability of energy over time. A good energy management plan needs to balance these goals to avoid unanticipated costs, and still exploit all of the available energy savings opportunities.

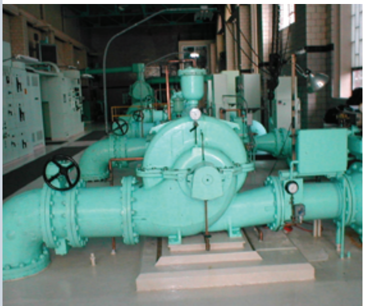
The goals of an energy management program can often overlap with other utility best management practices. For example, an effective preventive maintenance program can improve motor efficiency and will also improve system reliability. Similarly, improvements to the overall efficiency of water and wastewater treatment will improve energy performance as measured by energy benchmarks, such as gallons of water sold or treated per kilowatt-hour of electricity consumed. This effect can be seen resulting from improvements such as leak detection and repairs to the water distribution system, or reducing infiltration and inflow to wastewater collection systems.

Implementation of energy management practices can also have ancillary effects, such as an improvement in staff communications, morale, and understanding of the treatment process. These overlapping, and sometimes ancillary goals of energy management should also be considered when evaluating prospective energy management opportunities.

2.1.1 Improving Energy Efficiency and Managing Total Energy Consumption

Water and wastewater treatment is intrinsically energy intensive due mainly to the need to move large volumes of water, using pumps and electric motors. The cost of the electricity used in the treatment process is based on two main components, the quantity of electricity used and the demand for electricity.

The quantity of electricity is measured in kilowatt-hours (kWh), and reflects the amount of physical “work” that can be performed by the



electricity. Electric utility rates typically include an energy consumption charge that is based on the number of kWh consumed per billing cycle, and often the charge is further subdivided by "on-peak" versus "off-peak" consumption, where on-peak rates are higher than off-peak rates. Understanding the electric utility's pricing policies or "rate structures" is critically important to planning energy management programs. A detailed discussion of electric utility rates, bills, and kWh is provided in Appendix A.

One goal of reducing energy costs is to reduce the total number of kWh required to treat a given volume of water or wastewater. The amount of energy used by a utility for water and/or wastewater treatment is a function of various factors, including: topography of the service area, system size, treatment process, type and condition of equipment, and O&M practices. Still, no treatment system operates at one hundred percent efficiency, and consequently opportunities exist to improve energy efficiency and reduce the total consumption of kWh.

An example of an energy conservation measure that focuses on improving energy efficiency would be more closely matching pump and motor size to demand. Treatment plants often have excess pumping capacity due to factors such as exaggerated growth expectations, decrease in local population, or improvements in conservation. If pumps are not operated at the optimal efficiency point they consume more energy than is needed for a given situation. This situation is expected over some short term periods, but if pumps routinely operate outside of their design point for efficiency, then a new pumping solution may be warranted.

2.1.2 Controlling Peak Demand for Energy

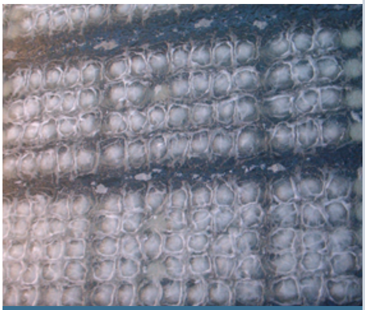
Electric utilities typically include a 'demand charge' in their rate structure that can account for anywhere from 30 – 60% of the overall cost of electricity. The demand charge is based on the customer's maximum demand for electricity (kW) measured during a billing period, and allows the electric utility to recover the capacity costs required to meet each customer's maximum energy needs.

From the electric utility's perspective, a high degree of variability in customer demand is the most difficult situation to anticipate, and requires a large investment in capital. Consequently, electric utilities will reward customers that can demonstrate a low variability in electric demand over time, or 'flattened' demand curve. This includes two separate but related goals:

- Minimizing changes in peak demand throughout the course of a billing period
- Shifting loads from peak periods, typically during daylight hours, to 'off-peak' periods

2. Energy Management Program Development

Water and wastewater utilities can realize significant savings in electric costs by minimizing demand charges. Sometimes this can be done indirectly by reducing the variability in demand placed on their own systems, through measures such as addressing infiltration and inflow, or providing supplemental water storage tanks to flatten pumping demands during peak periods. Other strategies focus on shifting loads to off-peak periods, or flattening demand by minimizing the overlap between treatment processes.



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2.1.3 Managing Energy Cost Volatility

The price of energy, including electricity, natural gas, and fuel, can vary significantly from day-to-day, or year-to-year. Water and wastewater utility revenues are less variable by nature, and therefore dramatic changes in energy costs can severely stress utility budgets and disrupt other programs. From a utility management perspective, protecting against volatility in costs is an important goal that should not be overlooked or undervalued in the energy planning process. Water and wastewater utilities have a variety of strategies available to protect against volatile energy prices. Examples include the long-term procurement of energy, and provisions for alternative energy sources and/or on-site generation of energy.

2.1.4 Improving Energy Reliability

As many local and system-wide power outages have proven in the past, energy, like money, water, or air, becomes noticeably important when it is unavailable. Good design practices, as well as state statutes, require water and wastewater utilities to provide critical systems with adequate backup power. The energy planning process should also identify opportunities to improve energy reliability whenever possible.

Reliability improvements can include protection against complete loss of power, as well as identifying changes in power quality (e.g. under voltage, power harmonics, or power surges) that can damage equipment, or instituting operating procedures to address changes in power availability. On-site power systems provide an obvious opportunity to improve reliability.

In recent years, the New York Independent System Operator (NYISO), the organization responsible for coordinating electrical demand throughout the state, has also offered various opportunities for large customers of power to participate in demand management programs. Customers are generally required to have generators rated 100 kW or higher, or to be capable of reducing at least 100 kW of load. These programs are designed to improve regional power reliability, while offering participating customers a revenue source in exchange for curtailing their energy use during high demand periods.

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2.2 Basic Steps Involved in Building an Energy Program

The following section outlines a seven-step approach to developing an effective energy management program. The seven steps are as follows:

Step 1. Establish Organizational Commitment
Step 2. Develop a Baseline of Energy Use
Step 3. Evaluate the System and Collect Data
Step 4. Identify Energy Efficiency Opportunities
Step 5. Prioritize Opportunities for Implementation
Step 6. Develop an Implementation Plan
Step 7. Provide for Progress Tracking and Reporting

The primary goal of this approach is to ensure that energy-related decisions are well thought out, and all stakeholders involved understand the reasoning behind any proposed changes.

Three common elements run throughout the approach, and each element contributes to reducing the amount of resistance to positive changes:

- A diverse project team
- Good information
- Understanding of "trade-offs"

Step one of the approach focuses on building a diverse project team that is committed to supporting the energy management process. Energy use cuts across many organizational boundaries, so it is important to have a diverse team to understand the wide variety of issues and needs associated with energy use. The specific level of effort required from different team members may vary throughout the process, but it is essential to maintain commitment.

Steps two through four focus on gathering information and building a strong understanding of existing energy use and costs. While step seven, the final step, reinforces the process by updating that information and reporting on results. The two main reasons that information is so valuable in the energy management process are:

- Energy use information is needed to weigh the costs and benefits of energy related decisions, and to evaluate the success of new programs
- Energy utilities value information because it allows them to efficiently allocate resources, and customers with a strong understanding of their energy use can often negotiate favorable energy rates

The final element, understanding "trade-offs", is particularly important in steps five and six when energy conservation measures are identified and evaluated. Most options for changing energy use involve some commitment of resources, typically a capital investment or a modification to standard operating procedures. These trade-offs can involve difficult decisions, which underscores the importance of the first two elements. Specifically, a diverse energy management team can evaluate trade-offs from a variety of perspectives so that people with different responsibilities can ensure that none of the utility's primary goals are compromised by proposed changes. Good quality energy use information also allows the team to evaluate trade-offs and explain the decision making process.

Each of the seven steps is described in more detail below.

2.2.1 Step 1: Establish Organizational Commitment

Energy use at a water or wastewater utility typically involves decision making responsibility from multiple departments, including operations, engineering, and business management. The first step in building an energy management program should be to assemble an energy management team that can bridge the gaps among decision makers, and represent the various interests and responsibilities found within a utility.

A strong team, backed by a commitment from utility management, will help to resolve many of the organizational barriers to improving energy use. For example, in some utilities the operations staff is never involved in evaluating energy procurement decisions, and may never see energy invoices. In this example, a cross-functional energy management team would help to improve the communications between the business group and the operations staff, so that energy use and energy procurement can have a logical connection. An example of an energy management team would include an elected official, such as the Town Engineer or the Mayor, a manager at the treatment plant, an operator, and a member of the financing department. In addition, for cases where changes to energy management practices will result in facility design changes, the appropriate regulatory agency (either NYS DOH or NYS DEC) would have to be involved.

The size of the energy management team should mirror the complexity and size of the utility. The team should be large enough to represent different perspectives on energy use, but should not be so large that decision making becomes cumbersome. The specific responsibilities of the energy management team should include:

- **Develop a Strategic Energy Management Plan.** This plan should establish the overall mission, and document the organization's commitment to energy management.
- **Establish performance goals, metrics, and incentives.** This includes establishing a communications plan to identify how information should be shared, and setting a schedule of milestones and deadlines.
- **Define resource needs.** Utility management should demonstrate a commitment to the program by allocating resources to achieve the stated goals. The team will be responsible for identifying resource needs such as staff time, equipment, and external consulting support. Resource requests should be balanced with preliminary expectations for energy savings.
- **Serve as an energy information clearinghouse.** The team should be a utilitywide resource to provide information about energy use and coordinate communications regarding any projects that affect energy use. For example, recommendations from the energy management team should be coordinated with the capital improvement planning process.

Keys to success:

- Management must participate in the energy management team.
- The energy management team should be cross-functional.
- Resources need to be allocated to the project, with a balanced commitment based on an initial estimate of energy savings.
- "Feedback loops" need to be established so that energy performance goals and key performance indicators are shared within the utility.

2.2.2 Step 2: Develop a Baseline of Energy Use

At a minimum, improving a specific utility's understanding of where, why, and when energy is used should be one of the main goals for the energy management program. Some studies have demonstrated that even the process of investigating energy use, and improving awareness among staff, can provide measurable energy efficiency gains on the order of 3-5%. This step should focus on gathering readily available energy use information, and organizing that information into a basic 'model' that can help to understand energy use patterns and communicate initial findings.

Successfully developing a basic understanding of energy use can be a good 'early victory' for an energy management team, allowing the team to demonstrate some value even before any significant resources are committed to the program.

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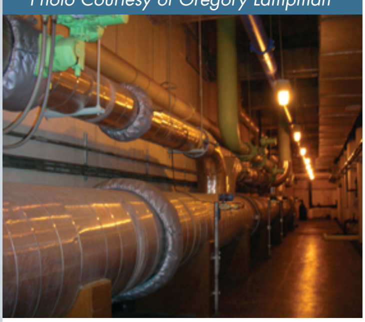

2. Energy Management Program Development

The typical goals of this step are to:

- Collect and organize equipment, energy use, and hydraulic data
- Develop an understanding of where, why, and when energy is used
- Create a baseline of energy use, and performance metrics to be used for comparison and evaluation purposes
- Understand energy bills and the rate structure that is used to set energy costs

The specific actions required to reach these goals include the following:

- **Gather basic information.** One year of data should be analyzed at a minimum to identify any seasonal patterns, but three or more years of data is ideal, so that any trends or anomalies can be identified. Data sources can include utility billing records, supervisory control and data acquisition (SCADA) system records, O&M records, and equipment/motor lists with horsepower and load information.
- **Organize treatment processes by functional area.** Identifying logical functional groups makes performance measurement and benchmarking easier, and will also facilitate planning for separating energy loads to manage demand.
- **Evaluate energy bills and understand the energy rate structure.** Many energy management strategies are directly linked to the pricing of energy, and it is critical to understand how the 'energy rate structure' impacts energy costs, as well as what other options are available. It can be helpful to reach out to the power utility or a consultant for this step.
- **Assess the connection between changes in hydraulic loading and energy use.** Hydraulic data (i.e. flow) should also be assembled to understand patterns of demand and correlations between flow and energy use. Analyze data at several time frames to identify diurnal patterns, seasonal patterns, and correlations between wet weather flows and energy demand.
- **Build a basic 'model' to organize data, and capture energy use patterns.** Typical models used in this stage of the process can be created using a generic spreadsheet, or for larger utilities it may be helpful to purchase specific software for organizing energy data. An example of a basic spreadsheet model is provided in Appendix B. The level of modeling sophistication can range from a basic motor list relating horsepower to energy demand, to a time-varying (dynamic) model that combines flow, process, and rate structure information to predict hourly demand and energy costs. The process of modeling can help to identify what types of information are most helpful, the limitations on currently available information, and what data needs to be gathered in the field. In addition, an energy use model can be a valuable tool for testing theories, validating your understanding of energy use, calculating performance metrics, and visualizing and communicating energy use patterns.
- **Create basic graphics and reports to communicate initial findings.** Although this is an early step in the process, it can produce some valuable insights that should be shared with a wider audience than the energy management team.

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Keys to success:

- **Build understanding in an iterative process.** Start small, and grow the level of complexity of your information gathering to match your goals, needs, and resources. Similarly, you should use your initial findings to organize future information gathering efforts and focus resources accordingly.
- **Link understanding of energy use with flow data, and the rate structure.**
- **Communicate early findings to a wider audience.** Use this opportunity to demonstrate some early success for the program.

2.2.3 Step 3: Evaluate the System and Collect Data

Whereas the initial baseline of energy use is developed primarily using historical records, this system evaluation step involves using data collected in the field to improve the understanding of energy use. This system evaluation step should also make a connection among utility operations, treatment processes, and energy use with the goal of identifying energy savings opportunities as well as the limitations to those opportunities. One important tool that should be used during this step is the interview of operations and maintenance staff. Interviews can help to verify your understanding of energy use, identify limitations to change, and provide helpful suggestions for energy conservation measures.

The specific actions required in this step include the following:

- **System walk-through.** Verify equipment lists, operating status, and motor sizes for major utility systems.
- **Staff interviews.** Build understanding of operating practices, maintenance practices and history, regulatory and engineering limitations, operational priorities, and collect suggestions for energy conservation opportunities.
- **Gather energy performance data.** Fill gaps in the energy model with field data, which may include direct measurements using a current meter, tracking average equipment run times of motors throughout the day, or using a more sophisticated sub-metering system to gather energy use data.
- **Benchmark energy performance.** Identify useful performance measures, and calculate energy use in comparison with utility performance data. Examples include: kWh per million gallons treated, comparison of peak demand (kW) with peak pumping rates (gpm), or energy use measures based on contaminant removal (kWh/lb of BOD removed). Performance metrics can be compared internally to historical data or engineering design criteria, or can be used for external benchmarking in comparison to similar facilities.
- **Update the energy use model.** Make any improvements and/or corrections in the energy use model using newly gathered field data and observations. This may include refining assumptions about the load or time of use for various motors.

Keys to success:

- **Use results from the energy baseline (Step 2) to prioritize field efforts on the most promising areas, typically the larger motors and energy intensive processes.** Similarly, it may only be necessary, or economical, to collect field data for the largest equipment. Approximations and assumptions are an acceptable alternative to field data for smaller systems and motors.
- **Interview a wide variety of staff.** Multiple interviews will provide different perspectives, and may help to identify any misconceptions about facility operations.

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2.2.4 Step 4: Identify Energy Efficiency Opportunities

Energy efficiency opportunities can be defined as any system change that helps to reach a stated energy management goal. At this stage the energy management team should identify a broad array of energy efficiency opportunities, with the understanding that the next step of the process will focus on identifying the 'low hanging fruit' and evaluating the most practical options. Ideas for energy efficiency opportunities can come from a variety of sources, including reference materials, success stories from similar utilities, interviews with staff, consultant recommendations, or discussions with energy providers. Categorizing energy efficiency opportunities can help to organize a large amount of information into a manageable format. For example, energy efficiency opportunities can be grouped by process area, or by the implementation approach used, such as:

- Capital program or equipment replacement
- Process change
- Operational change
- Automation or controls
- Maintenance improvements
- Business measures

The specific actions required in this step include the following:

- Research energy efficiency opportunities used at similar facilities
- Discuss energy efficiency opportunities with external resources (e.g. other utilities, NYSERDA, energy providers, or consultants)
- Categorize and list opportunities

Keys to success:

- Consider all stated energy management goals
- Include a wide array of energy efficiency opportunities, but focus efforts towards the larger systems


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2.2.5 Step 5: Prioritize Opportunities for Implementation

The final product of this step is a short list of energy efficiency opportunities that have been selected and carefully evaluated out of the list of opportunities generated in the previous step. This short list should meet the stated energy management goals of the team, be economically viable, and implementable without creating a high level of risks or conflicts.

The difficulty of prioritizing energy efficiency opportunities is evaluating the importance of different goals and risks, using one objective system. Whenever possible, the monetary value can be used as a common criterion for evaluating and prioritizing activities. It will be useful to apply some type of economic evaluation method such as the payback period or the lifecycle costs to prioritize candidate energy efficiency opportunities. A discussion and examples of these economic evaluation methods can be seen in Appendix C.

Assigning a dollar value to benefits such as reducing the risk of process failure, or improving operator safety, can be challenging. In such cases, it may be necessary to develop more specialized evaluation criteria.

The specific actions required in this step include the following:

- **Identify appropriate evaluation criteria for non monetary characteristics of energy efficiency opportunities.** Identify those costs and benefits of energy efficiency opportunities that cannot be easily quantified in monetary terms (e.g. operability, risk factors, ability to implement an energy efficiency opportunity), and define appropriate evaluation criteria for those situations.
- **Evaluate the costs and benefits of the non-monetary characteristics of energy efficiency opportunities.** Score and rank the costs and benefits, and organize the evaluation into a table or matrix to communicate results.
- **Evaluate the monetary characteristics of energy efficiency opportunities.** Choose appropriate evaluation methods, quantify costs and benefits, convert all costs into equivalent terms, and tally the results.
- **Combine non-monetary and monetary characteristics, and rank energy efficiency opportunities.**

Keys to success:

- **Convert all energy efficiency opportunities characteristics to monetary terms whenever possible.** Monetary evaluations are easy to compare and communicate.
- **Evaluate all energy management goals, including ancillary benefits whenever possible.**
- **Test the sensitivity of results to determine the impact of important assumptions.** For example, the time horizon of a project

and the economic discount rate chosen for evaluation can be very important to the overall result of an evaluation.
- **Make sure that the final results make sense in terms of the utility's overall capabilities (i.e. the list of prioritized energy efficiency opportunities should not overburden a utility's capacity to implement change)**

2.2.6 Step 6: Develop an Implementation Plan

The previous two steps helped to identify what to do. This step focuses on how to do it. The purpose of this step is similar to a business plan in that it should communicate to potential stakeholders exactly what you expect to do, what resources are needed, and what outcomes will result from the project.

The specific actions required in this step include the following:
- List the candidate energy efficiency opportunities chosen for implementation and describe the goals and objectives of the program
- Explain the resources needed, including a budget and financing plan
- Develop any specifications needed, including design criteria and procurement related documents
- Provide any changes in standard operating procedures, and/or process control strategies
- Set the schedule for implementation, including milestones and gaining the necessary regulatory approvals (if applicable)
- Set realistic expectations for the project in terms of resources required, schedule, procurement time frame, and expected results

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2.2.7 Step 7: Provide for Progress Tracking and Reporting

The success of a project should be measured as it is being implemented. Measurements should focus on providing performance metrics and the status of the schedule, as well as impacts on operations and maintenance, process performance, and staff. Performance monitoring should also be communicated to the right people, including anyone involved in the planning process, the O&M staff responsible for implementation, and utility management responsible for evaluating the project's success.

This last step is often overlooked, but critical to creating a sustainable energy management program for three main reasons:
- Progress tracking promotes adjustments to an existing program to improve its chances for success.
- Project reporting provides guidance for future decision making, and can help to refine planning assumptions.

- Communicating project results provides valuable feedback for planning and implementation staff, keeping them interested in the improvement process.

The specific actions required in this step include the following:

- **Assign the responsibility for tracking the progress of a project and reporting on that progress.** The staff responsible for progress reporting should also be allocated the resources necessary to fulfill their responsibilities.
- **Set the performance metrics that will be used.**
- **Create a communication plan.** The plan should identify who needs to be included in progress reports (examples: elected officials, public, etc.), when reports should be made, and any actions that need to occur in response to reports.

Keys to success:

- Performance metrics need to be focused so that only those benefits that can be directly attributed to a project are measured.
- Reporting should generate some follow-up activities to demonstrate a commitment to the project.

2.3 Constraints to Implementing an Energy Program

Most engineering decisions have to be made within the context of trade-offs, or counterbalancing constraints. Awareness and understanding of constraints is a requirement for good energy planning and decision making.

Typical constraints on energy improvements include the following:

- Organizational constraints
- Capital costs
- Process reliability
- Regulatory requirements and limits
- O&M capabilities, and non-energy O&M costs
- Engineering constraints
- Space availability

It should be noted that energy efficiency, while very important, should not undermine compliance with design conditions and regulatory requirements. Similarly, because of site-specific characteristics and all of the variables that influence project selection (labor, chemical costs, disposal costs, capital costs, etc.), the most efficient solution may not always be the best solution for a given application.

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3. Energy Management Best Practices

This section provides a collection of energy management best practices that are provided as a reference to develop an effective energy management program, identify "low hanging fruit", and make energy conservation, efficiency, and management a culture change. The energy management best practices are provided as technical guidance for facility personnel, engineers and/or regulators to consider energy conservation, efficiency, and management in design and operation of systems and equipment. They provide technical guidance on specific processes and equipment that are grouped into the following categories:

- **General Energy Management Best Practices**
- **Water Energy Management Best Practices**
- **Wastewater Energy Management Best Practices**
- **Building Systems Energy Management Best Practices**

General Energy Management Best Practices include design or operation practices that are applicable to equipment that is used both in Water Supply and Distribution Systems, and in Wastewater Treatment and Collection Systems. General approaches to develop an energy plan and manage electric bills are provided in this section. Most opportunities for energy efficiency improvements in both water and wastewater systems can be found in electric motors, and the use of controls to optimize operation according to variable conditions. Best practices for reducing electric use in pumps, filtration, and disinfection systems are included in this section.

Water Management Best Practices include design or operation practices that are applicable to Water Supply and Distribution systems. Regardless of whether a water system relies on a surface water supply or a ground-water supply, the majority (over 90%) of energy use is related to pumping, whether it is process pumping or backwash pumping. Opportunities for energy efficiency improvements in Water Supply and Distribution systems can be found in optimization of pump and well operations, and in reduction of the volume of water being treated and distributed.

Wastewater Energy Management Best Practices include design or operation practices that are applicable to Wastewater Treatment and Collection systems. The majority of electricity use in the wastewater sector occurs at the wastewater treatment plants (WWTPs). Nevertheless, electricity is consumed at pumping stations within the collection system as well. WWTPs with activated sludge systems typically use as much as two-thirds of their total energy consumption for aeration, that likely represents the greatest opportunity for energy savings. Other components that offer opportunities for energy efficiency improvements are the solids handling processes. One unique aspect of the wastewater sector is

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the potential for on-site electrical and thermal energy generation using anaerobic digester gas, a byproduct of the anaerobic sludge digestion process.

Building Systems Energy Management Best Practices include design or operation practices that are applicable to energy management in water and wastewater building systems. HVAC and lighting systems generally provide the highest opportunities for energy efficient improvements. The Leadership in Energy and Environmental Design (LEED) program focuses on the efficiency of building systems.

3.1 How to Use this Handbook

The Energy Management Best Practices are sequentially numbered for easier consultation and presented in a one-to-two-page format. Each Best Practice is self standing, so you can start at the beginning and work your way through until you have covered the whole facility, or search only for practices applicable to your facility. Best Practices that refer to the same process are referenced under "See Also". More information can be found in supplemental NYSERDA resources, such as the "10 Steps to Energy Efficiency", energy checklists, published articles, marketing materials highlighting NYSERDA programs, case studies, communication materials, and fact sheets.

Whether you are consulting this handbook in search of tips on how to operate your facility in a more energy efficient way, you are ready to invest some capital and are wondering about the expected energy savings and payback for a typical application, or you are designing a new facility or a single process equipment and are planning to integrate energy efficiency in the design, we hope that you find this handbook useful. Please feel free to send comments and/or suggestions for new materials and/or updates to the Energy Management Best Practices Handbook to water@nyserda.org.

Photo Courtesy of Gregory Lampman

3.2 Best Practices Summary

General Best Practices

G 1 – Facility Energy Assessment*
G 2 – Real Time Energy Monitoring*
G 3 – Energy Education for Facility Personnel*
G 4 – Comprehensive Planning Before Design*
G 5 – Design Flexibility for Today and Tomorrow*
G 6 – Electric Peak Reduction*
G 7 – Manage Electric Rate Structure*
G 8 – Idle or Turn off Equipment*
G 9 – Electric Motors: Install High Efficiency Motors*
G 10 – Electric Motors: Automate to Monitor and Control*
G 11 – Supervisory Control and Data Acquisition (SCADA)
G 12 – Electric Motors: Variable Frequency Drives Applications*
G 13 – Electric Motors: Correctly Size Motors
G 14 – Electric Motors: Properly Maintain Motors
G 15 – Electric Motors: Improve Power Factor
G 16 – Pumps: Optimize Pump System Efficiency*
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G 22 – Renewable Energy Options*

Water Best Practices

W 1 – Integrate System Demand and Power Demand*
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W 5 – Sequence Well Operation*
W 6 – Optimize Storage Capacity
W 7 – Promote Water Conservation*
W 8 – Sprinkling Reduction Program*
W 9 – Manage High Volume Users*

Wastewater Best Practices

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WW 3 – Manage For Seasonal/Tourist Peaks*
WW 4 – Flexible Sequencing of Basin Use*
WW 5 – Optimize Aeration System*
WW 6 – Fine Bubble Aeration*
WW 7 – Variable Blower Air Flow Rate*
WW 8 – Dissolved Oxygen Control*
WW 9 – Post Aeration: Cascade Aeration
WW 10 – Sludge: Improve Solids Capture in DAF System
WW 11 – Sludge: Replace Centrifuge with Screw Press
WW 12 – Sludge: Replace Centrifuge with Gravity Belt Thickener
WW 13 – Biosolids Digestion Options*
WW 14 – Aerobic Digestion Options*
WW 15 – Biosolids Mixing Options in Aerobic Digesters*
WW 16 – Biosolids Mixing Options in Anaerobic Digesters*
WW 17 – Optimize Anaerobic Digester Performance
WW 18 – Use Biogas to Produce Heat and/or Power
WW 19 – Cover Basins for Heat Reduction*
WW 20 – Recover Excess Heat from Wastewater*
WW 21 – Reduce Fresh Water Consumption/ Final Effluent Recycling*

Buildings Best Practices

B 1 – Install VFD Control on Air Compressors
B 2 – Install High-Efficiency Lighting
B 3 – Clean Lamps and Fixtures
B 4 – Monitor Light Operation
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
B 9 – LEED Energy Practice

Best Practices are reprinted or modified from the Water and Wastewater Energy Best Practice Guidebook provided by Focus on Energy, prepared by Science Applications International Corporation (SAIC), December 2006, with authorization.

General Best Practices

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G1 – Facility Energy Assessments

Best Practice	An annual energy survey should be a common practice for all water and wastewater systems to determine any opportunities to improve energy efficiency. The survey should review all energy consuming processes.
See Also	Not applicable.
Primary Area/Process	This practice should be completed for the entire facility, with emphasis on the major energy using processes such as pumping, aeration and solids management.
Productivity Impact	The only likely impact may be a short disturbance during implementation of the recommendations.
Economic Benefit	Payback period will vary with the complexity of the modifications and the required capital investment, if any.
Energy Savings	Energy savings will vary depending on the existing equipment and the opportunities identified. Savings range from 10% to 50% of the total system energy consumption. Several projects have resulted in energy savings of as much as 65%.
Applications & Limitations	None.
Practical Notes	Energy can be saved at every site, regardless of treatment process, age or size of facility.
Other Benefits	More attention is given to operations because of the desire to save money resulting from saving energy.
Stage of Acceptance	Acceptance of the value of energy assessments is growing and getting more attention. The acceptance of various energy efficient technologies and practices varies.
Resources	The US EPA recently released a tool for benchmarking wastewater and water utilities. The tool is a multi-parameter energy performance metric that allows for comparison of energy use among WWTPs. The tool can be accessed through the US EPA's EnergySTAR Portfolio Manager platform (see link below). Portfolio Manager is an interactive energy management Web-based system that allows commercial building managers as well as water and wastewater treatment plant operators to track and assess energy consumption and carbon footprint. The Portfolio Manager is appropriate for primary, secondary, and advanced treatment plants with or without nutrient removal. The tool is applicable to WWTPs having design flows of less than 150 MGD. After inputting the following information into the Portfolio Manager platform, the tool produces an energy use "score" for a facility, relative to the scores of a national population of WWTPs. The score is expressed on a scale of 1 to 100. • Zip code; • Average influent flow; • Average influent biological oxygen demand (BOD5); • Average effluent biological oxygen demand (BOD5); • Plant design flow rate; • Presence of fixed film trickle filtration process; • Presence of nutrient removal process, The tool can be accessed through Portfolio Manager at: http://www.energystar.gov/index.cfm?c=eligibility.bus_portfoliomanager_eligibility.

G2 – Real Time Energy Monitoring

Best Practice	An accurate, real-time energy monitoring system will permit the collection and analysis of 15-minute energy data for each treatment process and pump installation. This support tool enables utility staff and management to establish energy use reduction goals and monitor/verify demand consumption.
See Also	Not applicable.
Primary Area/Process	This technology can be applied to all process treatment units and is most beneficial to high energy users. High energy users may include large facilities and facilities that use an inordinate amount of energy or demand "per unit of water" of wastewater conveyance and treatment.
Productivity Impact	No impact on a facility's capability to meet treatment limits.
Economic Benefit	Payback depends on the cost of the monitoring system and on the system's adjustment capability.
Energy Savings	The achievable range of energy savings is typically 5% to 20% where energy efficiency is viewed as a daily performance goal.
Applications & Limitations	Each site must be individually assessed to identify the processes that can benefit the most from monitoring.
Practical Notes	The most common barrier to implementation is acquiring management approval and commitment for the capital expenditure. Be sure to include the potential savings from energy management in payback calculations. This practice has been suggested through benchmark studies.
Other Benefits	Monitoring also can support other functions, such as maintenance and the identification of failing equipment.
Stage of Acceptance	This concept is well known but not widely practiced since it is usually not necessary for meeting system performance goals (effluent limits).

G3 – Energy Education for Facility Personnel

Best Practice	All water and wastewater system personnel should understand the relationship between energy efficiency and facility operations. Information can be found in various publications, including this handbook and through training sessions offered through organizations such as NYSERDA.
See Also	Not applicable.
Primary Area/Process	This practice focuses on personnel, especially those who make both long- and short-term decisions that affect energy use (including elected officials). All parties involved in the operation of a water treatment and distribution system and a wastewater conveyance and treatment facility can benefit from understanding the system's energy use.
Productivity Impact	No impact.
Economic Benefit	There is no direct return on investment for this practice. The return will be a function of actual process changes made in response to recommendations.
Energy Savings	The energy savings for this practice will vary substantially depending on what measures are implemented.
Applications & Limitations	None.
Practical Notes	It is useful to establish an annual schedule for energy training to keep facility management and personnel up to date on available technology and management practices.
Other Benefits	Staff members and colleagues within the industry typically share and discuss the information they gain from attending education classes and reading publications.
Stage of Acceptance	Education and training is common and widely accepted throughout the industry.

G4 – Comprehensive Planning Before Design

Best Practice	Clearly define utility goals and objectives and set the design criteria for system improvements. Incorporate all appropriate energy efficiency best practices into capital and operations improvement plans. This helps the utility address the critical needs of the future system and optimizes capital and operating budgets.
See Also	Not applicable.
Primary Area/Process	All components of water treatment/distribution and wastewater treatment systems.
Productivity Impact	No impact.
Economic Benefit	Payback will vary by facility and by project, depending on the energy benefits and costs of alternative designs and operations. Payback may vary from a few months to several years.
Energy Savings	Future energy savings are derived from the incorporation of energy efficiency practices in the capital and operations improvement plans.
Applications & Limitations	There are no limitations on this practice because comprehensive planning should occur prior to project development.
Practical Notes	Proactive and open communications promote the success of capital and operations improvement planning, including energy management planning. Aggregating energy efficiency measures into a capital improvement project and justifying them in the aggregate, helps avoid lost opportunities for future energy savings. Energy saving improvements should be evaluated on a life-cycle cost basis.
Other Benefits	Well conceived and planned projects result in the highest value to the utility.
Stage of Acceptance	Increasingly, utilities are seeing the value of energy management. Its acceptance is growing, especially as a means to stretch limited budgets.

G5 – Design Flexibility for Today and Tomorrow

Best Practice	Operation, administration, and management personnel need to be involved with the planning and design of any improvements and/or expansions to their system. Plan and design improvements or expansions that have the flexibility to serve both current system and future system needs, taking into account any significant anticipated changes.
See Also	Not applicable.
Primary Area/Process	All components of water or wastewater system.
Productivity Impact	Impact should be negligible.
Economic Benefit	The selected design of any improvements or expansions should reflect the best quality for the most reasonable cost. The simple payback for installing smaller operating units and storage that can follow current system demand, compared with a larger, single unit operating at reduced capacity, is usually from one year to five years.
Energy Savings	Energy savings will vary by project, but are directly related to a system's ability to closely meet demands at all points throughout its lifetime, as opposed to being designed only for 20 year peak flows.
Applications & Limitations	None.
Practical Notes	An assessment of the size and space needed to install multiple smaller units, as compared to one or two large units, needs to be completed. Also, the continuous operation of smaller unit(s) will put less stress on a system than a large unit operating periodically.
Other Benefits	Having a system that operates effectively as well as efficiently through the life of its design, not just at its future design condition, is a value to the system operations.
Stage of Acceptance	Designers and owners are becoming more knowledgeable and accepting of equipment sized to match existing conditions, as opposed to only considering projected peak design needs.

G6 – Electric Peak Reduction

Best Practice	Management of peak demand (shifting to off-peak or shaving peak power usage) can substantially lower energy costs. The following can be done to optimize power use and reduce electric peak demand: • Assess electric bills to understand peak demand charges and examine facility operations to determine ways to avoid or reduce peak demand. • Develop an operation strategy that meets overall system demand and minimizes pumping and specific treatment processes during peak power demand periods. Consider adding storage capacity or simply delaying the time of operation. Assess the typical and peak operation of a water and/or wastewater system to identify areas where peak power demand can be trimmed or shifted.
See Also	G 7 — Manage Electric Rate Structure and G-8 Idle or Turn-Off Equipment.
Primary Area/Process	All energy-using components of water and wastewater systems, with a focus on the supply side. Candidates for off-peak operation in wastewater include biosolids management (operate sludge presses in off-peak demand times); shifting recycling to off-peak periods; loading or feeding anaerobic digesters off-peak so supernatant does not recycle on-peak; operating mixers or aerators in aerobic digesters off-peak; reducing recycling during on-peak; and accepting or treating hauled-in wastes during off-peak.
Productivity Impact	No impact.
Economic Benefit	Paybacks are typically less than a year because the modifications are generally procedural and do not have significant costs.
Energy Savings	Energy consumption savings (kWh) are generally minor. Savings result from reduced demand for peak power.
Applications & Limitations	Application may be limited by the amount of storage available and by the absolute minimum power requirement for necessary operations. Substantial savings are more likely with a time of use (TOU) rate. Smaller facilities may not be charged separately for demand.
Practical Notes	An understanding of the relationship between peak power demand and the demands of water supply and wastewater treatment are also necessary to make the application effective.
Other Benefits	Improved use of system components.
Stage of Acceptance	Electric uses provide information to assist customers with optimizing their consumption according to their specific rate structures. Most water and wastewater utilities are aware of this, but may not be optimizing operations to fit the rates.

G7 – Manage Electric Rate Structure

Best Practice	Work with the utility account manager to review the facility's electric rate structure. The review process should determine if the current structure is the most appropriate pricing structure for the facility, based on peak demand and overall energy consumption.
See Also	G 6 – Electric Peak Reduction.
Primary Area/Process	Facility wide, with special attention to accounting and purchasing.
Productivity Impact	No impact.
Economic Benefit	There is no direct return on investment for this practice. Nevertheless, economic benefit can result from actual process changes made in response to recommendations.
Energy Savings	The energy savings will vary with site and rate structure.
Applications & Limitations	All facilities should apply this practice.
Practical Notes	All personnel should be aware of how their specific facility is charged for energy consumption.
Other Benefits	Management will give more attention to the operation of a system if energy awareness is made available to everyone.
Stage of Acceptance	The practice of reviewing utility bills and rate structures is becoming more common as its value becomes recognized. As water and wastewater personnel are becoming more aware of energy costs and methods of billing, modifications to operations are also being made.

G8 – Idle or Turn off Equipment

Best Practice	Idle or turn off non-essential equipment when feasible, especially during periods of peak power demand. Review operations and schedules to determine if any equipment is not required for the proper operation of the facility.
See Also	G 6 – Electric Peak Reduction.
Primary Area/Process	This technology can be applied to almost all areas in a water or wastewater system.
Productivity Impact	No impact.
Economic Benefit	Paybacks are typically short, if not immediate, because the modifications are low or no-cost changes in procedures.
Energy Savings	Savings depend on the amount of non-essential equipment currently operating. Reduced power demand will also result if shut off occurs during periods of peak power demand.
Applications & Limitations	Care must be taken not to turn off an essential piece of treatment or monitoring equipment or warning system device. Provide as much automatic control, such as timers, as is feasible to reduce the need for operator attention and the potential for operator error. This practice should not undermine compliance with design conditions and regulatory requirements.
Practical Notes	It can be useful to ask why each piece of equipment is operating and if the equipment is critical to operation. This is of particular value when trying to reduce peak power demand charges.
Other Benefits	Increased equipment life, reduced maintenance, and possibly fewer spare parts required.
Stage of Acceptance	Water and wastewater utilities are increasingly more willing to turn off equipment once they understand that system requirements still can be met.

G9 – Electric Motors: Install High Efficiency Motors

Best Practice	Survey existing motors for possible replacement with new, high efficiency motors and specify the most energy efficient motors on all new installed and inventoried equipment. Include an emergency motor replacement program that specifies energy efficient motors.
See Also	G 10 - Electric Motors: Automate To Monitor and Control; G 12 - Electric Motors: Variable Frequency Drive Applications; G 13 - Electric Motors: Correctly Size Motors.
Primary Area/Process	Can be applied to all electric motors, especially on well and booster pumps for water systems, and on those wastewater facility motors with high annual operating hours and those that operate during peak demand, e.g., aeration blowers, disinfection systems, pumps, and clarifiers.
Productivity Impact	No impact, except for a possible short shutdown time for removal of the existing motor and installation of the new motor.
Economic Benefit	The simple payback is generally short, often less than two years, if the motor operates continuously; however, if the equipment's annual hours of operation are minimal, the simple payback period can become extended.
Energy Savings	Savings will vary, but should be minimally 5% to 10% of the energy used by the lower efficiency motor to be replaced.
Applications & Limitations	None. Still, physical characteristics and location of the existing motor must be considered when replacing a motor. For example, the new motor may have to be explosion-proof, spark-resistant or have immersion capability (flooding conditions).
Practical Notes	Typically, the best practice is implemented when an existing motor is replaced or needs to undergo major repairs. Nevertheless, in certain situations, such as high annual hours of operation, it may be worthwhile to replace a working motor. A program to determine whether it is economically justifiable to replace older motors instead of repairing them may be beneficial. Note that a premium efficiency motor may require a longer lead time than a standard or high efficiency motor of the same size. Allow extra time in the project schedule.
Other Benefits	Reduced emissions from the power source directly related to the reduced consumption of electrical power.
Stage of Acceptance	This is a well known, proven and accepted technology.

G10 – Electric Motors: Automate to Monitor and Control

Best Practice	Use automatic controls where possible to monitor and control system functions to optimize energy consumption and production demands or treated flows.
See Also	G 9 Electric Motors: Install High Efficiency Motors; G 11 – Supervisory Control and Data Acquisition; G 12 - Electric Motors: Variable Frequency Drives Applications.
Primary Area/Process	Automatic controls apply to many aspects of water and wastewater treatment processes.
Productivity Impact	Minimum impact after installation. In many cases control systems can improve system performance.
Economic Benefit	Payback varies significantly, depending on the complexity of the controls added.
Energy Savings	Typically, energy savings result from the ability to match equipment performance to the demands of the system. Variable frequency drives are an example of this.
Applications & Limitations	Control technologies vary from simple applications, such as time clocks, to prevent large equipment from operating during peak rate periods, to complex systems like filter backwash monitoring, to control equipment operation based on a number of variables, or automatic monitoring of dissolved oxygen integrated with controlling blower speed.
Practical Notes	Care should be taken in the design and installation of any automatic control system to ensure that the system will operate as necessary to meet operational requirements, especially in emergency situations. Make sure that system components needed for emergency situations are available. Look for vendors with process and controls experience to optimize the entire system.
Other Benefits	The use of automatic control systems to monitor a facility may lead to a more in-depth understanding of facility operations.
Stage of Acceptance	Acceptance of automatic controls in the water and wastewater industry is increasing with simple applications being viewed as "safer", and more complex application slowly gaining acceptance.

G11 – Supervisory Control and Data Acquisition (SCADA)

Best Practice	SCADA systems refer to the hardware and software systems that allow treatment plant operators to remotely monitor field instrumentation and equipment, and in some cases, make control adjustments to the treatment process. SCADA systems provide the "Human Machine Interface" (HMI) that allows operators to more easily interact with the various electronic controls and field instrumentation used in larger treatment plants. SCADA can improve energy use tracking with routine energy "benchmarking": • Monitor energy use over time, including comparisons with process variables (e.g. flow, chemical use, lb BOD, lb TSS). • Offset loads and control motor operating times to manage peak demand.
See Also	G 10 - Electric Motors: Automate To Monitor and Control.
Primary Area/Process	Instrumentation and Controls.
Productivity Impact	Minimum impact after installation. In many cases control systems can improve system performance.
Economic Benefit	Payback varies significantly depending on the complexity of the controls added.
Energy Savings	Typically, energy savings result from the ability to match equipment performance to the demands of the system.
Applications & Limitations	The capital investment required to implement a SCADA system can be cost prohibitive for some smaller utilities. Utilities that already use SCADA will also incur some additional capital costs for adding energy monitoring capabilities and defining energy benchmarking reports.
Practical Notes	None.
Other Benefits	Installation of a SCADA system for central equipment control benefits the whole plant.
Stage of Acceptance	SCADA systems are widely accepted in the water and wastewater sectors.

G12 – Electric Motors: Variable Frequency Drives Applications

Best Practice	Variable frequency drives (VFDs) match motor output speeds to the load requirement and avoid running at constant full power, thereby saving energy. Equipment must be designed to operate at peak flows. These designs often are not energy efficient at average existing flow conditions. Assess variations in facility flows and apply VFDs, particularly where peak demand is significantly higher than the average demand and where the motor can run at partial loads to save energy.
See Also	G 10: Electric Motors: Automate to Monitor and Control.
Primary Area/Process	VFDs apply to most processes in water and wastewater systems. They can replace throttling valves on discharge piping, control the pumping rate of a process pump, control conveyance pressure in forcemains, control air flow rates from blowers, and control the speed of oxidation ditch drives.
Productivity Impact	Impact should only be short term with interruption of service during installation, start up, and fine tuning.
Economic Benefit	Now more available and affordable, paybacks for VFDs range from six months to five years. The payback period will vary with application depending on size of drive, hours of operation and variation in load. Large drives, long hours and high load variability yield the highest savings.
Energy Savings	Savings vary with application and technology. Many VFD retrofits have saved 15% to 35%. In some installations, particularly where throttling is used to control flow, savings of 10% to 40% are possible. Applied to a wastewater secondary treatment process, a VFD can save more than 50% of that process's energy use.
Applications & Limitations	Applications for VFDs include controlling pressure, daily demand (gpm), fire flow, and well recovery and replenishment. Other applications include controlling aeration blowers, the pumping rate of raw sewage and sludge processing.
Practical Notes	Calculations that account for load variation can help justify the cost. The system must be reviewed by an expert before selecting and installing the VFD to ensure system compatibility and cost-effectiveness. VFDs allow operators to fine tune their collection, conveyance and treatment processes. Matching drives to loads also puts less stress on equipment and reduces maintenance.
Other Benefits	Associated benefits include better control of system flowrate and pressure, more consistent supply and increased flexibility to meet demand requirements with minimum energy use. Better control of process flows can lead to reduced chemical usage. Reduced emissions from the power source directly related to the reduced consumption of electrical power are additional benefits.
Stage of Acceptance	Widely accepted and proven in the water and wastewater sectors. New and upgraded wastewater systems are commonly equipped with VFDs for most treatment applications.

G13 – Electric Motors: Correctly Size Motors

Best Practice	Proper sized motors for the specific application. Motors should be sized to run primarily in the 65% to 100% load range. In applications that require oversizing for peak loads, alternative strategies, such as the use of a correctly sized motor backed up with a larger motor that only operates during peak demand, should be considered.
See Also	G 9 Electric Motors: Install High Efficiency Motors.
Primary Area/Process	All electric motors.
Productivity Impact	No productivity impact should result from this best practice, or minimum impact during installation if motors are replaced.
Economic Benefit	Savings will vary depending on motor size and application.
Energy Savings	Savings will vary depending on motor size and application.
Applications & Limitations	None.
Practical Notes	Many motors are oversized for their application, thereby wasting energy. Oversized motors can also result in a lower power factor. Motors that are oversized by more than 50% should be replaced with correctly sized, high-efficiency or premium-efficiency motors.
Other Benefits	None.
Stage of Acceptance	Not applicable.
Results	The Department of Energy has developed a popular motor selection and management tool: MotorMaster+ software. This free software includes a catalog of more than 25,000 AC motors and features motor inventory management tools, maintenance log tracking, predictive maintenance testing, energy efficiency analysis, savings evaluation capabilities, and environmental reporting. The motor load and efficiency values are automatically determined when measured values are entered into the software. MotorMaster+ can quickly help WWTPs identify inefficient or oversized motors and subsequently calculate the savings that can be achieved with more energy-efficient models. To download MotorMaster+ visit: http://www1.eere.energy.gov/industry/bestpractices/software.html

G14 – Electric Motors: Properly Maintain Motors

Best Practice	A regular program of preventive maintenance can increase motor efficiency and prolong service life. A typical maintenance program should include: • Performance monitoring. Periodic measurements of power consumed in comparison to an initial baseline. • Measurement of resistance provided by winding insulation (Megger testing). • Proper lubrication of motor bearings. • Verification of proper motor coupling alignment, or belt alignment and tension. • Cleaning of cooling vents. • Maintenance of protective circuitry, motor starters, controls, and other switchgear.
See Also	Not applicable.
Primary Area/Process	All electric motors.
Productivity Impact	No impact, or minimal impact during motor maintenance.
Economic Benefit	The resources required for motor preventive maintenance should be balanced with cost considerations and expected benefits.
Energy Savings	The energy savings will depend on the status of the equipment.
Applications & Limitations	None.
Practical Notes	None.
Other Benefits	Preventive maintenance benefits all processes in the treatment plant and reduces O&M costs.
Stage of Acceptance	Preventive maintenance of electric motors is well accepted in the water and wastewater sectors.

G15 – Electric Motors: Improve Power Factor

Best Practice	Improve the power factor of electric motors by minimizing the operation of idling or lightly loaded motors, avoiding operation of equipment above its rated voltage, replacing inefficient motors with energy-efficient motors that operate near their rated capacity, and installing power factor correction capacitors.
See Also	Not applicable.
Primary Area/Process	All electric motors.
Productivity Impact	No productivity impact should result from this best practice, or minimum impact during installation if motors are replaced.
Economic Benefit	Savings will vary based on motor size and electric utility rates.
Energy Savings	Savings will vary, but should be minimally 5% to 10% of the energy used by the low power factor motors.
Applications & Limitations	The installation of either single or banks of power factor capacitors is especially beneficial in facilities with larger motors. Many electric utility companies charge a facility if the power factor is less than 0.95.
Practical Notes	Periodic monitoring of power efficiency and load factors can provide valuable information, including inefficient motor operation or potential motor failure. A motor's efficiency tends to decrease significantly when operated below 50% of its rated load, and the power factor also tends to drop off at partial load. Replace motors that are significantly oversized with more efficient, properly-sized motors.
Other Benefits	Motors and drives require proper and periodical maintenance to ensure they are operating at optimum performance. Periodic monitoring of power efficiency and load factors can provide valuable information, including inefficient motor operation or potential motor failure.
Stage of Acceptance	Not applicable.

G16 – Pumps: Optimize Pump System Efficiency

Best Practice	Identify the optimum operational conditions for each pump and develop a system analysis. This analysis should include the start up flows and progress to the design flow capacity, usually a twenty year projected flow with a peaking factor to identify the range of flow(s) and head conditions required to efficiently meet the conditions and specifications of the system design. Select the pump with the peak efficiency point relative to the common operation condition of the pump. Consider operating a single pump, multiple pumps, and the use of VFDs.
See Also	G 12 - Electric Motors: Variable Frequency Drives Applications; G 17 – Pumps: Reduce Pumping Flow; G 18 – Pumps: Reduce Pumping Head
Primary Area/Process	This technology should be applied to all pumping applications.
Productivity Impact	Optimizing pumping systems can reduce unscheduled downtime, reduce seal replacement costs and improve unit process treatment efficiency and effectiveness.
Economic Benefit	The payback period depends on site specifics and whether it is new or retrofit. With a new facility, the payback period should be less than two years; in retrofit conditions, three months up to three years is a typical range.
Energy Savings	The energy saved will vary with the installation; 15% to 30% is typical, with up to 70% available in retrofit situations where a service area has not grown as forecast.
Applications & Limitations	None.
Practical Notes	Many computer models can help with the analysis; the model should address both static and dynamic conditions.
Other Benefits	Generally, improved pumping systems provide better treatment system control.
Stage of Acceptance	The technologies used to analyze pumping systems are readily available and their use is widely accepted.
Results	The Department of Energy (DOE) has developed a tool—the Pump System Assessment Tool (PSAT)—that can be used together with the Hydraulic Institute's Achievable Efficiency Estimate Curves to determine the achievable and optimum efficiencies for the selected pump type as well as correction factors at the specified operating conditions. This method can be used to calculate the energy savings based on the difference between the anticipated energy use of a high-efficiency pump and the baseline energy use associated with the inefficient or oversized pump.

G17 – Pumps: Reduce Pumping Flow

Best Practice	Reduce flow being pumped. Energy use in a pump is directly proportional to the flow being pumped. Compare design flow with current flow and evaluate if system conditions changed. In some applications (i.e., pumping to a storage tank), it is possible to pump at a lower rate over a longer period of time. Conservation measures such as reduction of infiltration and inflow or leak detection and repairs to the water distribution system can also reduce the flow that needs to be pumped.
See Also	G 16 – Pumps: Optimize Pump System Efficiency; W 3 - System Leak Detection and Repair; W 6 – Optimize Storage Capacity; W 7 - Promote Water Conservation.
Primary Area/Process	This energy saving practice can be applied to all pumps.
Productivity Impact	No impact.
Economic Benefit	The estimated payback will vary with improvements and comparison with a base alternative. While load shifting and demand flattening (pump at a lower rate over a longer period of time) do not necessarily result in reduced energy use, they do result in reduced electricity costs.
Energy Savings	The potential savings will vary with the type of modifications being considered.
Applications & Limitations	All pumping systems.
Practical Notes	A detailed evaluation should be completed to identify the potential energy savings for each installation.
Other Benefits	None.
Stage of Acceptance	Not applicable.

G18 – Pumps: Reduce Pumping Head

Best Practice	Reduce the total system headlosses, which include static head and friction headlosses (due to velocity, bends, fittings, valves, pipe length, diameter, and roughness). Energy use in a pump is directly proportional to the head. Plot system curve at the time of installation and compare output on the certified curve. Calculate efficiency and save for future reference. Plot system curve on a yearly basis; examine and re-plot at shorter period if problems develop. Avoid using throttling valves to control the flow rate. Run higher wet well level on suction side (if practical). Increase pipeline size and/or decrease pipe roughness.
See Also	See also G 16 – Pumps: Optimize Pump System Efficiency, and G 19 – Pumps: Avoid Pump Discharge Throttling.
Primary Area/Process	This energy saving practice can be applied to all pumps.
Productivity Impact	No impact.
Economic Benefit	The estimated payback will vary with improvements and comparison with a base alternative.
Energy Savings	The potential savings will vary with the type of modifications being considered.
Applications & Limitations	Applicable to all pumping systems. Note that reducing the head too much may result in the pump running to the far right of the BEP on the pump curve, which could result in inefficient operation and/or cavitations.
Practical Notes	A detailed evaluation should be completed to identify the potential energy savings for each installation.
Other Benefits	Reduced pump wear, longer service life, and less maintenance.
Stage of Acceptance	Reducing the head on pumping systems is readily accepted in the water and wastewater sectors.

G19 – Pumps: Avoid Pump Discharge Throttling

Best Practice	Modify operation of system to eliminate the use of throttling valves to control the flow rate from pumps. Consider energy efficient variable speed drive technologies, such as Variable Frequency Drives (VFDs).
See Also	G 12 - Electric Motors: Variable Frequency Drives Applications.
Primary Area/Process	This technology is most often applied to well and booster pump discharges.
Productivity Impact	No impact.
Economic Benefit	Payback varies by application and may be less than one year if pump run time is high and valve closure is significant. Still, the savings can be as low as 15% of total energy consumption if the pump has low hours of operation and the throttling valve is minimally closed.
Energy Savings	Energy savings can exceed 50% of pumping energy in some cases. Actual savings depend on the amount of closure of the throttling valve.
Applications & Limitations	All locations currently using valves to control flows.
Practical Notes	A detailed evaluation should be completed to identify the potential energy savings for each installation considering a Variable Frequency Drive.
Other Benefits	Ability to quickly and easily adjust flow as changes occur in the distribution system. Reduced pump wear, longer service life, and less maintenance.
Stage of Acceptance	The industry accepts the use of VFDs to replace throttling valves in order to save large amounts of energy.

G20 – Filtration: Sequence Backwash Cycles

Best Practice	A filtration system can have high energy costs, and the highest energy users for filtration systems are typically the backwash pumps. Consider sequencing of backwash cycles and off-peak backwash times to reduce the electric demand. In some applications, it is possible to pump at a lower rate over longer time to a water storage tank located at a higher elevation, and backwash by gravity.
See Also	Not applicable.
Primary Area/Process	Granular or membrane filtration systems are applied to water systems and in tertiary treatment of wastewater systems.
Productivity Impact	Productivity should not be impacted by sequencing of backwash cycles.
Economic Benefit	Savings will result from a lower demand due to the staggered operation of backwash pumps.
Energy Savings	Energy consumption savings (kWh) are generally minor. Savings result from reduced demand for peak power.
Applications & Limitations	When operators have to be present, backwashing during off-peak time can affect the staffing needs or labor costs.
Practical Notes	None.
Other Benefits	Sequencing of backwash cycles gives a more stable and constant operation of filter units.
Stage of Acceptance	Sequencing of backwash cycles is a well accepted practice.

G21 – Ultraviolet (UV) Disinfection Options

Best Practice	Consider low-pressure or low-pressure high output UV systems, which are more energy efficient than medium-pressure UV systems. Install lamp intensity adjustment based on flow rate or water quality, particularly UV transmittance (UVT), for low-pressure high output, and medium-pressure systems. Regularly clean lamps, as lamp sleeve fouling affects equipment performance.
See Also	Not applicable.
Primary Area/Process	UV disinfection options can apply to both water and wastewater facilities.
Productivity Impact	Minor impact on productivity during the installation of any improvements.
Economic Benefit	Paybacks will vary depending on the type of UV system in use and the extent of renovations required.
Energy Savings	Energy savings from UV result when the number of lamps "on" and lamp output are paced, based on flow and transmittance. Low-pressure, high-output UV lamps use about 50% less energy than medium-pressure lamps. Typical energy requirements for low-pressure, high-output systems range from 3.2 to 4.8 kWh/mgd, while medium-pressure systems use about 6.8 kWh/mgd. Sleeve cleaning alone can save 10% of UV system energy costs.
Applications & Limitations	Energy savings may be lower for systems that operate seasonally, due to limited annual hours of operation.
Practical Notes	Medium pressure lamps convert a lower percentage of the power they consume into useful light, compared with lowpressure, high-output lamps. Additionally, medium pressure lamps offer much lower turn down capabilities. Consequently, a medium pressure system may use significantly more energy, despite having fewer lamps. Low-pressure UV lamps are typically used for flows not exceeding 38 mgd. For higher wastewater flows, or when space is limited, medium-pressure UV lamps are required. Including an automatic cleaning (wiping) system ensures that the quartz sleeves stay clean and that the maximum amount of UV can be transferred.
Other Benefits	Installation of an ultraviolet (UV) system usually replaces a chlorination system, thereby eliminating the need to store chlorine on site as either a hazardous gas or corrosive liquid. Additionally, using UV disinfection reduces the potential for trihalomethane (THM) formation in the distribution system as a result on disinfection byproduct (DBP) precursors in the water.
Stage of Acceptance	Many varieties and configurations of UV disinfection systems are accepted and in use throughout the water and wastewater sectors.

G22 – Renewable Energy Options

Best Practice	Assess the availability of renewable energy resources (wind, solar, biogas or hydro) at the facility site. If available, investigate the technical and economic feasibility of installing equipment to harvest these resources to meet part or all of the facility's electric and heating needs.
See Also	Not applicable.
Primary Area/Process	Traditionally, renewable energy in the wastewater industry has meant the use of biogas to heat buildings and processes. Technological advancement in other renewable resource areas has led to their cost effectiveness for certain applications and under certain conditions. Now, more consideration is given to the use of wind and/or hydro power resources for electric generation and solar energy for space and process heating.
Productivity Impact	No impact beyond construction and commissioning.
Economic Benefit	Typically, payback periods for renewable energy technologies range from three to seven years.
Energy Savings	Energy savings will vary with location. Renewable energy benefits will increase by using cascading energy streams (e.g., first using recovered biogas to fuel an engine and then capturing the heat from the engine and exhaust systems to serve low-grade heat applications, such as space or process heating).
Applications & Limitations	The site must be assessed to identify the best match of the renewable resource to the application.
Practical Notes	A renewable resource must be available at the facility to be beneficially used.
Other Benefits	Renewable energy may offset electric utility demand. Their use avoids the use of dirtier, non-renewable fuels providing a favorable environmental impact.
Stage of Acceptance	The use of renewable energy sources within the wastewater industry is generally accepted, but not often implemented due to lack of knowledge and experience.

Water Best Practices

W1 – Integrate System Demand and Power Demand

Best Practice	Evaluate current system demand (user water consumption) and electric power demand. The analysis should address residential, commercial, institutional, and industrial usage plus required fire flow. Utility staff should direct new system designers to incorporate energy best practices to reduce electric demand for well pump systems and booster pump stations; consider the feasibility of applying variable speed drives and electric power monitoring, as well as demand controls to keep power demand charges low.
See Also	Not applicable.
Primary Area/Process	Includes all components of water treatment and distribution systems.
Productivity Impact	Production is assumed to improve for either a new system or retrofit.
Economic Benefit	The estimated payback will vary with improvements and comparison with a base alternative.
Energy Savings	The potential savings will vary with the type of modifications being considered.
Applications & Limitations	There are no limitations on this practice because comprehensive planning should occur prior to the development of any improvement project.
Practical Notes	Careful planning can decrease capital costs by ensuring that system improvements are appropriate and new/retrofit equipment is compatible with existing system components.
Other Benefits	Include improved production scheduling. Potential for environmental compliance. Lower utility costs mean lower customer bills and more satisfied customers.
Stage of Acceptance	Careful planning of system improvements has long been a hallmark of the water industry. The practice builds on this idea by incorporating the goal of energy efficiency.

W2 – Computer-Assisted Design and Operation

Best Practice	Develop a computer model of the water utility to demonstrate the impacts of proposed improvements to the distribution system. A model can evaluate the impacts on the distribution system from changes in pipe size, pumping rates, pump operating point, system pressure, location of booster pumps, location of storage, and variable flow rates. Adjusting system pressures, pump rates, pump operating points, and operational sequence can cut energy use.
See Also	Not applicable.
Primary Area/Process	All water distribution systems.
Productivity Impact	No impact on operation or production. Tests may be necessary to calibrate the model to actual field conditions.
Economic Benefit	Payback will be a direct function of the identified opportunities for energy savings. Payback benefits begin when the model is used to select energy efficient practices.
Energy Savings	The potential energy savings will vary with type of modifications being considered.
Applications & Limitations	This measure can benefit even small systems with minimal infrastructure. System pressure must always be high enough to meet customer demand and fire flow.
Practical Notes	Many computer models are available. The model should address both static and dynamic conditions. The analysis should include the startup flows and progress to the design flow capacity, usually a 20 year projected flow with a peaking factor to identify the range of flow(s) and head conditions required to efficiently meet design conditions. Look for user friendliness and expandability to allow the model to change and grow with the system. Perform analyses prior to new construction, to minimize capital costs and ensure the best long-term decisions.
Other Benefits	Helps document and justify infrastructure and operations decisions to management. Also provides data for annual reports and information needed for asset management.
Stage of Acceptance	Use of modeling technology for operations optimization is well received and widely accepted by the industry.

W3 – System Leak Detection and Repair

Best Practice	Review your facility's annual Public Service Commission water reports to determine the amount of water that is unaccounted for. If the amount exceeds "typical" losses for similar facilities, use leak detection and repair to reduce pumping energy requirements and save water. O&M practices such as a pipe inspection and maintenance program and a meter inspection and replacement program together with new technology, such as Automatic Meter Reading Technology (AMR) and Computerized Maintenance Management Software (CMMS) can be useful tools to identify leaks.
See Also	G 17 – Pumps: Reduce Pumping Flow.
Primary Area/Process	Throughout all water distribution systems.
Productivity Impact	There may be minor disruptions during repair and disinfection of the section to be repaired before placing it back into operation.
Economic Benefit	Payback varies considerably depending on the size and complexity of the distribution system and the extent of any required repairs. Payback periods tend to be longer than for many energy efficiency projects since the energy savings may be small compared with the cost to repair the leak. The economic evaluation should also consider the value of lost water.
Energy Savings	Potential energy savings will vary with number and severity of leaks, and with system pressure.
Applications & Limitations	All distribution systems.
Practical Notes	The amount of energy saved is small relative to the cost of repairing leaks in water mains because excavation in paved areas is expensive.
Other Benefits	Saving water, a limited resource.
Stage of Acceptance	Leak detection and repair is standard practice in the industry, but has traditionally been viewed as routine maintenance rather than as an energy efficiency practice.

W4 – Manage Well Production and Draw-down

Best Practice	Monitor, compile, and review the physical characteristics and operations of each well, including pumping rates, recharge capabilities, draw-down, and recharge areas. Develop a performance chart that presents historic and current conditions. Use this information to optimize the operation and planning of pumps, motors, and the control system. Particularly, monitor well draw-down during pump operation to detect any production changes over time. Diminishing production may expose potential for pump failure, or other mechanical problems. The water level may also drop to a point where pumping is inefficient.
See Also	W 5 – Sequence Well Operation.
Primary Area/Process	All water systems with wells.
Productivity Impact	Impact felt only during installation, if new equipment is necessary. Failure of pumps or excessive draw-down would eventually lead to impact on production.
Economic Benefit	A short payback is possible if equipment is in place and only requires adjustment. If new equipment, such as VFDs are required, the payback period will increase.
Energy Savings	Vary widely with the characteristics of each specific site.
Applications & Limitations	Monitored operations data helps establish the "best point" for operation and makes the system more efficient. Some utilities may require the assistance of an external consultant.
Practical Notes	A strong maintenance program, coupled with monitoring and review, will always provide energy savings. Keeping a log of changes and trending results will also support system planning.
Other Benefits	Many additional benefits may accrue: lower stress on system; reduced pumping rate; reduced electric peak demand charge. This allows for scheduled maintenance rather than emergency maintenance, makes fluctuations in the aquifer more predictable, and reduces surprises and emergencies.
Stage of Acceptance	Widely accepted in the water industry; however, many utilities do not realize the value of monitoring the condition of equipment and how it supports planned, preventive maintenance, and avoids emergency maintenance.

W5 – Sequence Well Operation

Best Practice	Compile and review all information available on each well. Observe the functional characteristics and the production capability of each well, noting that many wells are brought on line with equipment sized to achieve full capacity production, which may not be necessary. From these data, identify the proper sequence of operations, beginning with the most energy efficient well and ending with the least energy efficient.
See Also	W 4 – Manage Well Production and Draw-down.
Primary Area/Process	Water supply and distribution systems that are served by groundwater (wells).
Productivity Impact	This practice should have no impact on productivity.
Economic Benefit	Paybacks are typically short because the practice usually requires only a low-cost adjustment in procedures, rather than a capital investment.
Energy Savings	Savings vary from system to system depending on the condition of existing equipment and current operations.
Applications & Limitations	None, except for where potential water quality and/or distribution differences may require using one well instead of a more energy efficient one.
Practical Notes	This practice is easy to address since the data required to perform the analysis is already required for the annual Public Service Commission report.
Other Benefits	Utility personnel can more accurately gauge the upper limits of well production and system flexibility.
Stage of Acceptance	Widely accepted by the industry, but only a small number of utilities has adopted this practice. Its value is not generally understood.

W6 – Optimize Storage Capacity

Best Practice	Use storage capacity to minimize pumping requirements during peak demand periods for electric power. Develop a pumping and water distribution strategy to flatten electric demand during the peak periods, and shift as much pumping to off-peak periods as possible. • Track detailed water demand information by adding metering capabilities to water distribution and transmission lines. • Add or use existing storage capacity to minimize pumping costs during peak periods of electric power demand. • Use pressure sustaining or pressure reducing valves to assist in maintaining minimum pressure requirements in different regions of the water distribution system.
See Also	G 17 – Pumps: Reduce Pumping Flow.
Primary Area/Process	Water distribution systems.
Productivity Impact	This practice should have no impact on productivity.
Economic Benefit	Payback will depend on the extent of capital improvements such as addition of storage capacity, or no capital cost if only operational modifications are implemented.
Energy Savings	Savings are proportional to reduced electric demand charges.
Applications & Limitations	Capital cost of additional storage, new valves and additional metering has to be balanced with expected savings from reduced electric demand charges. Minimum pressure during peak flow periods and for fire protection must be maintained. Regulatory compliance should not be undermined and should always be a primary goal.
Practical Notes	None.
Other Benefits	Not applicable.
Stage of Acceptance	Widely accepted by the industry.

W7 – Promote Water Conservation

Best Practice	Reducing water consumption on the customer side reduces the energy needed to treat and distribute water. Conservation can also assist with managing diurnal and seasonal peak demand periods. • Assess water conserving plumbing fixtures and appliances and promote them within the community. • Use a multi-tiered residential rate structure that charges a higher rate for high consumption (also known as an "inclined block" or "inverted" rate structure). • Target all customer classes – residential, commercial, institutional, and industrial. • Offer water use audits for commercial and industrial customers. • Offer financial incentives for commercial and industrial customers to use more efficient systems for high water-use applications such as: cooling towers, ice making, laundry processing, medical imaging, and landscape irrigation.
See Also	G 17 – Pumps: Reduce Pumping Flow; W 8 – Sprinkling Reduction Program.
Primary Area/Process	All water utility customers, especially new construction and renovations requiring permits.
Productivity Impact	No impact.
Economic Benefit	Payback depends on campaign effectiveness and the number of fixtures replaced.
Energy Savings	Savings will depend on the number and types of fixtures and appliances that are replaced.
Applications & Limitations	All new construction and any renovations requiring permits. The transition from flat rates to metered and/or conservation rate structures can be politically sensitive and requires significant public education and outreach. Successful water conservation programs can actually reduce revenues for a utility, and the expected impact should be factored into program planning
Practical Notes	Develop a list of manufacturers that make water conserving fixtures and appliances, and make it available to all that inquire. The utility could also consider providing incentives to encourage water conservation or limiting landscape irrigation to overnight hours.
Other Benefits	Saving water, a limited resource. Also, helps consumers adjust to long-term water conservation without major impact on their lifestyles.
Stage of Acceptance	Water conserving fixtures and appliances are widely accepted in the industry and by consumers.

W8 – Sprinkling Reduction Program

Best Practice	Establish a customer program that manages lawn sprinkling to avoid peak time water consumption and minimizes duration of sprinkling. Automatic sprinkler systems have been shown to have a major impact on water use. Promoting this technology may help win public support.
See Also	W 7 - Promote Water Conservation.
Primary Area/Process	Residential water consumption/water distribution systems.
Productivity Impact	None. May have beneficial impact by reducing well drawdown during dry times.
Economic Benefit	Payback period will be very short, if not immediate, and begins when customers reduce their consumption.
Energy Savings	Potential energy savings, derived from reduced pumping costs, will vary with customers' sprinkling habits.
Applications & Limitations	While there are no physical limits regarding sprinkling regulations, gaining customer cooperation and enforcing the regulations are real challenges.
Practical Notes	The utility must assess summer use and the potential to affect peak summer water consumption through rules that regulate time and duration of lawn sprinkling. The effort requires an information campaign backed up with enforcement. The water utility can also consider providing guidance for landscaping practice to reduce irrigation requirements (xeriscaping).
Other Benefits	Saving water, a limited resource. Reduce well draw-down.
Stage of Acceptance	The effectiveness of this practice is widely understood and accepted. Still, public approval can be a challenge since restricting lawn sprinkling may be viewed as an infringement of personal rights.

W9 – Manage High Volume Users

Best Practice	Meet with the top four water users in your system to identify potential modifications to their operations that may reduce their water consumption, and consequently save energy.
See Also	Not applicable.
Primary Area/Process	Water distribution system.
Productivity Impact	No impact on the water utility. Any disruption during implementation would take place at the customers' facilities.
Economic Benefit	The payback for the water utility is nominal, since the cost is for promotion of the program. Customer payback varies with the amount of water conservation and the complexity of the measures needed to achieve the savings.
Energy Savings	Energy savings are proportional to the reduction in water consumption.
Applications & Limitations	Every water utility system has an economic limit on the amount of reduced consumption and the corresponding loss of revenue that can impact water utility rates.
Practical Notes	Take care to minimize water utility rate impacts by balancing reduced consumption with the potential reduction in utility revenues. Also, determine if customer peak usage of water can be shifted to off-peak times for both electric and water provision. Peak shifting of both electric and water consumption to off-peak demand periods, such as evening and nighttime hours, may benefit both customer and water utility.
Other Benefits	This practice may extend the life of water supply and distribution systems and may also postpone costly future expansions.
Stage of Acceptance	Not widely accepted due to the potential reduction in utility revenue. Typically, customers respond favorably to this concept as long as the suggested measures do not negatively impact production or operation.

Wastewater Best Practices

WW 1 – Operational Flexibility*
WW 2 – Staging Of Treatment Capacity*
WW 3 – Manage For Seasonal/Tourist Peaks*
WW 4 – Flexible Sequencing of Basin Use*
WW 5 – Optimize Aeration System*
WW 6 – Fine Bubble Aeration*
WW 7 – Variable Blower Air Flow Rate*
WW 8 – Dissolved Oxygen Control*
WW 9 – Post Aeration: Cascade Aeration
WW 10 – Sludge: Improve Solids Capture in DAF System
WW 11 – Sludge: Replace Centrifuge with Screw Press
WW 12 – Sludge: Replace Centrifuge with Gravity Belt Thickener
WW 13 – Biosolids Digestion Options*
WW 14 – Aerobic Digestion Options*
WW 15 – Biosolids Mixing Options in Aerobic Digesters*
WW 16 – Biosolids Mixing Options in Anaerobic Digesters*
WW 17 – Optimize Anaerobic Digester Performance
WW 18 – Use Biogas to Produce Heat and/or Power
WW 19 – Cover Basins for Heat Reduction*
WW 20 – Recover Excess Heat from Wastewater*
WW 21 – Reduce Fresh Water Consumption/Final Effluent Recycling*

WW1 – Operational Flexibility

Best Practice	Evaluate facility loadings and become familiar with the treatment systems in order to identify, plan, and design the most efficient and effective ways to operate the system. This may include: - operating fewer aeration tanks - installing variable frequency drives so equipment operation can match system loadings - installing dissolved oxygen monitoring and control equipment - idling an aeration tank during low-flow periods - reducing air flow to the aeration tanks during low-load periods (usually nights and weekends) - waiting to recycle supernatant during lower-flow periods, avoiding periods of high organic loading - operating diffusers or recycling backwash water during off-peak power demand periods.
See Also	G 12 – Electric Motors: Variable Frequency Drives Applications; WW 2 – Staging of Treatment Capacity; WW 3 – Manage for Seasonal/Tourist Peaks; WW 4 – Flexible Sequencing of Basin Use; WW 5 – Optimize Aeration System; W 8 – Dissolved Oxygen Control.
Primary Area/Process	This practice applies to secondary treatment processes, all pumping operations, and biosolids management.
Productivity Impact	Implementation usually involves changes to operations so there should be little or no impact on production.
Economic Benefit	Payback is generally within two years since most of the modifications are operational and will not incur significant capital costs.
Energy Savings	Energy savings will vary depending on the adjustment. A typical range is from 10% to 25%.
Applications & Limitations	All facilities should implement this practice to save on operating costs.
Practical Notes	This practice is best implemented with a committed energy management plan as described in the first section of this handbook, and where the flexibility of facility operations is feasible.
Other Benefits	Operations personnel will gain a better understanding of the capabilities of the treatment system they control.
Stage of Acceptance	Many facilities accept the need to adjust operations responsive to loadings after learning the magnitude of savings available.

WW2 – Staging of Treatment Capacity

Best Practice	When planning improvements, wastewater system personnel and designers should develop a team approach wherein they determine how modifications will effectively and efficiently meet current and projected conditions. Staging upgrades in capacity can help optimize system response to demand and also reduce energy costs.
See Also	WW 1 – Operational Flexibility.
Primary Area/Process	Staging is most applicable to the major energy users in a system, typically the secondary treatment process, pumping and biosolids management.
Productivity Impact	Usually a system will operate most efficiently when loaded nearer to its design load; therefore, staged systems will generally function more efficiently as the system grows.
Economic Benefit	The simple payback period will usually be less than two years because minimal modifications are required to implement staging.
Energy Savings	Proper staging of treatment capacity can achieve a savings of 10% to 30% of the total energy consumed by a unit process.
Applications & Limitations	Staging is applicable to all systems.
Practical Notes	Usually staging has a minor impact on construction and scheduling in exchange for the energy savings realized.
Other Benefits	Improved control of the system.
Stage of Acceptance	Staging of treatment capacity is gaining acceptance within the wastewater industry; however, it is not readily adopted because of the belief that the entire system must be constructed immediately, rather than efficiently staging a system and bringing components online as needed.

WW3 – Manage for Seasonal/Tourist Peaks

Best Practice	Flexible system design allows a utility to adjust and operate more efficiently during peak tourist loadings as well as during the "off-season." In many areas tourism-related loadings versus off-season may reach as high as 10:1. This may require removing tankage, that is used during tourist season, from service during the off-season.
See Also	WW 1 – Operational Flexibility.
Primary Area/Process	Primary area of focus is the secondary treatment process aeration system.
Productivity Impact	There is no productivity impact other than brief interruptions while new equipment is installed or placed into operation, if needed.
Economic Benefit	Most retrofit aeration modifications have paybacks of four-years-to six-years. If the concept is integrated into the design of new construction, the payback should be less.
Energy Savings	Savings can vary, but can reach 50% during the off-season.
Applications & Limitations	Environmental and/or climatic considerations must be accounted for to prevent damage to seasonally out-of-service equipment.
Practical Notes	This strategy needs to be carefully analyzed to ensure that adequate treatment can be provided during the tourist season. The aeration tanks must be sized so they can be taken off line during the off-season. It helps to have several years of facility loading data and utility bills to assess seasonal variation to define the on- and off-peak seasons and their respective peak loadings for proper sizing of equipment.
Other Benefits	If the secondary treatment process is improved, generally the functions of other processes improve.
Stage of Acceptance	These concepts are well known, understood, and widely accepted.

WW4 – Flexible Sequencing of Basin Use

Best Practice	The selection of basin sizes can have a large impact on the energy consumed at a facility during its lifetime. The facility design team should review the existing and projected organic loadings to identify the best selection of tank sizes. Typically, the use of smaller sized basins is beneficial so that initial loadings can be near the capacity of a smaller basin. The remaining basins can then be loaded sequentially until design capacity is met. This approach allows for energy efficient operation from start-up to design flow conditions.
See Also	WW 1 – Operational Flexibility.
Primary Area/Process	Secondary treatment processes, particularly activated sludge treatment facilities.
Productivity Impact	None.
Economic Benefit	Payback for constructing multiple tanks will depend on space availability at the site. Implementation can be as simple as adding an interior wall to subdivide an existing tank. This can provide a two-year-to three-year payback. Payback may take three-years-to five-years for major site modifications.
Energy Savings	Energy savings of 15% to 40% are common if multiple smaller tanks are available to step the system into operations, compared with having only two large tanks.
Applications & Limitations	All facilities should consider operational flexibility to be sure they can manage the ever-changing facility loads.
Practical Notes	Facility personnel should work closely with designers throughout the design process. Information on the sizes and operation of basins required for a treatment process is invaluable. Operating more fully-loaded smaller tanks, versus operating larger, under-loaded tanks, is preferable. Using intermediate tank walls (division walls) may be a simple, acceptable solution.
Other Benefits	Improves overall operation of the facility.
Stage of Acceptance	Acceptance varies from site to site based on facility staff preferences and experiences with maintenance of empty tanks.

WW5 – Optimize Aeration System

Best Practice	Determine whether the aeration system is operating as efficiently as possible for the required level of treatment. Assess present loading conditions and system performance through a comparison of kWh/MG and other key performance indicators with those of similar facilities. Consider the potential benefits and costs of improvements such as fine-bubble aeration, dissolved oxygen control and variable air flow rate blowers.
See Also	WW 1 – Operational Flexibility; WW 6 – Fine Bubble Aeration; WW 7 – Variable Blower Air Flow Rate; WW 8 – Dissolved Oxygen Control.
Primary Area/Process	Secondary treatment process activated sludge, aerobic digestion, and post aeration systems are the principal treatment processes where this energy saving practice can be implemented.
Productivity Impact	Modified aeration systems have also resulted in savings for other treatment unit processes. Savings have materialized in biosolids processing, particularly in reducing the polymer dosage for biosolids thickening and dewatering. Treatment capabilities have been increased at most facilities.
Economic Benefit	The payback period is generally three-years-to seven-years for retrofits and about one year for new construction.
Energy Savings	Savings of 30% to 70% of total aeration system energy consumption are typical.
Applications & Limitations	All aerated treatment systems.
Practical Notes	The best practice should be implemented at all facilities unless there is an overwhelming reason to avoid it.
Other Benefits	Improvement in other unit treatment processes on site and reduced maintenance at some installations.
Stage of Acceptance	Fine-bubble aeration methods are widely accepted, as are dissolved oxygen control systems and various methods of controlling the flow rate of air to the treatment process.

WW6 – Fine-Bubble Aeration

Best Practice	Assess the feasibility of implementing fine bubble aeration at activated sludge treatment facilities. This practice provides energy efficient treatment of wastewater. It can be installed in new or existing systems. The technology usually improves operations and increases the organic treatment capability of a wastewater treatment facility. For optimum performance, combine this practice with dissolved oxygen monitoring and control, and a variable capacity blower. Plan for periodic diffuser cleaning (in-place gas cleaning system or scheduled drain and manual cleaning), as diffuser fouling influences system pressure and oxygen transfer efficiency.
See Also	WW 5 – Optimize Aeration System; WW 7 – Variable Blower Air Flow Rate; WW 8 – Dissolved Oxygen Control.
Primary Area/Process	Primary application for this practice will be on aeration tanks and aerobic digesters.
Productivity Impact	A minor impact on production during installation.
Economic Benefit	Economic benefits vary from new facilities to retrofit applications. A new system may pay back in as little as one year. Payback on a retrofit will vary depending on the inefficiency of the existing system and the amount of new equipment required.
Energy Savings	Energy savings range from 20% to 75% of the aeration or aerobic digestion unit's energy consumption.
Applications & Limitations	This practice applies to all aeration systems. A limit exists for aerobic digestion – if the system operates at a solids concentration of 2.5% or greater, further review must be done.
Practical Notes	Fine bubble technologies have applications for all sizes of wastewater treatment facilities. The percentage range of energy savings will be similar regardless of facility size.
Other Benefits	Most sites that have implemented this practice report improved biosolids management, reduced polymer use, and experienced better clarification and better overall effluent.
Stage of Acceptance	This technology has gained a high level of acceptance within the industry.

WW7 – Variable Blower Air Flow Rate

Best Practice	Require that aeration system and aerobic digester blowers have variable air supply rate capability, such as single stage centrifugal blowers with VFD, positive displacement blowers with VFD, and inlet guide-controlled multi-stage centrifugal blowers. The range of variability should respond to the specific requirements a site needs to precisely match system demands. The blower system should be able to supply the minimum air flow required to meet existing lowload conditions or mixing, and to meet the high loads of design conditions. Avoid air flow discharge throttling.
See Also	WW 5 – Optimize Aeration System; WW 6 – Fine Bubble Aeration; WW 8 – Dissolved Oxygen Control; G 12 – Electric Motors: Variable Frequency Drives Applications.
Primary Area/Process	This practice applies to all aeration systems, including activated sludge aeration tanks and aerobic digestion systems.
Productivity Impact	Interruption in production should occur only during installation.
Economic Benefit	Payback is usually under three years.
Energy Savings	Energy savings depend on site conditions and which parameter, mixing or organic loading, dictates the lesser amount of air flow. Savings will range from 15% to 50% of the energy consumed by this process.
Applications & Limitations	This practice can be applied wherever blowers are installed.
Practical Notes	Variable air flow rate blowers should be integrated with fine-bubble aeration and dissolved oxygen monitoring and control for optimum energy efficiency. Also consider the potential advantages of replacing two blowers and staging loadings with three, four, or five smaller units that can both meet current and future demands.
Other Benefits	When teamed with fine-bubble diffusers and dissolved oxygen (DO) control technologies, effluent quality and biosolids processing are usually improved.
Stage of Acceptance	Technologies for varying air flow rates are well received. Variable speed positive displacement blower arrangements and variable capacity centrifugal blowers are becoming more available and well known.
Resources	The Department of Energy (DOE) has developed a tool—the Fan System Assessment Tool (FSAT)—that can be used to determine the achievable and optimum efficiencies for the selected blower type at the specified operating conditions. This tool can be used to calculate the energy savings based on the difference between the anticipated energy use of a high-efficiency blower and the baseline energy use.

WW8 – Dissolved Oxygen Control

Best Practice	Consider dissolved oxygen monitoring and control technology that will maintain the dissolved oxygen (DO) level of the aeration tank(s) at a preset control point by varying the air flow rate to the aeration system.
See Also	WW 1 – Operational Flexibility; WW 5 – Optimize Aeration System; WW 6 – Fine Bubble Aeration; WW 7 – Variable Blower Air Flow Rate.
Primary Area/Process	The primary applications are aeration tanks at activated sludge facilities and aerobic digestion and post aeration systems.
Productivity Impact	Installation of most systems can be accomplished without interfering with normal operation.
Economic Benefit	Paybacks from improved monitoring and controls using DO control are two-years-to three-years.
Energy Savings	Savings vary depending on the efficiency of the present system. Generally, energy savings for the aeration system are in the 20% to 50% range.
Applications & Limitations	Limitations will vary with characteristics of the waste being treated. If the waste has characteristics that would easily foul the DO probe, then the system will not be readily applicable.
Practical Notes	This control should be employed at post aeration systems, and wherever activated sludge is used as the secondary treatment process. Variable flow may be established with variable frequency drives (VFDs).
Other Benefits	Waste biosolids from a DO controlled system have reportedly better dewatering characteristics. Also, a DO controlled system usually has fewer problems treating a fluctuating influent load.
Stage of Acceptance	DO control is a well accepted control methodology. The primary factor affecting acceptance is the reliability and associated maintenance related to DO probes.

WW9 – Post Aeration: Cascade Aeration

Best Practice	Consider the installation of a cascade aeration system for post aeration applications. If the topography is favorable, this technology provides re-aeration of the effluent by increasing the water turbulence over the steps, with no need for electricity.
See Also	Not applicable.
Primary Area/Process	Post aeration of wastewater treatment plants effluent.
Productivity Impact	Installation can be accomplished without interfering with normal operation.
Economic Benefit	Payback varies depending on the existing post aeration system used.
Energy Savings	If cascade aeration is used to replace an existing post aeration system with a subsurface diffuser system and blowers, 100% of the electricity used is going to be saved.
Applications & Limitations	The application is site specific. At least 10 to 15 feet of head are needed between the plant effluent point and the final discharge, due to the low oxygen transfer rate and the temperature dependency of oxygen transfer.
Practical Notes	None.
Other Benefits	Not applicable.
Stage of Acceptance	Cascade aeration for effluent re-aeration is a well accepted method.

WW10 – Sludge: Improve Solids Capture in DAF System

Best Practice	Optimize the air-to-solids ratio in a Dissolved Air Flotation (DAF) system by adjusting the supply air and/or feeding the highest possible solids content. Additionally, energy use can be reduced by operating the DAF thickener continuously and adding polymers to the sludge.
See Also	Not applicable.
Primary Area/Process	DAF thickeners are used in sludge dewatering and thickening processes.
Productivity Impact	No impact.
Economic Benefit	DAF thickeners have high operating costs because they require a significant amount of energy for air pressurization. Payback will vary depending on the degree of optimization.
Energy Savings	Energy use can be reduced by improving solids capture. Savings will depend on the application.
Applications & Limitations	Continuous operation of the DAF thickener and addition of polymers can increase O&M or labor costs.
Practical Notes	None.
Other Benefits	Improved solids capture will benefit the other sludge treatment processes of sludge thickening downstream.
Stage of Acceptance	Widely accepted by the industry.

WW11 – Sludge: Replace Centrifuge with Screw Press

Best Practice	Replace the sludge dewatering centrifuge with a screw press for energy savings.
See Also	WW 12 – Sludge: Replace Centrifuge with Gravity Belt Thickener.
Primary Area/Process	Sludge dewatering and thickening.
Productivity Impact	Minimal impact during installation and replacement of equipment.
Economic Benefit	Payback will depend on the size of the application.
Energy Savings	Potentially high energy savings can be obtained by this best practice.
Applications & Limitations	A centrifuge is a relatively large energy consumer. Replacing a centrifuge with a screw press saves energy, due to the simple, slow-moving mechanical dewatering equipment that continuously dewaters the sludge by gravity drainage. The primary disadvantages with a screw press include potential for odor problems and larger space requirements. Solids thickening impacts energy use in sludge digestion, dewatering, and disposal. The screw press produces sludge with a lower solids concentration than a centrifuge, therefore the full life cycle of solids operation must be considered for cost effective operation.
Practical Notes	When designing sludge dewatering equipment it is more efficient to fit the minimum size equipment for the dewatering requirements and have the plant running continuously, than to install oversized equipment that runs for just a few hours per day. This can save energy in two ways. First, any sludge that is held in liquid form before dewatering will need to be agitated or aerated, both of which require unnecessary power. Second, smaller dewatering equipment will require smaller motors. Sludge-cake storage and transportation requirements must be considered prior to commencing 24-hour sludge dewatering operations.
Other Benefits	In addition to lower energy consumption, the screw press also has lower operation and maintenance costs than the centrifuge. Furthermore, the screw press can produce Class A biosolids if modified (by adding heat).
Stage of Acceptance	Screw presses are widely accepted for sludge dewatering.

WW12 – Sludge: Replace Centrifuge with Gravity Belt Thickener

Best Practice	Replace centrifuge with gravity belt thickener for improved sludge thickening.
See Also	WW 11 – Sludge: Replace Centrifuge with Screw Press.
Primary Area/Process	Sludge dewatering and thickening.
Productivity Impact	Minimal impact during installation and replacement of equipment.
Economic Benefit	Payback will depend on the size of the application.
Energy Savings	Potentially high energy savings can be obtained by this best practice.
Applications & Limitations	A gravity belt thickener consists of a gravity belt driven by a motor. As the sludge makes its way down the horizontally-moving belt, water drains through the porous belt. The solids are continuously turned to improve the drainage process. Solids thickening impacts energy use in sludge digestion, dewatering, and disposal. The gravity belt thickener produces sludge with a lower solids concentration than a centrifuge, therefore the full life cycle of solids operation must be considered for cost effective operation.
Practical Notes	None.
Other Benefits	Other advantages associated with gravity belt thickeners include small space requirements and ease of automation and control.
Stage of Acceptance	Gravity belt thickeners are widely accepted for sludge thickening.

WW13 – Biosolids Digestion Options

Best Practice	When planning new facilities or expansion, assess the energy and production impacts of various biosolids process options. Standard aerobic digestion of biosolids is energy intensive compared to fine-bubble diffusers with dissolved oxygen control and a variable air-flow rate blower. Some locations currently turn off the air-flow to the digester over extended periods of time to further reduce energy costs. Anaerobic digestion requires detailed assessment. While the capital cost of an anaerobic system is considerably greater than for an aerobic system, an anaerobic system will consume less energy and can produce biogas for energy production to help offset capital costs. Both types of systems should be considered.
See Also	WW 14 – Aerobic Digestion Options; WW 17 – Optimize Anaerobic Digester Performance.
Primary Area/Process	This practice applies to biosolids treatment and management.
Productivity Impact	The energy impact of recycling supernatant by each process should be assessed.
Economic Benefit	Payback will vary considerably from site to site and should be determined on a system specific basis.
Energy Savings	Both aerobic and anaerobic systems should be considered to determine the most energy efficient option.
Applications & Limitations	Each facility must identify the class of biosolids it wants to produce, which will affect the type of biosolids treatment selected.
Practical Notes	Operators should include all site specific parameters for the assessment, particularly the amount of energy both consumed and produced by each process.
Other Benefits	Each type of treatment process affects the characteristics of the solids product, which in turn affects production rates and thickening and dewatering capabilities.
Stage of Acceptance	Both aerobic and anaerobic biosolids digestion are readily available and widely accepted treatment processes.

WW14 – Aerobic Digestion Options

Best Practice	Assess your aerobic digester operation to determine if a smaller blower and/or using fine-bubble diffusers and equipment with adjustable airflow rates would provide better control of airflow. Many facilities operate aerobic digesters with surface aerators or coarse-bubble diffusers with limited ability to modify or control air flow delivered to the process. First, consider fine-bubble diffusers, which allow for variable airflow rates in digester applications. Second, choose equipment and/or controls with adjustable airflow rates. Often, air for the digestion process is bled from the secondary treatment process activated sludge blowers, allowing little or no control over the airflow delivered.
See Also	WW 5 – Optimize Aeration System; WW 6 – Fine Bubble Aeration; WW 7 – Variable Blower Air Flow Rate; WW 8 – Dissolved Oxygen Control; WW 13 – Biosolids Digestion Options; WW 15 – Biosolids Mixing Options in Aerobic Digesters.
Primary Area/Process	Applies to biosolids treatment and management.
Productivity Impact	Conversion to fine-bubble diffuser technology may improve reduction of volatile solids.
Economic Benefit	Payback varies with the modifications required.
Energy Savings	Application of fine-bubble diffusers in an aerobic digestion system can reduce energy consumption for the process by 20% to 50%.
Applications & Limitations	The key limitation is the final concentration of total suspended solids (TSS) in the digester. Operators may want to be involved in control of the concentration of TSS to maintain applicability of fine-bubble. Mixing can also be a limitation.
Practical Notes	This best practice is applicable to most systems, but will typically require that the diffusers and blowers be replaced. Some piping modifications may also be required.
Other Benefits	Fine-bubble aeration reportedly improves biosolids dewatering, reduces polymer demand when the digested biosolids are dewatered or thickened, results in less pin floc in the biosolids processing, improves reduction of volatile solids, improves decanting from the digester and reduces the volume of biosolids to be disposed.
Stage of Acceptance	This technology is readily available and widely accepted except in situations where the solids concentration within the digester exceeds 2.5% of total solids.

WW15 – Biosolids Mixing Options in Aerobic Digesters

Best Practice	Biosolids mixing is an energy intensive task that should be addressed in aerobic digestion. Mixing is generally provided by aeration, mechanical mixing, pumping or a combination of these methods. Aeration of the biosolids mass is required to destroy volatile solids and control odor. Still, aeration may not be the most energy-efficient way to provide complete mixing in a digester, especially if constant aeration is not required. Evaluate the energy costs of available options to identify the best technology for the site. A combination of mixing methods that will permit the system to be completely turned off periodically may be most practical.
See Also	WW 14 – Aerobic Digestion Options.
Primary Area/Process	This practice applies to all aerobic digestion systems.
Productivity Impact	No impact on productivity. A disruption should only occur during installation and start up.
Economic Benefit	The payback period for a retrofit condition will typically take one-year-to three-years. A new installation payback may only take one year.
Energy Savings	The potential energy savings will vary by application but can be as high as 50%.
Applications & Limitations	The limiting factor is the solids concentration in the aerobic digester.
Practical Notes	The solids concentration of the digester contents should be controlled to an approximate maximum suspended solids concentration of 2.5%.
Other Benefits	Improved volatile solids reduction
Stage of Acceptance	Mixing technologies, including a combination of a mixing regime and an aeration methodology, are accepted by the wastewater industry.

WW16 – Biosolids Mixing Options in Anaerobic Digesters

Best Practice	The contents of an anaerobic digester must be mixed for proper operation, the destruction of volatile suspended solids, and the production of biogas. Mixing is generally accomplished by injecting biogas into the bottom of the digester and having it pass through the contents of the tank. Some sites also continually pump the contents to provide mixing. Mechanical mixing can also be used to achieve a higher level of volatile solids destruction and greater biogas production.
See Also	WW 17 – Optimize Anaerobic Digester Performance.
Primary Area/Process	This practice applies to the anaerobic digestion of biosolids.
Productivity Impact	Disruption in production should only occur during installation and while the biological environment evolves to make the anaerobic system function.
Economic Benefit	Payback depends on whether the system is new construction or a retrofit of an existing system. Payback for a retrofitted system will take longer.
Energy Savings	Energy savings will vary substantially depending on the specific site conditions.
Applications & Limitations	Mixing should be employed by all anaerobic digestion systems to maximize volatile solids destruction and maximize biogas production.
Practical Notes	The various methods of mixing must be evaluated to identify the best option. It is important to assess the production and beneficial use of biogas.
Other Benefits	Maximizing the production of biogas may provide a lucrative renewable energy opportunity.
Stage of Acceptance	Various mixing technologies are widely accepted throughout the industry.

WW17 – Optimize Anaerobic Digester Performance

Best Practice	Optimize anaerobic digester performance and enhance biogas production. Primary ways of optimizing anaerobic digestion are: • Optimizing process temperature: changing the digester operating temperature from mesophilic (85-105 °F) to thermophilic (125-140 °F) increases the rate of destruction of the volatile solids in the sludge. Two-phased anaerobic digestion and temperature-phased digestion have shown potential benefits in volatile solids reduction and biogas enhancement. • Sludge pre-treatment: The hydrolysis step is often the limiting factor in anaerobic digestion. Hydrolysis can be improved by pre-treatment to enhance the ability of microorganisms to digest the sludge. There are various pre-treatment methods available, including chemical, physical, and biological methods. Three of the most promising methods include thermal treatment, ultrasonic treatment, and enzyme dosing. • Co-digestion of other wastes: It is often beneficial to co-digest sludge with other types of organic waste, such as restaurant grease, vegetable/fruit waste, and municipal organic waste. By doing so, the nutrient and moisture content can be optimized, process stability can be improved, and biogas yield enhanced substantially.
See Also	WW 18 – Use Biogas to Produce Heat and/or Power.
Primary Area/Process	Anaerobic sludge digestion.
Productivity Impact	Minimal impact during installation of equipment.
Economic Benefit	The economic benefit of increased biogas production may be reduced by the cost of sludge pre-treatment equipment, most of which is proprietary. Acceptance of other waste can generate revenue for the WWTP.
Energy Savings	Energy savings will be proportional to the additional production of biogas for power and/or heat generation.
Applications & Limitations	None.
Practical Notes	Optimization of the anaerobic digester performance will benefit sludge quality for downstream sludge processing, treatment and disposal.
Other Benefits	Not applicable.
Stage of Acceptance	These optimization techniques are not widely used, but are gaining industry interest.

WW18 – Use Biogas to Produce Heat and/or Power

Best Practice	Biogas produced in an anaerobic digester can be used to generate electricity with reciprocating engines, microturbines, turbines, or fuel cells. The thermal energy generated by these systems can often be used to meet digester heat loads and for space heating. Alternatively, the biogas can be used directly as boiler fuel for the production of heat.
See Also	WW 17 – Optimize Anaerobic Digester Performance.
Primary Area/Process	Anaerobic sludge digestion.
Productivity Impact	Minimal impact during installation of combined heat and power system.
Economic Benefit	Biogas-to-electricity systems are typically cost-effective options for WWTPs with an average influent flow greater than 5-mgd, that have installed or are planning to install anaerobic digesters.
Energy Savings	A commonly used rule states that the biogas generated from each 4.4 mgd of influent generates approximately 100 kW of electricity and 12.5 MMBtu of thermal energy in a combined heat and power (CHP) system.
Applications & Limitations	The level of hydrogen sulfide (H_2S) in digester gas and the moisture content will influence both the economic and technical decision to install a combined heat and power (CHP) system. High H_2S levels in the gas will cause corrosion in the engines; it may therefore be necessary to install gas scrubbers to lower the H_2S level. Most CHP suppliers claim that only levels higher than 1,000 ppm would justify the installation of gas scrubbers. Other trace compounds contained in the digester gas, such as siloxanes, can cause deleterious effects to combustion devices.
Practical Notes	Reciprocating engines can be used for a majority of WWTP sizes. Microturbines and fuel cells are available in smaller capacity sizes for small WWTPs, where emissions are a concern. Combustion turbines can be used for WWTPs with greater than 1-MW capacity.
Other Benefits	Collecting and using biogas avoids venting and flaring, that contribute to greenhouse gases without beneficial use.
Stage of Acceptance	Combined heat and power systems are gaining popularity in the wastewater sector.

WW19 – Cover Basins for Heat Reduction

Best Practice	In northern climates, basins are often covered to prevent the contents from freezing. This practice reduces, or possibly eliminates, the energy used to thaw equipment or tanks. For tanks located in rooms where frequent air changes are required, basins can be covered to reduce the requisite volume of air. Recovery of waste heat from the exhaust air or blending with outside air can provide additional savings.
See Also	Not applicable.
Primary Area/Process	This practice may be applied to any open tank treatment process including grit removal, comminution, clarification, aeration, gravity thickeners, aerobic digesters, biosolids holding tanks, and disinfection tanks.
Productivity Impact	Installation of covers would interrupt the use of a tank for a limited time during installation.
Economic Benefit	Payback depends on the number of tanks and the fuel used to thaw any frozen items, or the size of the room where tanks are located. The payback period will increase with the amount of equipment needed to implement this practice.
Energy Savings	Savings vary depending on the number of open tanks on site and the total storage volume.
Applications & Limitations	Limitations are related to weather conditions. The colder the climate, the better the application.
Practical Notes	Many enclosure materials are available. Information on these materials can be found on manufacturers' web sites.
Other Benefits	Reduced odor and aerosol control are auxiliary benefits from covering a structure. Operations will improve as a result of maintaining a more consistent temperature.
Stage of Acceptance	Covering open tanks is a widely accepted practice throughout the industry. Nevertheless, in most instances the tanks are being covered for odor or aerosol control. Covering systems as an energy efficiency measure is gaining acceptance.

WW20 – Recover Excess Heat from Wastewater

Best Practice	Recover excess heat from wastewater prior to its treatment and/or discharge to use at or near the wastewater treatment facility. Some industrial wastewater systems have a large volume of low grade heat available in their wastewater (typically able to provide 20°F to 25°F).
See Also	Not applicable.
Primary Area/Process	Wastewater stream processes where heat recovery is feasible, especially where the demand for additional heat is nearby.
Productivity Impact	There are possible minor disruptions during installation of piping and equipment and during start up.
Economic Benefit	The payback period is typically short (less than two years) but this varies and is a direct function of the distance between the heat source and where it is used.
Energy Savings	The total value of heat energy available varies depending on site characteristics. The heat value available can be in the millions of therms per year.
Applications & Limitations	Use of low grade heat is a challenge. In many applications it can be used to preheat influent river or well water to a tepid temperature (preheating influent raw water). Even if the available heat is insufficient to completely heat process streams, partial heating can reduce heating fuel costs and yield significant benefits. The distance between the heat recovery source and the application determines the economic feasibility.
Practical Notes	In order to optimize the use of waste heat, assess the locations within the facility where the waste heat could be captured at higher temperatures before mixing it with other wastewater streams to maximize the overall temperature differential and heat transfer potential.
Other Benefits	Warming raw water usually decreases the amount of pretreatment chemicals required for conditioning.
Stage of Acceptance	This process is accepted, but often not used, because the heat source is low grade. Operators often mistakenly perceive that partial heating, as opposed to complete heating, is insufficient and not worth it.

WW21 – Reduce Fresh Water Consumption/Final Effluent Recycling

Best Practice	Reducing the consumption of potable water through the use of final effluent (FE) in process applications or wash down of tanks may save energy by limiting the volume of water treated and/or pumped. The FE system should include a pressure tank and pump control system, where appropriate, and direct pumping where consistently high pressure is required (belt press). Additional applications are possible with an inline filter prior to each application.
See Also	Not applicable.
Primary Area/Process	Typical applications are in the recycle system for tank wash-down, gravity belt thickener, belt wash water, belt press, belt wash water, cooling water for a compressor, etc.
Productivity Impact	No impacts are expected, other than minor interruptions during the installation of any required equipment.
Economic Benefit	Payback periods for this best practice are typically two-years-to three-years and will vary with the volume of potable water currently used.
Energy Savings	Savings may reach 50% of the total system energy if the existing system does not use a pressure tank system to regulate supply.
Applications & Limitations	Application is limited by the quality of effluent available for recycling.
Practical Notes	This best practice is usually implemented when the final effluent quality is sufficiently high that its use will not hamper the function of pumps, hoses and nozzles used in its distribution. The practice is also cost effective when large volumes of wash water are required, such as for biosolids processing or facility wash down.
Other Benefits	Other potential benefits associated with this measure include reducing well water consumption, reducing operation of booster pumps, where applicable, and possibly eliminating the need for two water distribution systems throughout the facility.
Stage of Acceptance	Reducing the volume of potable water used in the wastewater treatment process is widely accepted throughout the industry.

Buildings Best Practices

B1 – Install VFD Control on Air Compressors

Best Practice	Compressors produce low volumes of air at 80-to-140 psi. Most air compressors are rotary screw-type and are typically operated in an inlet modulation with unloading mode. In this control scheme, the air compressor produces compressed air until a desired value is reached, at which point it begins modulating and then unloads. When it unloads, the air compressor continues rotating until the maximum pressure value is reached. The unload mode is highly inefficient because it still requires about 20% of its full electrical load. Replacing the inlet modulation with an unload mode control scheme with a VFD-controlled rotaryscrew air compressor saves energy, especially in part-load operation.
See Also	G 12 – Electric Motors: Variable Frequency Drives Applications.
Primary Area/Process	Air compressors are often found in machine shops where they are used for various maintenance functions. They are also used to feed aeration basins and operate hydraulic drives and pumps.
Productivity Impact	Better constant pressure compressed air can be more productive, since there may be no slowdowns in air usage or possible reduction in air needed.
Economic Benefit	Payback depends on the operating hours and size of the compressor.
Energy Savings	Energy savings depend on the operating hours and size of the compressor.
Applications & Limitations	None.
Practical Notes	None.
Other Benefits	Not applicable.
Stage of Acceptance	Widely accepted by the industry.

B2 – Install High-Efficiency Lighting

Best Practice	Incandescent lamps can be replaced with compact fluorescent lamps (CFLs), which come in all shapes and sizes and can directly replace most incandescent lamps in most fixtures. In addition, fluorescent dimming is now available for both linear fluorescent T-8 and compact fluorescent lamps. Outdoor lighting, warehouse lighting, and indoor lighting with ceiling heights exceeding 15 feet typically use a high intensity discharge (HID) type lamp, such as mercury vapor lamps, high pressure sodium lamps, or metal halide lamps. Mercury vapor lamps are an old and inefficient technology that should generally be replaced. If the color of the light is not an issue, then high-pressure sodium lamps can provide a very efficient source of light. Otherwise, replacing mercury vapor lamps with pulse start metal halide lamps is often the best option where white light is desirable. High output Fluorescent T8s or T5s should also be looked into since they have high efficacy and can produce significant amounts of savings. Furthermore, fluorescent lights are now able to work at 20°F or colder and are a viable option for lower wattage outdoor lighting.
See Also	Not applicable.
Primary Area/Process	Buildings, process areas, hallways, high bay applications, offices and parking lots.
Productivity Impact	Lighting quality can have significant impacts on productivity.
Economic Benefit	Payback depends on the number and type of lights being replaced, and is typically less than four years.
Energy Savings	Energy savings depend on the number and type of lights being replaced, but typical lighting projects can reduce the electrical lighting energy needed by 30% or more.
Applications & Limitations	Look for the ENERGY STAR label, and Consortium for Energy Efficiency (CEE) qualified fixtures on replacement lighting.
Practical Notes	Lighting projects usually have a short simple payback period, and can often be used to help finance additional energy work.
Other Benefits	Not applicable.
Stage of Acceptance	Generally accepted, as long as the color of the new lights is not an issue.

B3 – Clean Lamps and Fixtures

Best Practice	Dirt can accumulate on lamps and fixtures, resulting in a decrease in light output ranging from 5-50%. Fixtures and lamps should be washed on a regular schedule using the proper cleaning solution. The frequency of cleaning depends on the amount and type of dirt in the air, whether the fixture is of the ventilated or non-ventilated type, and the location of the lighting. Older style fluorescent lamps last as little as three years; therefore, it may not be necessary to clean between lamp replacements. Newer fluorescent lamps can last up to 10 years and therefore must be cleaned regularly. Most normal maintenance procedures call for lamps and fixtures to be cleaned on an annual basis but that may be difficult to accomplish with limited staff. Frequent cleaning may be required if the room is exposed to large amounts of dust and grease, if the lamps are directed upward without protection from falling dust, or if the lighting is outside. Many luminaries initially provide the same illumination level, but their ability to be economically maintained and to continue their maximum effectiveness is dependent on quality and appropriateness. Properly selected fixtures can reduce the need for cleaning or can simplify the cleaning process.
See Also	Not applicable.
Primary Area/Process	All Lighting.
Productivity Impact	Cleaner fixtures mean more lighting output, and brighter spaces. Better lighting can increase productivity.
Economic Benefit	This practice can ensure that the fixtures can remain in service for the duration of their expected life, which can save capital funding for when full replacements are necessary.
Energy Savings	None.
Applications & Limitations	None.
Practical Notes	None.
Other Benefits	Not applicable.
Stage of Acceptance	Well accepted.

B4 – Monitor Light Operation

Best Practice	Manually switching off lights is one of the best no-cost methods of saving lighting energy. With the exception of security lights and exit signs, turn off, and make staff aware of how to turn on and off, all lights and signage when daylight is sufficient or whenever they are not needed. Occupancy sensors use various detection technologies to turn off lights in unoccupied areas. Occupancy sensors can potentially be installed in conference rooms, restrooms, storage areas, and other spaces prone to intermittent occupancy that have lighting that is left on. Unilaterally installing occupancy sensors without understanding of the use of the space can lead to spending unnecessary additional capital.
See Also	Not applicable.
Primary Area/Process	Areas that have intermittent or low personnel usage.
Productivity Impact	No impact.
Economic Benefit	Occupancy sensors are relatively inexpensive, with installation costs typically ranging from $50 to $150 per sensor, but can have a significant impact on energy savings.
Energy Savings	Typical energy savings from occupancy sensors range from 15 to 90%, depending on type and use of space. For example, occupancy sensors integrated with bi-level fluorescent lighting can provide substantial energy savings in hallways, stairways, and warehouses.
Applications & Limitations	Limited application in high traffic areas due to excess cycling of lighting fixtures, which can decrease fixture life expectancy.
Practical Notes	None.
Other Benefits	Not applicable.
Stage of Acceptance	Widely accepted.

B5 – Maintain Boilers and Furnaces

Best Practice	Burners should be inspected several times per year. Replacing damaged burner tips, and removing soot and other deposits from the burners will improve heat transfer and burner efficiency and will ensure smooth ignition and proper flame. It is also necessary to clean the heat transfer surfaces within boilers and furnaces annually to eliminate fouling and scale and to maximize heat transfer efficiency. Boilers need to be inspected for leaks and damaged insulation. Repairing leaks in pipes, connections, and ducting, as well as repairing or replacing poor insulation on boiler jackets, condensate and feedwater tanks, hot water pipes, and air ducts will reduce heat loss and energy consumption. A malfunctioning steam trap can waste a large amount of energy. It is also important to clean the boiler tubes and monitor the temperature of stack gases.
See Also	Not applicable.
Primary Area/Process	Buildings.
Productivity Impact	No impact.
Economic Benefit	Cost savings may be achieved through reduced energy usage.
Energy Savings	Tune-ups can achieve boiler energy savings of 2-20%.
Applications & Limitations	None.
Practical Notes	Performing regular maintenance on boilers and furnaces also can be a good way of understanding operation to help predict failures or maintenance needs.
Other Benefits	Not applicable.
Stage of Acceptance	Well accepted.

B6 – Adjust Burners on Furnaces and Boilers

Best Practice	Adjusting burners to yield the correct air-to-fuel ratio will optimize combustion efficiency. Generally a small amount of excess air is necessary, but the optimal ratio is dependent on the particular system and fuel type. For example, a forced draft gas boiler may operate well with 5-10% excess air (which relates to 1-2% excess oxygen). In some instances, replacing older burners with new efficient burners can be cost-effective. Stack emission readings need to be constantly taken in order to control oxygen trim. The U.S. Department of Energy's Federal Energy Management Program (FEMP) recommends that a boiler's combustion efficiency be measured and recorded at least once a month during the heating season.
See Also	Not applicable.
Primary Area/Process	Buildings.
Productivity Impact	No impact.
Economic Benefit	Cost savings may be achieved through reduced energy usage.
Energy Savings	Savings can range from 5-10% of total fuel usage.
Applications & Limitations	Proper oxygen levels in the stack need to be maintained, since too much or too little oxygen left after the burn decreases efficiency or equipment life.
Practical Notes	None.
Other Benefits	Not applicable.
Stage of Acceptance	Well accepted.

B7 – Check Outside Air Ventilation Devices, Ventilation/Supply Fans & Clean Fan Blades

Best Practice	Many ventilation systems use outside air "economizer" dampers that automatically modulate the amount of outside airflow used to condition the space. These economizers allow up to 100% outside air for "free-cooling" during moderate outdoor conditions, but restrict the outside airflow to a minimum setting when it is too cold or hot outside for beneficial use. Outside air dampers and economizer cycles can have reliability problems. If the outside air damper becomes stuck open, too much outside air may enter the system and the cooling coils can be overloaded. If it is stuck closed, then the opportunity for "free cooling" is lost. It is necessary to clean and lubricate the movable parts and check the actuator movement periodically to ensure proper operation and to maintain maximum system efficiency. Additionally, ventilation/supply fans require routine maintenance for optimal operation. It is necessary to lubricate bearings, adjust or change fan belts, and clean fan blades on an annual basis to maximize fan efficiency.
See Also	Not applicable.
Primary Area/Process	Buildings.
Productivity Impact	No impact.
Economic Benefit	Can have significant impact on costs, and provide simple cost effective solutions to save energy.
Energy Savings	Can be significant source for energy savings.
Applications & Limitations	The main purpose of a ventilation system in a WWTP is to supply sufficient outside ventilation air for the dilution of odor-causing contaminants, such as hydrogen sulfide and ammonia. The discharge from the ventilation system is typically treated by vapor phase systems, including wet air scrubbing and carbon adsorption. If large amounts of air are ventilated, vapor-phase systems can also be effective at providing adequate ventilation for occupancy. The ventilation system also plays an important role in conditioning the interior space.
Practical Notes	None.
Other Benefits	Not applicable.
Stage of Acceptance	Well accepted.

B8 – Replace Ventilation Air Filters

Best Practice	The ventilation system removes particulates contained in outside air by way of air filters. Particulate accumulation on air filters reduces airflow and increases fan energy consumption. Air filter technology has been significantly improved; the use of modern air filters improves indoor air quality while reducing the total cost of operation if the system is using VFD technology. The cost of the filter can be significant compared to the cost of fan energy required to push air through the filter. The most common improvement is to replace two-inch pleated filters with four-inch extended service pleated filters.
See Also	Not applicable.
Primary Area/Process	Buildings.
Productivity Impact	No impact.
Economic Benefit	Energy and air quality benefits.
Energy Savings	Savings can be significant if filters are old and not allowing air through.
Applications & Limitations	None.
Practical Notes	None.
Other Benefits	Not applicable.
Stage of Acceptance	Widely accepted.

B9 – LEED Energy Practice

Best Practice	**The Leadership in Energy and Environmental Design (LEED)** Green Building Rating System is a voluntary, consensus-based national rating system for developing high-performance, sustainable buildings. LEED addresses all building types and emphasizes state-of-the-art strategies in five areas: sustainable site development, water savings, energy efficiency, materials and resources selection, and indoor environmental quality. Projects typically will need energy efficiency measures in order to qualify for LEED certifications.
See Also	Not applicable.
Primary Area/Process	Affects all areas of building construction, location and energy. LEED is a comprehensive energy approach and encompasses many measures, and counts on the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) and other code sources for some of its best practices.
Productivity Impact	No impact.
Economic Benefit	Proportional to energy savings achieved.
Energy Savings	In order to achieve LEED ratings, energy reductions need to reduce energy usage by specific amounts as listed for each of the LEED qualifying areas.
Applications & Limitations	Projects should be looked at to see if applying for LEED ratings is valuable for the project.
Practical Notes	None.
Other Benefits	Not applicable.
Stage of Acceptance	Starting to receive wide levels of acceptance.

As an industrial or commercial electricity user, a number of items can influence the rate that is paid for electricity.

Service classification –	most water and wastewater plants are SC-3.
Supply voltage –	dependent on what size of equipment is at the facility.
Load zone –	geographical area where large amounts of power are drawn by end users.
Rate Structure –	negotiated costs per kWh use, per kW demand, how demand is charged, other fees, etc.
Usage patterns –	on-peak vs. off-peak, fixed price for first fixed amount of kWh.

BASIC TERMINOLOGY ON BILL

Electricity at most facilities is billed to account for both demand and consumption.

- **Consumption Charge** based on electricity use ($/kWh)
- **Demand Charge** typically based on peak 15-minute demand during each month ($/KW)

Note that the demand charge can be billed on the maximum demand for that month or the maximum demand over the previous 12 months. It depends on the billing arrangement for specific utilities.

ABC Energy Provider		Account 000934561 March 20 - April 19, 2008
Meter Reading	**Energy**	**Demand**
April 19 (Actual)	20500	56.2
March 20 (Actual)	10100	42.9
Difference/Peak	10400	56.2
Billed Usage	10400	56.2
Charges		
Delivery 10400 kWh @ $0.0175		$182.00
Supply 10400 kWh @ $0.105		$1,092.00
Demand 56.2 kW @ $16.65		$935.73
SBC/RPS Charge 10400 kWh @ $0.0025		$26.00
Total ABC Electric Charges		$2,235.73
Note: SBC is System Benefits Charge RPS is Renewable Portfolio Standard		

This is a sample electric bill for a small commercial/industrial facility. The blue squares illustrate the consumption portion of the bill – 10,400 kilowatt-hours of electricity was used during the billing period. In this case, the facility relies upon ABC Energy Provider for both supply and delivery of electricity, so the bill includes both charges. In many cases, many municipalities may be going to a separate provider for supply and demand; therefore, there will usually be two separate bills (one may go to City Hall for the overall supply contract that supplies power to the entire city, including fire halls, city buildings, traffic lights, pumping stations, etc. while a second bill may detail delivery charges). To understand your total costs, it is critical to have both bills in hand.

The red squares illustrate the demand portion of the bill. Again, this includes both supply and delivery of the peak demand.

The green square highlights the System Benefits Charge and Renewable Portfolio Standard charge. These charges are used to fund many NYSERDA and Public Service Commission programs to improve energy efficiency and the reliability of New York's electric supply, and to promote the development and use of renewable energy sources. To be eligible for many of NYSERDA's programs, it is necessary to pay into this program.

It's important to note what a significant portion of the overall bill is related to demand costs – over 40%.

APPENDIX B – EXAMPLE SPREADSHEET SHOWING BASELINE OF ENERGY USE

EQUIPMENT	POWER	UNIT	VARIABLE SPEED	OPERATION	UNIT	USAGE	UNIT	PEAK DEMAND	UNIT
Comminutor	0.5	hp	N	8,760	hrs/yr	3,267	kWh/yr	0.4	kW
Aerator									
Full Speed	5	hp	Y	4,380	hrs/yr	16,337	kWh/yr	3.7	kW
Half Speed	2.5	hp	Y	4,380	hrs/yr	8,169	kWh/yr	1.9	kW
Clarifier	0.5	hp	N	8,760	hrs/yr	3,267	kWh/yr	0.4	kW
Hypo Pump	0.33	hp	N	8,760	hrs/yr	2,157	kWh/yr	0.2	kW
Sludge Pump	2	hp	N	8,760	hrs/yr	13,070	kWh/yr	1.5	kW
Sump Pump	0.5	hp	N	4,380	hrs/yr	1,634	kWh/yr	0.4	kW
Lights	11	kW	N	4,380	hrs/yr	48,180	kWh/yr	8.2	kW
Grinder	0.5	hp	N	8,760	hrs/yr	3,267	kWh/yr	0.4	kW
Unit Heaters	2	kW	N	5,840	hrs/yr	11,680	kWh/yr	1.5	kW

APPENDIX C – Economic Evaluation Methods

To determine whether an energy efficiency improvement project will be cost effective, most municipalities consider the "Simple Payback" (SPB) or the "Life Cycle Cost" (LCC). Typically, for smaller projects involving equipment replacement and/or low up-front capital costs, with low maintenance costs, using the SPB method is appropriate. Still, for larger projects involving significant up-front capital costs, multiple cost factors and variations in annual cash flow, LCC analysis is preferred.

Simple Payback

The SPB method calculates the length of time over which cumulative energy savings and other project benefits will be equal to (or "payback") the initial project investment. To calculate the SPB, divide the total project cost by the total expected benefit.

$$SPB(yr) = \frac{Cost\_of\_project(\$)}{Annual\_savings(\$/yr)}$$

For example, assume that a facility is evaluating Project A: whether to replace its motors with more efficient models. If the new motors cost $200,000, and are expected to reduce energy costs by $100,000 per year and last for five years before another $200,000 motor replacement is needed, then the SPB for Project A is two years.

Life Cycle Cost

LCC analysis considers the initial cost of the project as well as all of the costs and benefits over the lifetime of the project. The LCC approach incorporates the time value of money, the volatility of utility costs and other factors, such as operation and maintenance or other costs.

$$\begin{aligned}
&LCCSavings = LCC(Current_process) - LCC(New_process)\\
&where:\\
&LCC(Current_process) = \sum AnnualCosts - \sum AnnualSavings\\
&LCC(New_process) = CapitalCost + \sum AnnualCosts - \sum AnnualSavings
\end{aligned}$$

For example, assume the same facility is evaluating Project B: whether to use a new treatment process, which will cost $700,000 in the first year, with replacement costs of $200,000 every five years. Project B is expected to save the facility $184,000 per year for 20 years. The SPB of this project is 3.8 years. On first look, Project A is more appealing with a SPB of two years versus nearly four years for Project B. Nevertheless, Project B will generate more savings over time. Assuming an interest rate of 7% and an escalation rate of 3%, the LCC of Project A saves $660,000 in today's dollars, whereas Project B saves $1,300,000 – a difference of $650,000.

Backup calculations for both examples are provided in the following pages.Note: the examples provided are an oversimplification provided for the purpose of showing the payback and life cycle costs calculations. The examples do not take into consideration labor and parts costs over the life of the project.

The US Environmental Protection Agency (EPA) Energy Star Tools and Resources Library (http://www.energystar.gov/index.cfm?c=tools_resources.bus_energy_management_tools_resources) provides links to various Financial Evaluation Tools, including a Cash Flow Opportunity Calculator (a Microsoft Excel-based tool) to help decision-makers to evaluate the benefits of installing energy efficient equipment.

The US Department of Energy's *Federal Energy Management Program* (FEMP) offers many resources to assist with Life-Cycle Cost Analysis (http://www1.eere.energy.gov/femp/program/lifecycle.html) including FEMP's Building Life-Cycle Cost Software, training opportunities and a Life-Cycle Costing Manual.

LIFE CYCLE COST EXAMPLE - PROJECT A

Interest Rate = i = 7.0%

Escalation Rate = e = 3.0%

Year (n)	Project A				
	Capital Cost	Replacement Cost	Energy Savings (Annual)	Total Annual Cost	PW Cost
0	$200,000			$200,000	$200,000
1			-$100,000	-$100,000	-$93,458
2			-$106,090	-$106,090	-$92,663
3			-$109,273	-$109,273	-$89,199
4			-$112,551	-$112,551	-$85,865
5		$231,855	-$115,927	-$115,927	-$82,655
6			-$119,405	-$119,405	-$79,565
7			-$122,987	-$122,987	-$76,590
8			-$126,677	-$126,677	-$73,727
9			-$130,477	-$130,477	-$70,971
10		$268,783	-$134,392	-$134,392	-$68,318
11			-$138,423	-$138,423	-$65,764
12			-$142,576	-$142,576	-$63,305
13			-$146,853	-$146,853	-$60,939
14			-$151,259	-$151,259	-$58,661
15		$311,593	-$155,797	-$155,797	-$56,468
16			-$160,471	-$160,471	-$54,357
17			-$165,285	-$165,285	-$52,325
18			-$170,243	-$170,243	-$50,369
19			-$175,351	-$175,351	-$48,486
20		$361,222	-$180,611	-$180,611	$46,673
					-$662,140

Future Annual Cost = Present Annual Cost x $(1 + \text{Escalation Rate})^{\text{Year}} = A_0 (1 + e)^n$ (present annual cost)

Present Worth Cost = PW = Future Annual Cost/$(1 + \text{Interest Rate})^{\text{Year}} = F/(1+i)^n$

LIFE CYCLE COST EXAMPLE - PROJECT B

Interest Rate = i = 7.0%
Escalation Rate = e = 3.0%

Year (n)	Project B				
	Capital Cost	Replacement Cost	Energy Savings (Annual)	Total Annual Cost	PW Cost
0	$700,000			$700,000	$700,000
1			-$184,000	-$184,000	-$171,963
2			-$195,206	-$195,206	-$170,500
3			-$201,062	-$201,062	-$164,126
4			-$207,094	-$207,094	-$157,991
5		$231,855	-$213,306	$18,548	$13,225
6			-$219,706	-$219,706	-$146,399
7			-$226,297	-$226,297	-$140,926
8			-$233,086	-$233,086	-$135,658
9			-$240,078	-$240,078	-$130,587
10		$268,783	-$247,281	$21,503	$10,931
11			-$254,699	-$254,699	-$121,006
12			-$262,340	-$262,340	-$116,482
13			-$270,210	-$270,210	-$112,128
14			-$278,317	-$278,317	-$107,936
15		$311,593	-$286,666	$24,927	$9,035
16			-$295,266	-$295,266	-$100,017
17			-$304,124	-$304,124	-$96,278
18			-$313,248	-$313,248	-$92,679
19			-$322,645	-$322,645	-$89,214
20		$361,222	-$332,324	$28,898	$7,468
					-$1,313,240

Future Annual Cost = Present Annual Cost x (1 + Escalation Rate)^{Year} = $A_0 (1 + e)^n$ (present annual cost)
Present Worth Cost = PW = Future Annual Cost/(1 + Interest Rate)^{Year} = $F/(1+i)^n$

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US Department of Energy:
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US Green Building Council:
http://www.usgbc.org

American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) http://www.ashrae.org/