



Energy Efficiency Best Practices for North American Drinking Water Utilities

 Subject Area: Management and Customer Relations



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About the Water Research Foundation

The Water Research Foundation (formerly Awwa Research Foundation or AwwaRF) is a member-supported, international, 501(c)3 nonprofit organization that sponsors research to enable water utilities, public health agencies, and other professionals to provide safe and affordable drinking water to consumers.

The Foundation's mission is to advance the science of water to improve the quality of life. To achieve this mission, the Foundation sponsors studies on all aspects of drinking water, including resources, treatment, distribution, and health effects. Funding for research is provided primarily by subscription payments from close to 1,000 water utilities, consulting firms, and manufacturers in North America and abroad. Additional funding comes from collaborative partnerships with other national and international organizations and the U.S. federal government, allowing for resources to be leveraged, expertise to be shared, and broad-based knowledge to be developed and disseminated.

From its headquarters in Denver, Colorado, the Foundation's staff directs and supports the efforts of more than 800 volunteers who serve on the board of trustees and various committees. These volunteers represent many facets of the water industry, and contribute their expertise to select and monitor research studies that benefit the entire drinking water community.

The results of research are disseminated through a number of channels, including reports, the Web site, Webcasts, conferences, and periodicals.

For its subscribers, the Foundation serves as a cooperative program in which water suppliers unite to pool their resources. By applying Foundation research findings, these water suppliers can save substantial costs and stay on the leading edge of drinking water science and technology. Since its inception, the Foundation has supplied the water community with more than \$460 million in applied research value.

More information about the Foundation and how to become a subscriber is available on the Web at www.WaterResearchFoundation.org.

Energy Efficiency Best Practices for North American Drinking Water Utilities

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Jointly sponsored by:

Water Research Foundation

6666 West Quincy Avenue, Denver, CO 80235-3098

and

New York State Energy Research and Development Authority

Albany, NY 12203-6399

Published by:



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ISBN 978-1-60573-159-9

Printed in the U.S.A.



Printed on recycled paper

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FOREWORD

The Water Research Foundation (Foundation) is a nonprofit corporation that is dedicated to the implementation of a research effort to help drinking water utilities respond to regulatory requirements and address high-priority concerns of the water sector. The research agenda is developed through a process of consultation with Foundation subscribers and other drinking water professionals. Under the umbrella of a Strategic Research Plan, the Board of Trustees and Board-appointed volunteer committees prioritize and select research projects for funding based upon current and future needs, applicability, and past work. The Foundation sponsors research projects through the Focus Area, Emerging Opportunities, and Tailored Collaboration programs, as well as various joint research efforts with organizations such as the U.S. Environmental Protection Agency and the U.S. Bureau of Reclamation.

This publication is a result of one of these sponsored studies, and it is hoped that its findings will be applied in communities throughout the world. The following report serves not only as a means of communicating the results of the water industry's centralized research program but also as a tool to enlist the further support of the nonmember utilities and individuals.

Projects are managed closely from their inception to the final report by the Foundation's staff and large cadre of volunteers who willingly contribute their time and expertise. The Foundation serves a planning and management function and awards contracts to other institutions such as water utilities, universities, and engineering firms. The funding for this research effort comes primarily from the Subscription Program, through which water utilities subscribe to the research program and make an annual payment proportionate to the volume of water they deliver and consultants and manufacturers subscribe based on their annual billings. The program offers a cost-effective and fair method for funding research in the public interest.

A broad spectrum of water supply issues is addressed by the Foundation's research agenda: resources, treatment and operations, distribution and storage, water quality and analysis, toxicology, economics, and management. The ultimate purpose of the coordinated effort is to assist water suppliers to provide the highest possible quality of water economically and reliably. The true benefits are realized when the results are implemented at the utility level. The Foundation's trustees are pleased to offer this publication as a contribution toward that end.

Roy L. Wolfe, Ph.D.
Chair, Board of Trustees
Water Research Foundation

Robert C. Renner, P.E.
Executive Director
Water Research Foundation

ACKNOWLEDGMENTS

The authors of this report are indebted to the following water utilities and individuals for their cooperation and participation in this project:

- American Water, Voorhees, NJ, Harold Reed and Mark LeChevallier
- Ann Arbor Water Treatment Services, Ann Arbor, MI, Sumedh Bahl
- Austin Water Utility, Austin, TX, David Greene and Raj Bhattarai
- Cedar Rapids Water Department, Cedar Rapids, IA, Roy Hesemann
- Cleveland Water Division, Cleveland, OH, Carl W. (Bill) Eger III and Rolfe Porter
- Columbus (GA) Water Works, Columbus, GA, Cliff Arnett and Lynn Campbell
- Las Vegas Valley Water District, Las Vegas, NV, Kevin Fisher
- Metro Vancouver/Greater Vancouver Water District, Vancouver, British Columbia, CN, Jeff Carmichael and Vince Hanada, BC Hydro
- Mohawk Valley Water Authority, Utica, NY, Richard Goodney
- Monroe County Water Authority, Rochester, NY, Chris King and Richard Metzger
- New Jersey American Water, Somerset, NJ, Michael Wolan and Mark LeChevallier
- Queensbury Water District, Queensbury, NY, Bruce Ostrander
- Suffolk County Water Authority, Oakdale, NY, Joseph Pokorny and Stephen Jones
- Village of Waterloo, Waterloo, NY, Jim Bromka and Theodore Young
- West Basin Municipal Water District, Carson, CA, Christiana Daisy and Uzi Daniel

In addition, the authors wish to acknowledge the invaluable assistance and advice from the Project Advisory Committee (PAC) including Richard Metzger, Executive Engineer, Monroe Valley Water Authority, Rochester, NY; Kevin Fisher, Director of Operations, Las Vegas Valley Water District, Las Vegas, NV; and Steve Conrad, Principal, Resilient Consulting Group, Inc. and Simon Fraser University, Vancouver, BC, CN. Special thanks also go to Kathleen O'Connor, project manager for the co-funding organization, the New York State Energy Research and Development Authority, and Linda Reekie, the project manager for the Water Research Foundation.

Invaluable assistance was provided by the following Cadmus staff: Karen Sklenar, Mike Grimm, and Kim Marsh for assistance in developing the case studies; Kim Marsh and Rustom Meyer for assistance in researching and conducting the literature review; Aaron Jenniges for developing the searchable database; Keenan Patterson for assistance in populating the database; and Kathy Martel for quality assurance review.

EXECUTIVE SUMMARY

Providing safe drinking water and reliable wastewater services is highly energy-intensive in North America with estimates of \$4 billion spent annually in the U.S. for energy in the water sector. Approximately 3 to 4 percent of national energy consumption is used to provide drinking water and wastewater services. According to the U.S. Environmental Protection Agency, this is equivalent to approximately 56 billion kilowatt hours, and equates to adding almost 45 million tons of greenhouse gas to the atmosphere each year.

Energy is typically needed for raw water extraction and conveyance; drinking water treatment; drinking water distribution and storage; and wastewater collection, treatment, and discharge. Approximately 80 percent of energy consumption goes to pumping and distributing water and wastewater with the remaining for treatment. This can represent a significant percentage of a water utility's operating budget. Further, drinking water and wastewater utilities are typically the largest energy consumers of municipal governments, accounting for 30 to 40 percent of total energy consumed.

USEPA estimates that utilities across the U.S. could reduce annual energy costs by an average of 10 percent, representing a savings of more than \$400 million annually to the water industry. There are substantial opportunities and potential to reduce energy costs, some of which can be implemented easily with a limited investment cost. These opportunities, however, need to be more broadly shared and understood within the water industry.

OBJECTIVES AND PRODUCTS

Recognizing the need to better document and share information on energy efficiency practices in the water sector, the Water Research Foundation and the New York State Energy Research and Development Authority jointly funded this project. The objective of the research study is to: (1) provide a compendium of energy efficiency best practices and case studies across the full spectrum of water utility operations; (2) present options for incremental improvements in energy efficiency through optimization of existing assets and operations, and adoption of new technologies; and (3) present several approaches that might be considered by a utility to improve incremental and overall energy efficiency. The products of this research project include: (1) this compendium report of best practices; (2) a searchable database of energy efficiency best practices based on a comprehensive literature review; and (3) 16 case studies of actual water utility experiences implementing energy efficiency approaches with a summary of themes and lessons learned.

BACKGROUND

Energy usage and costs for drinking water utilities are increasing as a result of many factors associated with regulations, treatment technology complexity, aging infrastructure, supply challenges, and growth. While a number of utilities have begun to recognize the importance of containing and actually reducing energy consumption and costs, many utilities, including smaller and medium-sized water systems may not yet fully understand the options available to them to better manage their energy budget.

APPROACH

Energy efficiency best practices have been identified and documented through an extensive literature review and 16 case studies documenting successful utility practices to reduce energy use. These practices were organized and consolidated into eight major areas including management tools, plant improvements and management changes, water treatment, water distribution, water conservation, alternative/renewable energy sources, financial assistance, and partnerships. The information comes from utilities of different sizes and geographic locations across North America with a focus on relevancy to New York State utilities. A range of actions is presented that will enable water utilities to learn about, evaluate, and implement energy efficiency options that could save millions of dollars annually in energy costs and dramatically reduce greenhouse gas emissions.

This project is part of a larger international effort to collect and share similar information on best practices in energy efficiency from North America, Europe, Asia, Australia, and South Africa for both drinking water and wastewater utilities. The international effort is spearheaded by the Global Water Research Coalition through the UK Water Industry Research Limited and will result in the creation of a global compendium of best practices and technologies that can be shared with drinking water and wastewater utilities around the world. This report represents the contribution for energy efficiency best practices for drinking water utilities in North America.

RESULTS/CONCLUSIONS

Through the conduct of an extensive literature search and case studies, the authors of the report identified numerous energy efficiency best practices available to and currently in use at drinking water utilities in North America. Many of these practices do not require expensive or extensive capital investments—simply optimizing a utility’s current equipment and operations practices can lead to significant reductions in energy consumption. Key findings include: (1) some level or type of energy efficiency improvement can be made by utilities of all sizes and management structure; (2) management support and operator and staff buy-in is critical for long-term success in reducing energy consumption; (3) partnerships with energy providers may be particularly useful in identifying cost savings related to electric rate structures and time-of-use; (4) the primary area to target improvements is pumps and motors; (5) benchmarking and conducting energy audits can help a utility define its current energy usage and establish a baseline to track changes over time; (6) investment in adequate databases and monitoring and tracking systems is critical for managing energy usage, measuring success, and formulating new energy efficiency strategies; (7) energy efficiency efforts should be tied to asset management plans and systems to ensure assets are properly maintained; (8) water efficiency can lead to energy efficiency since less water is treated and moved through the distribution system; (9) funding is available to water utilities to implement energy efficiency options; and (10) utilities need to understand that efforts to increase energy efficiency are not without risks and tradeoffs that may impact water quality and public health protection.

APPLICATIONS/RECOMMENDATIONS

Drinking water utilities, regardless of size, can and should take steps to reduce energy costs and consumption. Estimates indicate that between 10 and 30 percent savings are readily

achievable by almost all utilities. These efforts can result in a number of benefits including: (1) cost savings that can be reinvested in infrastructure or additional energy reduction measures; (2) less strain on the current energy grid; (3) meeting state energy reduction targets; (4) reduced greenhouse gas emissions; (5) improved environmental stewardship; and (6) improved customer relations.

Utilities have found that identifying approaches to integrate energy efficiency practices in daily management and long-term planning also contributes to long-term sustainability by reducing operating costs and improving efficiency and process control. There are substantial opportunities and potential to reduce energy costs, some of which can be implemented easily with a limited investment cost. These savings can be realized through a range of actions including: (1) utilizing new, energy-efficient technologies; (2) incorporating energy efficient practices into daily operations; (3) taking advantage of incentives and rebates from energy providers; (4) installing premium efficiency motors and variable speed drives; (5) resizing pumping systems; (6) developing alternative pumping schemes and pump system upgrades; (7) installing controls and monitoring systems; (8) optimizing operations; (9) implementing building upgrades (e.g., lighting and heating and cooling); (10) benchmarking and energy audits; (11) shifting power consumption from on-peak to off-peak hours; (12) adding or more effectively using storage; (13) promoting water conservation and use of energy efficient products; (14) reducing system leaks; (15) evaluating system life cycle energy costs associated with proposed projects; and (16) evaluating the use of alternative energy sources.

This is also not a case of one-size-fits-all. Each utility is unique and needs to evaluate its own goals, financial condition, and commitment to improved energy efficiency. Regardless of where a utility is on the path to energy efficiency, they can always take additional steps.

Economic Implications

Utilities have found that implementing energy efficiency practices has resulted in significant cost savings from thousands to hundreds of thousands of dollars each year. Many of the improvements, such as optimizing current treatment, pumping, and operational practices, can be easily implemented with limited cost. Where capital investment is needed, payback periods can range from several months to several years. Longer payback periods (10 to 15 years) are often associated with renewable/alternative energy options. Funding for energy efficiency improvements may be available through drinking water state revolving loan funds, incentives and rebates from energy providers, and performance contracting from energy services companies.

Environmental Implications

Reducing energy consumption has a direct impact on reducing greenhouse gas emissions. This can help utilities and municipalities meet aggressive carbon reduction goals established in many states, in addition to helping the environment. Investment in renewable/alternative energy can provide long-term “clean” energy for water utility operations.

Operational Benefits

Utilities have found that identifying approaches to integrate energy efficiency practices in daily management and long-term planning also contributes to long-term sustainability by reducing

operating costs and improving efficiency and process control. In many cases, measures taken to improve water efficiency also translate into energy savings as less water is required to be produced and pumped. This can also result in monetary savings on chemicals and other treatment supplies, and extend the life of treatment units and components.

Customer Relations Benefits

Taking steps to reduce energy consumption can enhance customer relations by demonstrating environmental stewardship and sustainability. Providing or supporting programs to improve energy and water efficiency at customers' homes can further demonstrate a utility's commitment to helping the environment and helping customers save money.

MULTIMEDIA

The printed report is accompanied by a CD-ROM that contains a searchable database of the energy efficiency best practices and case studies identified in this report.

RESEARCH PARTNERS

This project was co-funded by the New York State Energy Research and Development Authority.

PARTICIPANTS

The following utilities participated in this project through development of case studies: American Water, Voorhees, NJ; Ann Arbor Water Treatment Services, Ann Arbor, MI; Austin Water Utility, Austin, TX; Cedar Rapids Water Department, Cedar Rapids, IA; Cleveland Water Division, Cleveland, OH; Columbus (GA) Water Works, Columbus, GA; Las Vegas Valley Water District, Las Vegas, NV; Metro Vancouver/Greater Vancouver Water District, Vancouver, British Columbia, CN; Mohawk Valley Water Authority, Utica, NY; Monroe County Water Authority, Rochester, NY; New Jersey American Water, Somerset, NJ; Queensbury Water District, Queensbury, NY; Suffolk County Water Authority, Oakdale, NY; Village of Waterloo, Waterloo, NY; and West Basin Municipal Water District, Carson, CA.

CHAPTER 1

INTRODUCTION

OVERVIEW: WHY ENERGY EFFICIENCY?

Providing safe drinking water and reliable wastewater services is a highly energy-intensive activity in North America with estimates of \$4 billion spent annually in the U.S. for energy in the water sector. The Electric Power Research Institute (EPRI) estimated that 3 to 4 percent of national energy consumption is used for drinking water and wastewater services (EPRI 2002). According to the U.S. Environmental Protection Agency (USEPA), this is equivalent to approximately 56 billion kilowatt hours (kWh), and equates to adding approximately 45 million tons of greenhouse gas (GHG) to the atmosphere each year.

Energy is typically needed for raw water extraction and conveyance; drinking water treatment; drinking water distribution and storage; and wastewater collection, treatment, and discharge. EPRI (2002) reported that 80 percent of the energy consumption goes to pumping and distributing water and wastewater with the remaining for treatment. Further, drinking water and wastewater utilities are typically the largest energy consumers of municipal governments, accounting for 30 to 40 percent of total energy consumed according to USEPA and the Consortium for Energy Efficiency (CEE).

A number of states have also documented energy usage in the water industry. Wisconsin estimated that from 1997–2000 its drinking water utilities consumed 345 million kWh per year of energy in the production of 214 billion gallons of drinking water (WFOE 2003). The California Energy Commission (CEC) found that water-related energy consumption and demand accounted for a significant portion—over 19 percent—of the state’s electricity requirements of which 5 percent was attributable to energy used by water and wastewater utilities and their operations. The remaining 14 percent was attributable to end uses for agricultural, residential, commercial and industrial purposes for heating and pumping water. Energy consumption for drinking water and wastewater treatment and end uses also accounted for 32 percent of the state’s non-power related natural gas consumption (CEC 2005). The New York State Energy Research and Development Authority (NYSERDA) conducted a statewide survey and found that the water sector as a whole was approximately 10 percent more efficient than the national average, consuming less than 2,400 kWh/million gallons (MG). However, with an average retail price for electricity that is 40 to 60 percent higher than the national average, New York’s water and wastewater sector is spending 35 percent more on electricity than their national counterparts on a per unit basis (NYSERDA 2008).

Several studies have been conducted in the last few years that have helped to better describe energy usage in the water sector. These findings indicate that in the U.S.:

- Water utility energy use can vary widely; Carlson and Walburger (2007) found ranges from 804 to 4,321 kWh/MG of drinking water produced and delivered
- Eighty percent of water treatment plant energy consumption goes to pumping—raw water, high service, backwash, and distribution system boosters (EPRI 2002)
- Drinking water and wastewater treatment consume up to 35 percent of a utility’s operating budget (Jacobs, Kerestes, and Riddle 2003).

Energy usage and costs are increasing as a result of: (1) utilities installing new technologies to meet more stringent and increasing drinking water standards; (2) drought and climate change impacts necessitating treatment of water from lower quality sources and using more energy-consuming technologies like membranes and desalination; (3) aging infrastructure that adds to increased energy consumption through water losses and inefficient mechanical systems such as pumps and motors; (4) growth and system expansion that have dictated that utilities transport water to greater distances and greater system elevations; and (5) installation of new generating plants and transmission lines and demands for high quality power.

USEPA estimates that utilities across the U.S. could reduce annual energy costs by an average of 10 percent, representing a savings of more than \$400 million annually to the water industry. Important areas to research for energy savings include improved pumping and other treatment efficiencies, reduction of water loss in distribution systems, and energy and water efficiency improvements in residential water use. NYSERDA estimated that energy consumption at most utilities in New York could be reduced by 10 to 20 percent with opportunities to reduce energy consumption in some utilities by up to 50 percent (NYSERDA 2008). CEC estimates that water system energy savings of 15 to 30 percent is readily achievable.

This has led some utilities to develop aggressive energy management strategies to improve energy efficiency and reduce energy consumption and costs. Energy efficiency is the use of less energy to provide the same level of service and water quality. Through application of energy management strategies and practices, energy costs can be controlled. There are substantial opportunities and potential to reduce energy costs, some of which can be implemented easily with a limited investment cost, such as taking advantage of systems upgrades or expansion to incorporate energy efficient processes and technologies. Savings can be realized through a range of actions including:

- utilizing new, energy-efficient technologies
- incorporating energy efficient practices into daily operations
- taking advantage of incentives and rebates from energy providers
- installing premium efficiency motors and variable speed drives
- resizing pumping systems
- developing alternative pumping schemes and pump system upgrades
- installing controls and SCADA systems
- operations optimization
- building upgrades (e.g., lighting and HVAC)
- benchmarking and energy audits
- evaluating demand-side management opportunities to reduce energy consumption during peak hours by shifting power consumption from on-peak to off-peak hours
- adding storage to pump and store water during off-peak electric rate periods
- promoting water conservation and use of energy efficient products by customers
- reducing system leaks
- evaluating system life cycle energy costs associated with proposed projects, and
- evaluating the use of alternative energy sources.

Monetary benefits are commonly at the forefront of any system improvement. However, reducing energy consumption not only reduces energy costs and operating expenditures, but has a direct impact on reducing GHG emissions. Utilities have found that identifying approaches to integrate energy efficiency practices in daily management and long-term planning also contributes to

long-term sustainability by reducing operating costs and improving efficiency and process control. Improving energy efficiency is a smart way to save money, extend the life of existing infrastructure, improve the environment, and enhance customer relations by demonstrating environmental stewardship and sustainability.

PROJECT BACKGROUND AND OBJECTIVES

Approximately 80 percent of municipal water processing and distribution costs are for electricity (EPRI 2002). This can represent a significant percentage of a water utility's operating budget. Energy usage and costs are increasing as a result of many factors associated with regulations, treatment technology complexity, aging infrastructure, supply challenges, and growth. This also leads to an increase in GHG emissions. Historically, energy costs have been seen by utilities as just one of the many costs of doing business. For those utilities that are able to fully recover operational expenses through billing their customer base, these costs have been passed on to the consumer in the form of higher water rates. For many utilities, however, water rates are not adequate to fully recover the cost of producing potable drinking water and any increase in energy costs may have a significant impact on the utility's bottom line. While a number of utilities have begun to recognize the importance of containing and actually reducing energy consumption and costs, many utilities, including smaller and medium-sized water systems may not yet fully understand the options available to them to better manage their energy budget.

Recognizing the need to better document and share information on energy efficiency practices in the water sector, the Water Research Foundation (Foundation) and NYSERDA jointly funded this project to develop a compendium of best practices, utility case studies, and energy efficiency approaches. The objective of the research study is to:

- Provide a compendium of energy efficiency best practices and case studies across the full spectrum of water utility operations
- Present options for incremental improvements in energy efficiency through optimization of existing assets and operations, and adoption of new technologies
- Present several approaches that might be considered by a utility to improve incremental and overall energy efficiency

The scope of this project and report covers the principal activities of drinking water business including water transmission, treatment, storage, and distribution. Information on water conservation approaches, funding mechanisms, and partnerships are also presented to provide additional information on tools and resources available to water utilities. The goal of this project is to compile successful strategies to help water utilities reduce energy consumption. This will reduce energy costs for individual utilities and ultimately reduce emissions of greenhouse gases that contribute to global climate change.

These best practices have been identified and documented through a comprehensive literature review and case studies documenting successful utility practices to reduce energy use. This report provides a comprehensive documentation of energy efficiency practices and savings that can be realized across the full spectrum of water utility activities including water treatment and distribution, demand-side management and water loss, alternative/renewable energy sources, conservation practices, and funding mechanisms and partnerships. The requisite staff support and

skills as well as appropriate information technology necessary to optimize energy efficiency in water supplies are also identified, as appropriate.

It is important for utilities to take a holistic view of energy management. In addition to improving energy use in the treatment and distribution process itself, there are a number of other tools and management approaches that can help utilities reduce their overall energy consumption. In many cases, measures taken to improve water efficiency also translate into energy savings as less water is required to be produced and pumped. This can also result in monetary savings on chemicals and other treatment supplies, and extend the life of treatment units and components. The bottom line is that saving energy is a win-win proposition for utilities, their customers, and the environment.

INTERNATIONAL EFFORT

This project is part of a larger international effort to collect and share similar information on best practices in energy efficiency from North America, Europe, Asia, Australia, and South Africa for both drinking water and wastewater utilities. The international effort is spearheaded by the Global Water Research Coalition (GWRC) through the UK Water Industry Research Limited (UKWIR) and will result in the creation of a global compendium of best practices and technologies that can be shared with drinking water and wastewater utilities around the world. This report represents the contribution for energy efficiency best practices for drinking water utilities in North America. The Water Environment Research Foundation (WERF) developed the companion report on energy efficiency best practices for wastewater utilities, available at: (<http://www.werf.org/AM/Template.cfm?Section=Search&Template=/CustomSource/Research/PublicationProfile.cfm&id=OWSO4R07e>).

SIGNIFICANCE OF THE PROJECT

The cost of energy is a significant percentage of almost all water utility budgets. While historically viewed as just another business expense, increasing energy costs, combined with state initiatives to reduce energy consumption and a new emphasis on sustainability and GHG emission reductions, makes this the best time for utilities to learn about and take steps to reduce their energy costs and carbon footprint. Financial incentives such as rebates and lowered energy rates through partnerships with energy providers and state agencies and funding for green projects through state revolving loan funds provide resources and opportunities not historically available to water systems.

The drinking water community will gain the following benefits from this project:

- Improved understanding among water utilities of the tools, practices, and technologies available and in-use to improve energy efficiency and reduce energy costs
- An easy-to-use searchable database of energy efficiency best practices based on a comprehensive literature review
- Case study examples and lessons learned about how real-world utilities have implemented energy efficiency best practices
- A discussion of several different types of approaches that a utility might use to begin evaluating and making energy efficiency decisions
- A discussion of the particular relevancy of the findings to utilities in New York State

The project provides findings on a variety of energy efficiency approaches that are relevant to water utilities in North America and around the world. The information comes from utilities of different sizes and geographic locations across North America with a focus on relevancy to New York State utilities. A range of actions is presented that will enable water utilities to learn about, evaluate, and implement energy efficiency options that could save millions of dollars annually in energy costs and dramatically reduce GHG emissions.

The products of this research project include: (1) this compendium report of best practices; (2) a searchable database of energy efficiency best practices based on a comprehensive literature review; and (3) 16 case studies of actual water utility experiences implementing energy efficiency approaches with a summary of themes and lessons learned.

The primary audiences for the products include municipal decision-makers and drinking water utility operators and managers who are interested in developing and implementing energy efficiency programs at their water utilities. The information is grouped by tools, practices, processes, or technologies as they pertain to management tools, plant improvement and management changes, treatment, distribution, water conservation, financial resources, and partnerships. As appropriate, the information is presented with some discussion on complexity and applicability to various utility sizes.

ORGANIZATION OF THE REPORT

After the introductory chapter, this report is organized as follows:

- In chapter 2, an overview is provided of the project including the steps taken to identify best practices related to energy efficiency. These steps included the conduct of a literature review, development of 16 case studies, development of a searchable database, and coordination with an international effort collecting similar best practices at drinking water and wastewater utilities around the world.
- In chapter 3, challenges to energy efficiency are identified as well as numerous best practices covering the areas of management tools, plant improvements/management changes, water treatment, water distribution, water conservation, alternative/renewable energy sources, financial assistance, and partnerships.
- In chapter 4, 16 case studies are provided covering a variety of energy efficiency practices at utilities of different sizes and geographic locations. Each case study follows a similar format that includes a background on the utility issues(s) of concern, identification of the best practice or process being evaluated, a discussion of the changes implemented and results, specific IT or staff expertise needed to implement the best practice, a summary of the lessons learned, and a conclusion.
- In chapter 5, information is provided to assist utilities in getting started on developing and implementing an energy efficiency program. The seven steps of a program are discussed and three different approaches are highlighted ranging from a comprehensive approach, to an intermediate approach, to a targeted approach. The goal is to encourage all utilities to take some steps, however small, to improve energy efficiency.
- In chapter 6, a summary of the key findings is provided as well as a discussion of the significance of the findings to utility practice in general and to utilities in New York State in specific. Additional research needs are identified and recommendations for next steps are identified.

CHAPTER 2

METHODS AND APPROACH

IDENTIFICATION OF ENERGY EFFICIENCY PRACTICES

In order to identify and document energy efficiency practices, the project investigators conducted a comprehensive literature review and researched and prepared 16 case studies. In addition, the original scope of the project was expanded to include conservation practices, funding mechanisms, and partnerships. The rationale was that conserving water can result in reducing energy needs and is a viable tool for water utilities to consider. Federal, state, and energy provider partnerships are also considered key to identifying energy efficiency needs and in many cases providing on-site assistance and incentives and rebates to implement energy efficiency practices. Other funding mechanisms such as the state revolving loan funds are identified that utilities should consider when implementing energy efficiency changes requiring capital improvements, particularly with the new emphasis on “green projects” for both drinking water and wastewater utilities.

Literature Search

A comprehensive, detailed literature review was conducted to identify energy efficiency tools, practices, processes, and technologies associated with the design, construction, and operation of the water supply in North America. This research included energy efficiency practices associated with management tools, treatment, distribution, conservation practices, alternative/renewable energy, funding mechanisms, and partnerships. The requisite staff support and skills as well as appropriate information technology necessary to optimize energy efficiency in water supplies were identified, if available. This research included review of numerous water industry publications, pertinent Water Research Foundation reports, presentations on energy efficiency made at regional and national conferences, and Web sites of state and Federal agencies and energy-related organizations and associations. A number of the key sites included:

- NYSERDA (<http://www.nyserda.org>)
- USEPA ENERGY STAR® (<http://www.energystar.gov>)
- USEPA Green Power Partnerships (<http://www.epa.gov/greenpower>)
- USEPA WaterSense (<http://www.epa.gov/watersense>)
- AWWA WaterWiser (<http://www.awwa.org/Resources/Waterwiser.cfm?>)
- Consortium for Energy Efficiency (<http://www.cee1.org>)
- USGBC and LEED program (<http://www.usgbc.org>; <http://www.usgbc.org/DisplayPage.aspx?CategoryID=19>)
- Alliance for Water Efficiency (<http://www.allianceforwaterefficiency.org>)
- Alliance to Save Energy (<http://www.ase.org>)
- California Urban Water Conservation Council (<http://www.cuwcc.org>)
- National Regulatory Research Institute (<http://www.nrri.org>)
- Electric Power Research Institute (<http://my.epri.com/portal/server.pt>)
- DOE’s Energy Efficiency and Renewable Energy Clearinghouse (<http://www.eere.energy.gov>)

Based on this research and input from the PAC, the following broad categories were identified and formed the framework for identifying and presenting information on energy efficiency practices:

- Management Tools
- Plant Improvements and Operational Changes
- Water Treatment
- Water Distribution
- Water Conservation
- Alternative/Renewable Energy Sources
- Financial Assistance
- Partnerships

The discussion on each of these topics includes an introduction to the topic area, a description of the various practices, the energy or cost savings realized, and references and resources. The findings from the literature review are presented in Chapter 3 of this report.

Utility Case Studies

Prior to award of the project, the project investigators identified and contacted a number of utilities to ascertain their interest in participating in the project. Based on preliminary criteria which included a requirement that at least 20 percent of the utilities be located in New York State, 10 drinking water utilities indicated a willingness to provide in-kind participation in the project as case studies. These utilities represent utilities of various sizes and geographic distribution, and employ a variety of energy efficiency practices. Once the project was awarded and more specific criteria were obtained from the PAC and the GWRC, six additional case studies were added for a total of 16 case studies. A map of the utility locations is shown in [Figure 2.1](#).

A final list of the participating utilities, their size, geographic location, and energy efficiency practices is found in [Table 2.1](#).

The case study findings are presented in Chapter 4 of this report. Based on input from the PAC and the GWRC, the format of the case studies includes:

- Utility name, location, and population served
- Background on the water utility and history of the “issue”
- Type and size of process or technology evaluated
- Change(s) implemented and results
- Special staff or IT needs or other considerations
- Lessons learned
- Conclusions

In addition, the GWRC requested that a specific table of information be completed for each case study to ensure that consistent information was collected from utilities around the world. Those tables can be found in Appendix A. The specific format of the case studies is discussed in the section in this Chapter titled *Coordination with International Effort*.



Figure 2.1 Map of case study utility locations

**Table 2.1
List of utilities, locations, population served, and energy efficiency practices**

Utility	City, state	Energy efficient practices	Population served
American Water	Voorhees, NJ	USEPA's Climate Leaders program Reducing non-revenue water Pump optimization Lighting Fleet management Green power generation Green power purchase	16,000,000 in 32 states
Ann Arbor Water Treatment Services	Ann Arbor, MI	Demand Management System Computerized air handling Motor replacement and VFDs Ozonation optimization	120,000
Austin Water Utility (1)	Austin, TX	Optimize pumping Gravity flow Fleet management Solar power	850,505
Austin Water Utility (2)	Austin, TX	Water conservation Incentive rebates Water efficient equipment	850,505
Cedar Rapids Water Department	Cedar Rapids, IA	Monitoring industrial water use Monitoring and tracking power use and demand VFDs Partnership with power provider	125,000

(continued)

Table 2.1 (Continued)

Utility	City, state	Energy efficient practices	Population served
Cleveland Water Division	Cleveland, OH	Operation optimization and staff training Wind power Off-peak pumping Replacing pumps and motors	1,500,000
Columbus Water Works	Columbus, GA	Energy management plan SCADA On-site generation	227,600
Las Vegas Valley Water District	Las Vegas, NV	EWQMS Solar power HVAC SCADA Pump optimization Water conservation	1,300,000
Metro Vancouver/Greater Vancouver Water District	British Columbia, Canada	Partnership with power provider Hydraulic modeling Pump optimization Gravity feed	2,000,000
Mohawk Valley Water Authority	Utica, NY	Hydroturbines	130,000
Monroe County Water Authority	Rochester, NY	Pump maintenance Load shedding VFDs	650,000
New Jersey American Water	Somerset, NJ	Solar power	530,000
Queensbury Water District	Queensbury, NY	Pump replacement Effective use of storage	35,000
Suffolk County Water Authority	Oakdale, NY	Off-peak pumping SCADA	1,200,000
Village of Waterloo	Waterloo, NY	SCADA	9,500
West Basin Municipal Water District	Carson, CA	Partnership with energy providers Solar power Recycled water program Desalination pilot study	1,000,000

DEVELOPMENT OF SEARCHABLE DATABASE

Due to the volume of information contained in this report, the project investigators developed a simple, easy-to-use, searchable database. This will allow users to quickly search on the various energy efficiency practices and obtain information on the practice description, energy/cost savings, barriers or special implementation issues, staff expertise, and IT needs. Links to relevant URL sites are also provided as well as links to relevant case studies. Users are able to search and compare various processes or practices and can print hard copy summaries of the information. A

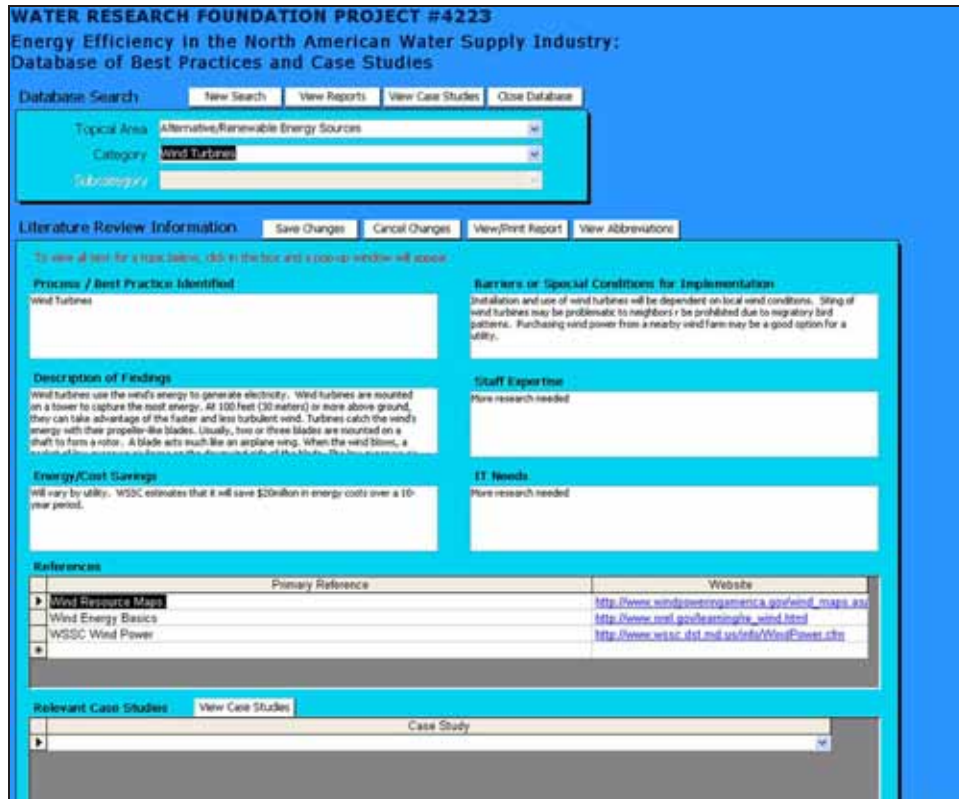


Figure 2.2 Screen shot of best practices database

copy of the database is included on the CD-ROM for this report along with a *User Guide*. A screen shot of the database is shown in [Figure 2.2](#).

COORDINATION WITH INTERNATIONAL EFFORT

Communication

An important aspect of this project was to communicate and coordinate activities with the GWRC contractor responsible for coordinating the larger international effort. To accomplish this, a number of conference calls were held at the beginning of the project and as data were being gathered. Coordination also took place with WERF which managed the companion project that evaluated energy efficiency at wastewater utilities in North America.

Standard Templates and Formats

The international effort was particularly focused on findings from the case studies. Copies of the literature review and final case studies were provided to GWRC and the table requested in the case study template was completed for each utility. [Figure 2.3](#) outlines the format of the case studies and [Figure 2.4](#) provides the format for the table template requested by GWRC. The completed case study table templates are found in Appendix A.

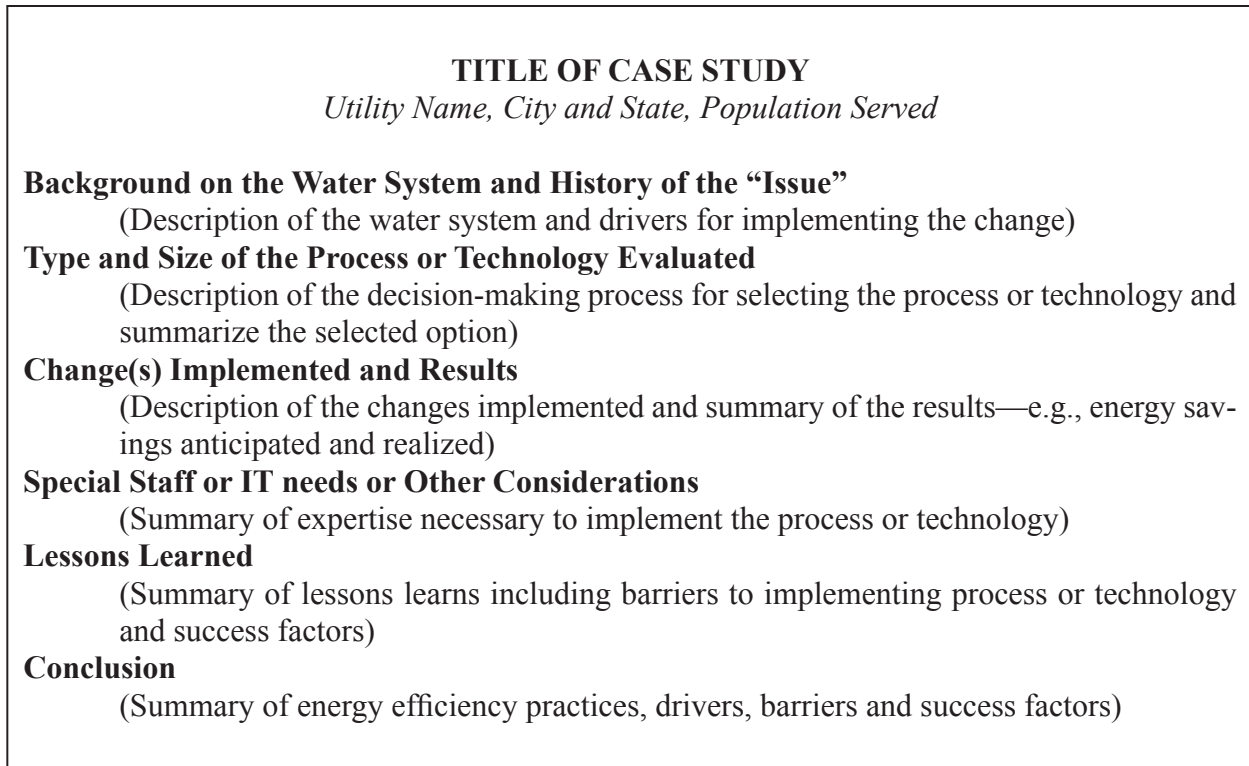


Figure 2.3 Case study format

TITLE OF CASE STUDY <i>Case Study Information Table</i>		
Ref.	Enquiry Item	Response information, description, and remarks
1	Location: Country, urban or rural and small, medium or large system:	USA or Canada
2	Sector: drinking water [clean], wastewater [waste] or sludge:	Drinking Water
3	[Utility] Works Owner or Operator: with financial set-up, regulatory or not.	
4	Size: flows and loads or population equivalent:	
5	Energy Provider: with costs, incentives, taxes and conditions:	
6	Process: physical, chemical, or biological description:	
7	Component: all or part of the works:	
8	Specific energy problem: including quality or consent details:	
9	Process/Plant changes: mechanical, electrical or controls:	
10	Civil/Physical Changes: to water/effluent quality, civil works, or process:	
11	Operational Changes: skill levels, procedures and maintenance routines:	
12	Risks and Dependencies: risk assessment of project and changes.	
13	Implementation: design, build, procurement, installation and commissioning:	
14	Energy Efficiency gains: kWh & kWh/m ³ before and after implementation	
15	Cost/Benefit analysis: financial appraisal or payback time.	
16	Project review: could it be improved or developed?	
17	Confidence grade: on data provided.	

Source: GWRC.

Figure 2.4 GWRC case study information table

CHAPTER 3

BEST PRACTICES IN ENERGY EFFICIENCY

CHALLENGES TO ENERGY EFFICIENCY

Although energy efficiency improvements can be a win-win for the utility, its customers, and the environment, there are a number of barriers or hurdles that may need to be overcome by the utility. Some of these barriers were outlined in a recent NYSERDA report (NYSERDA 2008). These barriers include:

- *Operational barriers:* commonly the result of staff having limited or no experience in the identification or implementation of energy efficiency measures.
- *Institutional barriers:* results from staff and management not changing the “status-quo” and difficulties implementing new policies and a holistic approach across multiple departments.
- *Political barriers:* associated with the lack of understanding of the technical or economic aspects of the improvement and unwillingness to invest in the project, and avoiding rate increases and rate shock.
- *Regulatory barriers:* results from management not wanting to risk any decrease in public safety in an attempt to improve energy efficiency; therefore, equipment is typically oversized.
- *Financial barriers:* results from the inability to obtain funding without implementing rate increases, the concern that the potential savings will promote smaller operating budgets, and the dependence on the relatively low costs of energy. In many cases, utilities are unaware of financing incentives and rebates that could help pay for energy efficiency improvements.

A number of tools and best practices to help overcome these barriers are described in this chapter.

OVERVIEW OF FINDINGS

The purpose of the literature review, which formed the foundation of this chapter, was to identify and target energy efficiency best practices currently in use at drinking water utilities in North America. These practices were organized and consolidated into eight major areas including management tools, plant improvements and management changes, water treatment, water distribution, water conservation, alternative/renewable energy sources, financial assistance, and partnerships. These areas cover the full breadth and scope of utility services as well as identify resources and partnerships that can aid utilities in implementing energy efficiency improvements. In many cases, such improvements will not require expensive or extensive capital investments—simply optimizing a utility’s current equipment and operations practices can lead to significant reductions in energy consumption. This chapter provides detailed discussions in each of these eight areas along with references to resources and additional materials that can be used by utilities to develop energy management plans and improve energy efficiency. Some major findings include:

- Some level or type of energy efficiency improvement can be realized by utilities of all sizes and management structure. It requires, however, leadership commitment at the utility level and operator buy-in to be successful. Partnerships with energy providers may be particularly useful in identifying energy conserving options. While simple approaches like working with energy providers to evaluate the schedule and timing of pump usage can lead to significant cost reductions (although perhaps not energy use reductions), such cost savings can inspire a utility to look for other opportunities to enhance energy efficiency. For drinking water utilities, the primary area to target improvements is pumps and motors since pumping accounts for 80 percent of the energy used at most water utilities (EPRI 2002). This may include pump rehabilitation, pump optimization, correctly sizing pumps, and use of variable frequency drives (VFDs).
- Benchmarking and conducting energy audits can help a utility define its current energy usage and establish a baseline from which to measure and track changes and reductions over time as energy improvements are implemented. This does not have to be complicated or overwhelming. For small systems, in particular, USEPA's ENERGY STAR® *Portfolio Manager* is free tool that can be used to establish an energy use baseline and even evaluate carbon emissions.
- While not crucial to a utility management's energy plan, SCADA and other electronic monitoring and reporting systems can significantly enhance a utility's ability to coordinate, track, and manage energy-related decisions and operational changes.
- Unlike wastewater systems, options to "generate" energy are somewhat limited for drinking water utilities. The most common approach is the use of in-line turbines that generate energy to run ancillary equipment such as pumps at the site location. Some larger utilities have incorporated alternative energy sources such as solar and wind but this may not be cost effective for smaller systems.
- Water efficiency can lead to energy efficiency since less water will be treated and moved through the distribution system. Leak identification and repair in the distribution system, water audits, and conservation programs for commercial and residential users can reduce water use. Key to success is adequate metering and a rate structure that does not penalize a water utility by reducing revenue because it has successfully encouraged its customers to conserve water.
- Funding is available to water utilities to implement energy efficiency options. Beginning in 2009, drinking water SRFs now include a requirement for the states to allocate 20 percent of the capitalization grant to "green projects." For drinking water, this includes funding for on-site production of power, energy audits, equipment upgrades, leak detection equipment, meter installation, and installation of water efficient devices. State energy offices, other state authorities, and individual energy providers may have funding for studies and pilot projects as well as financial incentive and rebate programs that can help pay for project implementation costs. In some cases, energy providers will "pay" utilities to improve energy efficiency.
- It is important for utilities to understand that efforts to increase energy efficiency may come with risks and tradeoffs that may impact water quality and public health.

As applicable, these concerns are discussed in this chapter and throughout the report.

ENERGY EFFICIENCY BEST PRACTICES

It is important for drinking water utilities to take a holistic view of energy management. In addition to improving energy use in the treatment and distribution process itself, there are a number of other tools and management approaches that can help utilities reduce their overall energy consumption. In many cases, measures taken to improve water efficiency also translate into energy savings as less water is required to be produced and pumped. This can also result in monetary savings on chemicals and other treatment supplies, and extend the life of treatment units and components. The energy efficiency best practices identified and discussed in this report focus on the following critical areas of water supply and energy savings:

- Management Tools
- Plant Improvements and Management Changes
- Water Treatment
- Water Distribution
- Water Conservation
- Alternative/Renewable Energy Sources
- Financial Assistance
- Partnerships

[Table 3.1](#) identifies the specific practice or process discussed under each of these major topical areas. The narrative provides an overview of the practice or process, describes options for improving energy efficiency, and provides a number of resources to assist water utilities in learning more about the topic.

Management Tools

Best Practices

- Benchmarking
- Energy Audits
- Energy Management Systems
- Energy and Water Quality Management Systems

There are a number of management tools and best practices available to drinking water utilities to better understand their energy consumption, determine the most energy intensive areas of their system, define goals and energy conservation measures, develop a plan of action, and monitor progress. These tools and best practices represent effective ways for water systems to improve their overall energy efficiency. They include: (1) benchmarking; (2) energy audits; (3) energy management systems; and (4) Energy and Water Quality Management Systems.

Benchmarking

Energy Index Development for Benchmarking Water and Wastewater Utilities. In 2007, AwwaRF published a research report titled *Energy Index Development for Benchmarking Water and Wastewater Utilities* (Carlson and Walburger 2007). The project was designed to develop

Table 3.1
Energy efficiency best practices

Management tools	Plant improvements/ management changes	Water treatment	Water distribution	Water conservation	Alternative/ renewable energy sources	Financial assistance	Partnerships
Benchmarking	Lighting and HVAC	Slow Sand Filtration	Hydraulic Modeling	Supply Side	Solar Power	DWSRF and CWSRF	Federal Government
Energy Audits	Fuel Efficient	River Bank Filtration	Post Flocculation	Leak Reduction	Wind Turbines	ARRA-GPR	State Government
Energy Management Systems	Fleet Vehicles	Conventional Filtration Treatment	Distribution System Piping	Metering	Geothermal	Financial Incentives	University
Energy and Water Quality Management Systems	Long-Range Planning	Direct Filtration Treatment	Pumps	Alternate Supply	Lake/Ocean Water Cooling	NYSERDA Programs	Energy and Water provider
	Rate Structures	Forecasting and Load Demand Profiles	Motors	Water Loss Audits	Micro-Hydro Generation	State Funding Programs	Trade Associations and Other Business Networks
	Short-term Consumption Forecasting	Diatomaceous Earth Filtration	Variable Frequency Drives	USEPA's WaterSense Program			
	SCADA	Air Stripping	Pressure Reducing Valves and Inline Turbines	Water Efficient Devices			
	Computerized Maintenance Management Systems	Membranes		Metering			
		Ozone		Commercial and Industrial Efficiency			
		Ultraviolet Disinfection		Conservation Rate Structure			
		Desalination		Alternate Supply			

metrics to allow the comparison of energy use in drinking water and wastewater utilities. The project produced a water utility metric model that related energy consumption to total flow, total pumping horsepower, distribution main length, distribution elevation change, raw pumping horsepower, and the amount of purchased flow. Energy use in production, treatment, and distribution were correlated to utility characteristics. The model can be used for both internal tracking and external comparisons across the industry. A secondary use of the model is to characterize the typical energy use attributable to specific characteristics or processes on an empirical basis. The metric score can serve as an initial screening when identifying plants or utilities where energy conservation efforts should be applied and can provide a plant operator with perspective on how much energy performance can be improved. This research laid the foundation for development of USEPA's ENERGY STAR® *Portfolio Manager*.

ENERGY STAR® *Portfolio Manager*. Another benchmarking tool available is USEPA's ENERGY STAR® *Portfolio Manager*. Currently, the tool focuses on wastewater systems but efforts are underway to improve the tool for drinking water systems. The ENERGY STAR® program incorporates a benchmark metric system that provides a score based on data inputted by the user and as compared to a random unbiased survey sample of similar wastewater treatment plants

in the U.S. The *Portfolio Manager* tool “normalizes” the data for various factors including weather and plant characteristics. Once all data is entered, the tool assigns a score from 1 to 100 for the treatment plant. The score provides a sense of the relative energy efficiency at the plant level. For example, an ENERGY STAR® score of 60 indicates the plant performs better than 60 percent of similar plants nationwide.

With the automatic tracking of energy performance allowed by *Portfolio Manager*, a wastewater treatment utility can use the ENERGY STAR® score as an energy management indicator by continually tracking energy performance over time to define specific facilities for energy efficient upgrades, to evaluate the success of energy efficiency projects, and to make improvements and assess feedback. ENERGY STAR® *Portfolio Manager* can be used for tracking energy intensity and energy efficiency improvement over a drinking water facility’s own baseline, but there is no ENERGY STAR® score for drinking water treatment and distribution systems at this time.

The *Portfolio Manager* includes various tools to assist water systems with tracking multiple energy and water meters for each facility, identifying under-performing buildings, monitoring progress and verifying improvements, and monitoring energy and water costs. *Portfolio Manager* also calculates greenhouse gas emissions (including carbon dioxide, methane, and nitrous oxide) from on-site fuel combustion and purchased electricity and district heating and cooling. More information on ENERGY STAR® *Portfolio Manager* is available at http://www.energystar.gov/index.cfm?c=evaluate_performance.bus_portfoliomanager.

ENERGY STAR® Cash Flow Opportunity Calculator v2.0. USEPA is also in the process of developing an ENERGY STAR® *Cash Flow Opportunity Calculator v2.0*. The purpose of the tool is to help decision-makers quantify the costs of delaying an energy efficiency project by addressing three critical questions:

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

The spreadsheet model is currently being beta tested and will be uploaded to the ENERGY STAR® Web site in the near future (<http://www.energystar.gov/benchmark>).

Energy Audits

One way for a water utility to identify areas or opportunities to reduce energy use without negatively affecting the system processes or water quality is through an energy audit. The goal of any energy audit is for management to assess the energy use or energy flows of the water system and to identify the most energy-intensive areas of the system, outline possible actions and energy conservation measures, and set a plan of action in motion. Typically, up to 80 percent of a drinking water system’s energy use is consumed by pumping (raw water to distribution) and treatment processes (EPRI 2002).

Water utility staff can perform either a “high-level” or a comprehensive “detailed process” energy audit. Typically, a high-level or walk-through energy audit is initially performed to identify the major problem areas or the most energy-use intensive processes. The walk-through energy audit will help direct management where to concentrate the detailed process energy audit or audits.

Detailed process audits focus on the assessment of a specific process or operation identified as being energy intensive and provides for an understanding of where improvements can be made. Raw water pumping, distribution system pumping, and filtration and treatment processes are good focal points for performing a detailed process energy audit. Data gathered during the energy audit can be used to create an energy inventory and help in developing an energy map. The “Lean and Energy Toolkit” from USEPA (<http://www.epa.gov/lean>) outlines the process of developing an energy map.

The same procedures apply when performing an energy audit using either a high-level or detailed process audit approach; however, the information collected for a detailed process audit will focus on energy use for a specific process or operation not the overall water system as with a high-level audit. The energy audit process as outlined in EPRI (1994) typically includes:

- Holding a kickoff meeting
- Creating a team of water utility staff, electric utility personnel, and outside experts
- Collecting plant or specific operational process data, whichever is applicable for the type of audit being performed
- Evaluating electric bills and electric rate schedules
- Conducting field investigations and holding discussions with operations staff
- Creating an equipment inventory and distributions of demand and energy
- Developing energy conservation measures and strategies
- Following up on implemented measures

It is likely that water utility staff may not have the background, time, and training to perform an energy audit. Various resources are available to assist in the performance of an energy audit including state assistance programs (e.g., NYSERDA), energy audit software, and energy audit experts. Additionally, many power companies provide assistance to their customers with performing energy audits. When a water utility is ready to proceed with an energy audit, it is important to first contact the electric provider and discuss any assistance they can provide and request involvement from electric utility personnel. Including electric utility personnel in the audit process provides the water utility management the opportunity to understand the electric billing process and rate structures. Additionally, building a relationship with the electric provider creates an opportunity to discuss any possible changes to billing or the use of rebates/incentives for implementing energy conservation measures. If a water utility decides to hire an outside expert, it is important to find out if an energy audit certification or license is required by the state.

To build support and understanding regarding the importance of the energy audit and energy conservation, water utility management should request energy conservation ideas from staff, include operational personnel in the energy audit discussions, and promote buy-in from water utility personnel. In order for energy measures to yield the most impact, staff responsible for implementing and operating any new technologies, equipment, or programs must be involved in the process to understand that their role is important and vital to meeting the energy conservation goals.

After conducting an energy audit, water utility management then evaluates and discusses the possible energy saving opportunities, defines their energy conservation measures (ECMs), sets goals, and designates specific staff personnel to be responsible for implementing the ECMs. Due to various reasons, such as cost/benefit analysis, impacts on process and water quality, and lack of funding, it is likely not feasible for a water utility to implement all of the energy measures

identified. Therefore, management should select and prioritize the ECMs into attainable 0–2 years, 3–5 years and 6+ year projects that will allow the system to obtain the defined energy efficiency goals. Some ECMs may involve capital projects and others may be easily done with minimal costs or impacts to operations.

The CEC has various resources available on how to conduct an energy audit and how to hire an energy auditor (http://www.energy.ca.gov/reports/efficiency_handbooks/index.html). Other resources available for energy audit assistance may include state programs and the state's rural water association. Links to the various state rural water associations are available at <http://www.nrwa.org/>.

Energy Management Systems

Thirty to 40 percent of municipal energy bills are associated with drinking water and wastewater systems. It is within the water utility's control to manage its energy use, and subsequently reduce its energy usage and costs. One way a water utility can "control" costs and manage rate savings to pass on to consumers is by implementing an Energy Management System (EMS) or Plan. USEPA (2008) has developed a guide called *Energy Management System (EMS) Plan-Do-Check-Act Approach to Improve Energy Management—Ensuring a Sustainable Future: An Energy Management Guidebook for Wastewater and Water Utilities (Guidebook)* that can assist utilities in developing a plan. A copy of the USEPA *Guidebook* can be downloaded at http://www.epa.gov/waterinfrastructure/pdfs/guidebook_si_energymangement.pdf.

Some of the various ways a water utility can control energy use and associated energy costs include, but are not limited to:

- the use of new technologies and new energy-efficient equipment
- the adjustment of processes that operate with electric rate schedules
- the utilization of electric rebates or incentives

An EMS allows water utilities to define goals, set priorities, and determine the specific improvements to implement. For successful implementation of an EMS, a water system will need to overcome operational and institutional barriers by securing and maintaining management commitment; establishing energy improvement goals; creating a team responsible for implementation of the goals, including providing staff training to develop skills necessary to implement improvements; establishing an energy champion; securing and maintaining employee buy-in; and communicating results.

USEPA's *Guidebook* outlines a step-by-step process that instructs water utilities on how to implement an energy management program. The goal of the *Guidebook* is for systems to realize the benefits of implementing a management approach by optimizing energy conservation at the water utility. The *Guidebook* will improve management's understanding of energy used by the water system and will assist management in defining goals and setting priorities for energy efficiency improvements.

The following steps for developing an EMS are outlined in the USEPA *Guidebook*:

1. Benchmarking and tracking monthly and annual energy use;
2. Identifying and prioritizing energy operations and issues that can increase efficiency;
3. Identifying energy efficiency objectives and targets;

Table 3.2
Components and benefits of an energy management plan

Key components of an energy management plan	Benefits of enhanced energy management
Creates a system to track energy use and costs	Reduced O&M costs
Promotes upgrades of equipment and processes when capital funds are spent	Improved treatment efficiency Improved process control
Creates a cost-effective energy supply purchasing strategy	Improved water quality
Optimizes load profiles—peak demand and load shifting	Generates revenue stream(s)
Enhances communication with local officials	Accommodates regional development
Necessitates key energy-management trained personnel	Enhances community relations Environmental stewardship

4. Defining the performance indicator(s) to use to measure progress towards energy targets;
5. Establishing energy management programs (i.e., action plans to meet system goals);
6. Monitoring and measuring the performance of established target(s);
7. Documenting and communicating success; and
8. Reviewing progress periodically and making adjustments as necessary.

A summary of the components and benefits of an energy plan are presented in [Table 3.2](#).

Energy and Water Quality Management Systems

In the early 1990s the AWWA Research Foundation (AwwaRF; now the Water Research Foundation) embarked on a research program (*Energy and Water Quality Management Systems: Collaborative Project for Water System Optimization*) to develop an information technology system for water utilities to provide opportunity for controlling and optimizing energy savings and enhance the ability to meet ever changing water quality standards. The research found that in order to minimize operations and maintenance costs and integrate proper controls, integration of energy management and water quality management must be considered. Through a collaborative research project, AwwaRF published the *Energy and Water Quality Management System (EWQMS)* report in 1997 and has continued to expand this research.

The complexity of daily operations of a water utility has increased over the years as systems must address stricter water quality regulations, many of which require more stringent controls and monitoring, and the need for advanced or additional treatment. The EWQMS provides water utility staff a way to optimize the operation of the entire water system to provide for the highest cost reductions in energy and operation and maintenance budgets. The management system also provides for improved water quality and water supply management through ability to properly plan, schedule, and monitor the increased complexities (Jentgen 2003).

The EWQMS is a series of individual application software programs and organizational practices that permit “flexible” planning and scheduling of operations to “solve” water quality and energy management problems. System planners and operators incorporate information from the entire water system to prepare daily operation plans and schedules. Optimization and simulation techniques are built into the software programs that determine the optimal operating plan that provides the lowest operating costs. The software has the ability to use time-based energy costs

in conjunction with predicting energy consumption and load demands to control operations. The series of software programs easily integrates and retrieves data from a water utility's existing SCADA system. EWQMS expands beyond the traditional SCADA systems which focus on operations and individual components to control actual operations by incorporating the entire water system. Some benefits of establishing an EWQMS include cost savings, cost avoidance, energy efficiency, improved water quality, and revenue increase.

EWQMS Application Software Programs. The core of the EWQMS is the Operations Planning and Scheduler (OPS) function. To properly develop daily, weekly, and annual operating plans and schedules to optimize efficiency of operations and reduce energy use and costs, the entire water system processes, energy costs/rates, and water utility performance criteria/goal information are integrated into the OPS. This data is integrated by a variety of individual application programs and input from water utility staff and operators. With the ability to compare all the system data, the OPS easily identifies “conflicts” between the most energy-saving operations and maintaining water quality. OPS easily changes to model the next best operating alternative for lowest cost and highest optimization when the “desired” lowest cost operating plan conflicts with water quality requirements or other criteria.

The individual application programs are specific to the separate components of the water system and include treatment operations, pumping operations, maintenance schedules, water consumption forecasts, water quality and monitoring, energy cost and forecasts, and management performance criteria/goals. The OPS can also receive data from an existing SCADA system. Each individual application program has its own set of data and information it uses to optimize the specific component of the water system to minimize energy consumption. All the individual application programs are integrated, including the pump operation scheduling program which uses the pump characteristics to match the treatment plant schedule; water demand; pump maintenance schedules; and other factors such as energy rates and cost per hour to “model” the schedule to provide the lowest operating costs. The OPS uses the “modeled” criteria from all programs to plan and schedule the most effective operation to maintain water quality standards. The OPS plans can be created daily or weekly and changed if needed. Once the plan is established, system operators use the SCADA system to monitor the system and if needed, make changes to realign various components.

Steps Involved With Developing an EWQMS. Prior to developing an EWQMS, it is useful to first develop a business model reflecting how the utility responds to external events (i.e., water pressure complaints). The business model will help identify software requirements and the major components for an EWQMS. Using the main functions of the water system, the architecture of the EWQMS is developed by creating a diagram that represents how data flows in and out of each system function. A helpful resource in establishing a business model and business architecture is the Water Research Foundation report, *The Utility Business Architecture: Design for Change*, available for download at: <http://www.waterresearchfoundation.org/research/topicsandprojects/projectSnapshot.aspx?pn=165>.

The AwwaRF report *Energy and Water Quality Management System* (Curtice, Jentgen, and Ward 1997) outlines the decision-making process to develop an EWQMS and provides ideas on how to evaluate the software program needs of the water system. Jentgen et al. (2005) outlined the following steps for developing an EWQMS:

- Planning—project development plan (timelines and tasks)
- Analysis—develop needs and requirements (inputs/outputs)

- Design—detailed structure of system and each module
- Construction—convert structure to programs and applications
- Testing—verify system satisfies requirements and needs
- Start-up—begin operations and refine system as needed until operations meets user requirements

Once the decision is made to move forward with an EWQMS, the water utility should evaluate the cost/benefits of developing and installing an EWQMS through hiring a consultant to design the individual software applications or establish and participate in a Forum with other water utilities that may include electric utility and software vendors. A benefit of utilizing a Forum is that it brings together multiple sets of knowledge to establish and define common solutions that water utilities can employ to improve service, water quality, and control costs. Many water utilities, especially small/medium systems, may lack available staff or lack the expertise to proceed with developing and implementing EWQMS that a Forum may be able to provide. The *Energy and Water Quality Management System* report (Curtice, Jentgen, and Ward 1997) discusses the benefits for participating in a Forum and how a water utility can establish a Forum.

Benefits and Barriers With EWQMS. Each water utility is different and will bring various complexities to the EWQMS based on the input data associated with the water system including details such as system head, pressure, storage limitation, topography, etc. The addition of multiple software programs increases the technical complexity of the system and makes the EWQMS more difficult to design and manage. Implementing an EWQMS requires a long-term commitment from upper management. It is therefore helpful to have knowledgeable management who understand technology and who can work with operations staff. Additionally, management must support training of staff or hiring of special technical staff to ensure that the most benefit is received from the EWQMS.

Water utilities can start slowly and build the EWQMS over time and utilize or modify an existing SCADA system to help monitor energy management needs. Added benefits of implementing the EWQMS in phases is that operators have time to learn system constraints and become familiar with the new functionality.

A variety of lessons have been learned through the Foundation’s research collaboration efforts regarding developing and utilizing an EWQMS (Jentgen et al. 2005). These include:

- Utilize water system staff’s “in-depth” knowledge and have staff involved with software development, deployment, and testing.
- Communication of the development process among staff, management, and programmers is necessary for program success.
- Positive attitudes and strong leadership is vital in promoting the “cultural” shift to a proactive operations approach and moving away from a reactionary approach.
- System data must be up-to-date for programs to properly model and create a “plan.”

Initial pilot test results outlined in the 1997 report showed EWQMSs allowed for easier changes to operations schedules and shifting pumping to off-peak hours; improved water quality; and provided savings of 18 percent on annual electric energy purchases (Curtice, Jentgen, and Ward 1997). Jentgen et al. (2005) reported that the EWQMS provides for easy access of data, especially energy costs; and allows for better planning for future needs by downsizing new facilities or deferring construction to a later date. Another benefit from using an EWQMS is improved water

resources management through the ability to improve water consumption forecasting. A pilot utility in the AwwaRF 2003 report, *Implementing a Prototype Energy and Water Quality Management System* (Jentgen et al. 2003), estimated a return on investment (ROI) of 3 years or less. However, the ROI will be dependent on the scale and complexity of the EWQMS.

Plant Improvements and Management Changes

Best Practices

- Lighting and HVAC
- Fuel Efficient Fleet Vehicles
- Long-Range Planning
- Rate Structures
- Forecasting and Load Demand Profiles
- Short-term Consumption Forecasting
- SCADA
- Computerized Maintenance Management Systems

This section provides drinking water utilities with an understanding of how various plant improvements and management changes can help achieve energy efficiency improvements. With regard to energy efficiency plant improvements, water utility management should focus on those measures that can be implemented facility-wide and not on measures for specific operation/treatment processes.

Common facility-wide plant improvements include upgrading the lighting and heating, ventilation, and air conditioning (HVAC) of the facility plant, grounds, and buildings; installing electric and natural gas submeters; and installing an automatic control system, such as SCADA. Lighting and/or HVAC improvements can be completed easily and the improvement will typically not impact operations. Commonly, incentives and rebates are available from electric providers and others (e.g., NYSERDA) for installing energy-efficient fixtures and equipment which can reduce the financial impact. Installation of energy submeters are important plant improvements and can be inexpensive when associated with installing new facility equipment.

Typically, the most challenging energy measures to implement are management changes as it takes a modification to one's way of thinking to promote policy and procedural amendments or a new policy direction. A water utility, and the municipality that owns the system, will need to prioritize energy saving measures and determine which plant improvements and management changes it is financially and technically capable of implementing. The prioritization should consider the staff capabilities and skill sets needed to implement the ECMs. Additionally, the prioritization should address those measures that will allow the water utility to best meet its energy reduction goals.

A computerized maintenance management system (CMMS) or enterprise asset management (EAM) system can be useful tools for managing operational changes or management policy changes related to fleet management, lighting and HVAC, and other equipment maintenance programs.

Lighting and HVAC Improvements

An integral part of a water system's facility energy improvements include the evaluation of potential benefits from upgrading the lighting and HVAC at the facility. Retrofitting with new lighting and HVAC technologies and implementing maintenance programs have the potential to

produce significant energy reductions and efficiency improvements. Occupancy sensors are also being incorporated more often into new building construction.

Lighting. The CEC estimates lighting accounts for 35 to 45 percent of a building's energy use (incorporating both indoor and outdoor lighting) (CEC 2000b). These percentages may not be as applicable to all facilities of a water system. However, new high-efficiency lighting technologies available today produce better lighting while using less energy and installing energy efficient lighting can easily be integrated into a water system's ECMs.

As part of designing a new facility or planning a facility upgrade lighting retrofit or replacement program, it is important that the water utility select the correct lighting technology to best fit the location of use. Outdoor lighting selections will likely be different than indoor lighting selections. With design of a new facility or facility expansion, the use of natural light can provide beneficial savings and reduce energy use. Additionally, as part of any improvement being considered, the water utility should evaluate the payback for different technologies and determine which options correlate best to its energy efficiency goals. Payback on lighting retrofits may be 2 to 3 years, or less, if rebates/incentives are available. If a water utility cannot afford a complete lighting retrofit program, an alternative is to update and revise the lighting maintenance manual to require any replacements to adhere to new energy efficiency standards.

To gain the most benefit from a new facility or a lighting retrofit or replacement program, the water utility should implement a maintenance plan that includes a regular cleaning schedule and group lamp replacement. Dirt and materials accumulating on lighting can reduce the lighting output by as much as 30 percent (CEC 2000b). Additionally, once a light reaches 80 percent of its useful life it produces 15 to 35 percent less light, becoming less efficient.

USEPA's ENERGY STAR® Web site (<http://www.energystar.gov>) has an on-line *Building Upgrade Manual* that details lighting selections and their appropriate use. Several of the new energy efficient lighting technologies include the following:

- *Advanced Fluorescent Lamps (T8s)* are used to replace the older T12 lamps and are up to 34 percent more energy efficient. Their limitation is for use indoors where temperatures do not fall below 60 degrees Fahrenheit.
- *Advanced Fluorescent Lamps (T5s)* have similar energy consumption and lighting usage as T8s; however the 5/8th of an inch diameter makes retrofits difficult. T5s have better performance in certain locations as they have better optical control than T8 lamps.
- *Electronic ballasts* are approximately 12 percent more efficient than conventional magnetic ballasts and eliminate flicker and hum.
- *Compact Fluorescent Lamps (CFLs)* replace incandescent lamps and are extremely energy efficient using 75 percent less energy. Even with a higher initial cost, the payback is provided by the CFLs' long life.
- *High-Intensity Discharge Lamps (HIDLs)* are for high ceilings (over 15 feet) and outdoor use. They provide intense point sources of light; however these lamps require longer startup times. Two common HIDLs are metal halides that produce a good color quality but have long start-up times and high ultraviolet (UV) output, and high-pressure sodium lamps that produce a yellow tint and are best for outdoor use.
- *Light-emitting diodes (LEDs)* have a growing number of potential uses; however, currently they are primarily used for outdoor lighting. LEDs have a long life and are

small in size, but the costs are still higher than other lighting options and an evaluation is necessary to determine the cost/benefit.

- *Photocell lighting* senses existing light and turns electric lights on when natural light levels are low or turns off when light levels are high. When used for outdoor applications, they can be combined with motion sensors or timers for additional energy savings.
- *Automatic Control Lighting* switch or dim lighting based on time, occupancy, and lighting-level strategies and can reduce unnecessary lighting by 25 to 50 percent (CEC 2000b).

HVAC. New high-efficiency HVAC systems can reduce energy use by 20 to 40 percent as compared to conventional systems from 10 to 20 years ago (CEC 2000a). At least 25 percent of rooftop units are oversized and do not work efficiently; therefore, an evaluation of current equipment is a necessary component of an overall energy management plan to ensure existing equipment is properly sized and working at optimal efficiency. When evaluating an existing HVAC system for proper size and optimization, a water utility must understand the current and future potential load demand. It is recommended that an outside HVAC expert be hired to assist in understanding the load demand and selection of equipment for the various water facility buildings. As with any equipment, establishing a routine maintenance program will assist in preventing energy loss and extend the life of the equipment.

Air conditioning systems include roof top units, heat pumps, and chilled water systems. The energy efficiencies are associated with improved compressors, high-efficiency motors, and better insulation incorporated into the HVAC units. Adding operational controls, such as timers and electronic time clocks that can stop equipment operation or change temperature at scheduled times, can reduce energy consumption by up to 20 percent (CEC 2000a). Many of the operational controls can be automated with computerized systems that adjust operation by taking into account the weather and building-use patterns. Additionally, proper duct work installation and sealing can provide up to 11 percent reduction in energy use and optimizing performance of existing systems can provide up to 20 percent reduction. Replacement of single, older, larger air conditioning and heating units with several smaller units can reduce energy use by up to 40 percent since the multiple units can be operated as needed to match load demand (CEC 2000a).

The ventilation system is vital to ensure overall HVAC system efficiency. Ventilation systems either supply or remove air from a space by natural or mechanical means. Facilities consume large amounts of energy by heating, cooling, and blowing outside air for ventilation. Potential energy saving measures can include installing outside air economizers that automatically control air flow; for manual dampers, reducing energy use by setting air flow to match ventilation needs; and installing variable-speed drives on exhaust fans and hoods.

The U.S. Department of Energy (DOE) has various programs and information available for water utilities to use when evaluating their HVAC systems. These programs include the Federal Energy Management Program (FEMP) that provides tools and fact sheets at: http://www1.eere.energy.gov/femp/pdfs/unitary_ac.pdf and the Energy Efficiency Renewable Energy Network that provides information regarding upcoming federal minimums for various equipment. This information can be downloaded at: http://www1.eere.energy.gov/buildings/appliance_standards/commercial/ac_hp.html. Additionally, the CEE has various resource links regarding commercial HVAC systems available at <http://www.cee1.org/com/hecac/hecac-main.php3>. This includes *Guidelines for Energy-Efficient Commercial Unitary HVAC Systems* which is available at <http://>

www.cee1.org/com/hecac/Com_HVAC_spec.pdf. A Fact Sheet on *Energy Efficiency in Industrial HVAC Systems* has also been developed by the North Carolina Department of Environment and Natural Resources. It includes steps to conducting an HVAC audit (<http://www.p2pays.org/ref/26/25985.pdf>).

Use of Fuel Efficient Fleet Vehicles

Energy efficiency can be addressed not only by reducing consumption of electricity, but also by reducing reliance on petroleum fuel. It is important for water utilities to consider reducing use of petroleum fuel as a cost saving measure to reduce the impact of volatility in petroleum fuel prices. Another benefit of reducing reliance on petroleum fuel is the reduction in GHGs. Each gallon of gasoline or diesel burned releases 22 pounds of carbon dioxide, the major GHG pollutant (Les 2008).

More and more cities and states are implementing fleet management programs that include replacement of fleet vehicles with fuel efficient or alternative fuel vehicles. Fuel efficient vehicles achieve better than average gas mileage and run on petroleum-based fuels. Alternative fuel vehicles operate on non-petroleum based power or mixed technology. The following DOE Web sites contain valuable information on the various alternative fuels available: <http://www.fueleconomy.gov> and <http://www.eere.energy.gov/afdc/fleets/index.html>.

As part of an overall energy management plan, energy policy, or business practices, water utility managers can include a strategy for fleet vehicle replacement. The strategy should include realistic goals to gradually upgrade fleets or implement other fuel efficiency measures to reduce fuel consumption. These business practices or goals may include monitoring fuel usage by vehicle or class of vehicle, implementing maintenance programs to optimize efficiency, reducing miles traveled, implementing a no-idling policy, sharing vehicles between departments, eliminating non-essential vehicles, and leasing vehicles. Water utilities should also evaluate which vehicles they use the most and least and what types of vehicles are necessary. Since technology continues to improve, water utility managers should research which vehicle type best suits the needs of the facility. They may determine a mixture of fleet vehicles is required; both fuel efficient and alternative fuel vehicles.

An important component of any fleet replacement program is the evaluation of the life cycle costs including upfront and annual costs, the payback period, and the rate of return and maintenance costs of existing and new vehicles. The evaluation should also look at the availability of the various vehicles, the time frames for delivery, and the availability of fueling stations for alternative fuels. Typically, fuel efficient vehicles have a lower purchase cost, are more readily available, and have more models/selections as compared to alternative fuel vehicles. Alternative fuel vehicle challenges lie in limited refueling stations and low-mileage limit to the battery.

Long-Range Planning for Energy Management

Developing and implementing long range energy strategies is important to sustaining energy efficiencies of the system and ensuring the water system has a reliable energy source. Long-range planning incorporates supply-side and demand-side management, asset management, and life-cycle cost analysis. Typical management strategies assess energy supply and rates, operational changes, retrofitting equipment, and water conservation. Strategies for long-range planning must account for future energy requirements related to increased water demand and associated treatment

costs. Additionally, since differential growth in the service area and energy needs based on topography can impact a water system, it is important to integrate land-use planning or “smart-growth/sustainable” principals in long-range planning strategies. By limiting or delaying growth in certain areas—as longer transmission/distribution mains increase pumping requirements, infrastructure needs, and energy use or promoting use of on-site conservation options, as appropriate—utilities can optimize energy efficiency strategies. Furthermore, long-range energy management requires annual review and, if necessary, the modification of strategies and goals due to changes in technologies, water use, pricing options, and regulatory requirements.

Supply-side management focuses on understanding how energy is acquired or generated. Optimizing or negotiating energy rate structures and energy incentives with the electric provider can assist water utilities in meeting their ECM goals and reduce the water facility’s energy costs. It is important for water utilities to set up a process to re-evaluate pricing options and keep lines of communication open with the electric and other energy providers. One component of supply-side management is ensuring that the water utility has a reliable energy supply to operate the system. As energy demands increase the possibilities for power outages or power sags increase. Water utilities can contract for guaranteed power from an electric provider or incorporate on-site electric generation into their facilities to ensure adequate supply. Backup electric generation can be fueled by an alternative energy source such as wind, solar, hydropower, and geothermal or by diesel or natural gas. On-site generation provides two benefits: it acts as a backup power source during power outages or power sags or it can be used to replace electricity pulled from the grid during on-peak demand periods.

Demand-side management focuses on controlling the amount of energy used from conveyance, treatment, and distribution processes. For long-range planning and management, water utilities can establish procedures to curtail energy use by changing operational schedules, retrofitting or replacing equipment, installing electric submeters, optimizing overall system operations, incorporating gravity feed into the system, and conserving water.

In addition, asset management and life-cycle cost analysis are important procedures to incorporate into long-range planning. Asset management and life cycle cost analysis can ensure that the water system designs, selects, and operates the most energy-efficient equipment. The process also aids in establishing maintenance schedules for equipment to ensure optimum efficiency and defines plans and programs for repair/replacement. Hiring qualified engineers and maintenance staff may be required to provide expertise in energy procurement, asset management and analysis, and operation of equipment.

Electric Rate Structures for Lowest Energy Costs

Electric rate structures were developed to benefit both the electric utility and its customers. Electric utilities can reduce their costs by reducing the energy consumed during peak demand periods. Many rate structures correlate to a demand response option or program that encourages customers to reduce on-peak demand usage. The rate options available vary by electric provider and many providers are open to negotiating special rates; therefore, water utilities should open the lines of communication and work with their energy provider in order to select the best available rate structure. Changes in rate structure do not implicitly result in reduced energy use by the water system; they result in reduced energy costs billed to the water system. Using rate structures to lower energy costs is inexpensive to implement and a water facility can see the results quickly.

The various available rate structures are outlined below and provide multiple opportunities for water facilities to reduce costs:

- *Fixed pricing* is when a customer is charged a fixed rate per unit of energy.
- *Demand pricing* incorporates two charges, a demand charge based on capacity needed and an energy charge based on consumption. This structure is common for high energy use customers.
- *Time of Use (TOU) pricing* is when certain rates apply for different time periods and seasons of the year. TOU periods are typically categorized as on-peak, partial-peak, and off-peak. This rate structure is designed to encourage reduced energy consumption during on-peak demand periods and designed to lower customers overall energy costs with lower rates being charged during off-peak or partial-peak hours.
- *Real-Time Pricing (RTP)* is when rates are charged on a ‘real-time’ basis resulting from market forces of supply and demand. The rates are linked to wholesale costs that change on an hourly (or subhourly) basis. Prices are provided to customers on a day-ahead or hour-ahead basis. Typically, this rate structure is available for the largest customers that will receive the most benefit. Due to constant changes in prices, communication between the electric utility and customer is relayed via automatic metering infrastructure (AMI).
- *Interruptible Load* programs provide the customer with a 1-hour notice to reduce load in exchange for a lower rate.
- *Demand Bidding* programs have customers bid on the time of day and number of hours to curtail load for financial incentives.

Implementing TOU rate structures encourages water utilities to shift load demand from on-peak to off-peak periods by changing operation schedules. However, shifting pumping operations to off-peak or partial-peak hours requires the water system to have adequate water storage or on-site electric generation as well as adequate staffing. Utilities should use water consumption forecasting to help operations to take advantage of various electric rates and off-peak periods. EPRI estimates a water utility can reduce its energy costs from 10 to 15 percent by shifting its load to off-peak periods.

New York State has a Day Ahead Demand Response Program (DADRP) where commercial and industrial electric customers specify the hours of the next day they are willing to reduce electricity use, the amount of the reduction, and the compensation required. A bid is submitted to the New York Independent System Operator (NYISO) and is evaluated. If selected, the NYISO expects the demand to be reduced during the specified time. If the customer reaches the goal, it is billed the day-ahead market-clearing price. If the goal is not reached, the customer is billed the higher of the day-ahead and real-time prices. The DADRP requires a minimum reduction requirement of 100 kW per facility for each hour.

Energy Forecasting and Developing Load Demand Profiles

Calculating and evaluating electric consumption data is vital for water utility managers to understand energy use and to determine how to best make improvements. From load demand profiles, water managers can determine how much energy is used, when it is used, and by what

equipment it is used. Since energy usage can vary from minute-to-minute, hour-to-hour, and month-to-month, a water utility manager should develop various load demand profiles.

The load demand profiles should compare water demand usage to energy usage, electric usage (load) as a function of time as related to water demand, and electric usage as related to electric rate schedules (on- and off-peak periods). Collection of the necessary data can occur during an energy audit or benchmarking process. For many water utilities, it may be necessary to request assistance from the electric provider or hire an outside expert to help collect the appropriate data and develop the load profiles. If small water utilities need assistance, they can look for help through the state's rural water association. Additionally, software programs are available to assist water utilities with load demand profiles. Based on the load demand profiles generated, water utility managers can develop energy forecasting models for the short- and long-term to assist in energy conservation strategies.

Understanding electric billing can help the water utility to adjust its operational schedules based on the load demand profiles. The most common electric billing includes two components: demand charges which vary with time of day and with highest rates during periods of peak utility use, and energy consumption charges which are based on kilowatt hours consumed. The demand charges typically are the most significant to a water system's monthly energy bill since peak water demand normally correlates to peak energy demand. This billing structure may not be applicable once a water system uses/accepts special rate or incentive structures, such as real-time pricing, interruptible load, or demand bidding.

Providing the demand profiles and energy forecast to a system's electric utility is a beneficial tool in working with the electric utility to find ways to reduce peak demand usage. Additionally, a water utility can work with its electric utility to evaluate alternative rate structures or to possibly develop a partnership that will provide incentives based on peak-load energy consumption reductions. It is costly for the electric utility to generate power and therefore, electric utilities are interested in ways to reduce peak demand usage.

Water facilities typically have diurnal peak patterns that correlate to the hydraulic loading on the facility. Additionally, pumping patterns and peaking are driven by the customer mix; more residential load results in higher water demand. The hydraulic loading on the facility and the number and types of processes that are operated concurrently have a direct influence on peak load demand. Based on the analysis and full understanding of the load demand profile, water utilities can reduce energy consumption by adjusting operation schedules to correlate to off-peak demand or finding alternative energy sources, such as natural gas, diesel, or solar, to operate equipment during peak demand periods. Additionally, load demand can be reduced by optimizing existing equipment, installing VFD motors for equipment that must operate during peak demand, or adding smaller motors that can operate during low demand periods.

If primary meter and submeters are not already installed at various processes and equipment throughout the water system, it would be a very beneficial improvement to consider, especially if the water utility plans to implement or utilize energy forecasting and create demand load profiles to reduce electrical demand and costs. Retrofits to existing equipment are possible; however, installation of meters and submeters during installation of new equipment is less expensive and provides a start to collection of real-time data. An integral component to the installation of electric meters is having an available SCADA system to collect, store, and relay the data. Useful references on this topic include *Water Supply Related Electricity Demand in California* (CEC 2006) and *Ensuring a Sustainable Future: An Energy Management Guidebook for Wastewater and Water Utilities* (USEPA 2008).

Short-Term Water Consumption Forecasting

Water utilities need to move away from a reactive management approach to a proactive approach to reduce energy costs associated with pumping and treating water supply (Jentgen et al. 2007a). Operation of pumps and water treatment is directly related to water demand and consumption.

When water demand increases beyond normal capacity, reservoir levels and distribution system pressures fall and pumps turn on. When water demand is less than normal capacity, reservoir levels and distribution pressure rise until normal capacity is reached and the pumps shut off. By utilizing a proactive management approach through forecasting water consumption (demand) for daily, hourly, and subhourly periods, water utilities can optimize system operations to minimize energy consumption while still meeting water supply needs. Short-term water consumption forecasting projects the daily, hourly, and subhourly demand for up to a seven-day period (Jentgen et al. 2007a). Changes to system operating schedules based on the forecast must consider any system limitations such as reservoir levels, pressures, and system configuration (Jentgen et al. 2007b). A benefit of short-term water consumption forecasting is that water utility staff can adjust operating schedules so that the fewest number of pumps or highest efficiency pumps operate at a given period to reduce electric consumption. By reducing the number of concurrent pumps operating, the kWh demand decreases.

Another benefit of short-term water consumption forecasting is that the forecasting can be used on its own or used in combination with other management software programs, such as an EWQMS. Additionally, the forecast can be used to plan and schedule maintenance of equipment based on the operating schedule (Jentgen et al. 2007b). By knowing and predicting the hourly and subhourly water demands, the water system can take better advantage of interruptible electric rates, electric block rates, and TOU rates by shifting as much pumping as possible to off-peak periods.

Forecasting methods and models incorporate time-based electric rates, demand charges, historic demand trends (daily, hourly, and subhourly), pump efficiencies, energy production, and block-rate energy supply contracts to find the operating configuration that provides the lowest cost to move, treat, and distribute water (Jentgen et al. 2007b). Developing accurate forecasting can take time and with improved accuracy, result in increased energy reductions and cost savings. Selection of a forecasting method and “expected” accuracy depend on “applications” that will use the forecast, initial cost and maintenance of the software, and complexity of the forecast. Refer to Jentgen et al. (2007b), *Water Consumption Forecasting to Improve Energy Efficiency of Pumping Operations*, for details on setting up a forecast model and case studies showing energy savings potential. Short-term water consumption forecasting can provide significant opportunity to reduce energy costs.

Supervisory Control and Data Acquisition Systems

Use of automatic data collection and computerized monitoring and control systems, such as Supervisory Control and Data Acquisition (SCADA) systems as a management tool is becoming more popular with water utility managers. SCADA systems are versatile and include multiple applications and can be set up to automatically monitor and control a single component of the water facility or all aspects of the water facility such as wells, pump stations, valves, treatment

plants, storage facilities, etc. The systems can track energy use, and improve overall water system efficiencies by automatically controlling equipment operations, flow rates, and pressure based on real-time data. SCADA can also monitor equipment efficiency, leak detection, and meter reading and can sound necessary alarms when operations are out of “normal” range. Data collected and processed is relayed to a human operator who can make supervisory decisions and adjust or override controls of the system.

Benefits of SCADA include optimizing the complete water system process and providing cost savings by reduced operation and maintenance (O&M). SCADA systems allow utilities to implement energy management strategies that can achieve 10 to 20 percent energy savings (EPRI 1997). The computerized systems help operators ensure that a high level of performance is achieved. Additionally, water utilities can install SCADA systems in a step-by-step manner over time which allows the water utility to use the automatic control in areas that will provide the most benefit. A SCADA system is an important management tool with regard to data storage as it provides the water system with useful operation information for analysis of the facility’s processes, energy use, and benchmarking comparisons.

Computerized Maintenance Management Systems

One way that the engineering and operation sections of a water utility can work toward the same goals is to have a robust CMMS in place. The CMMS allows the utility to gather, record, and organize maintenance data from the utility’s infrastructure in a way that it can be used to schedule routine maintenance, determine the labor and materials resources needed for facility maintenance, trend facility efficiency levels, and establish facility useful life projections. Generally, the CMMS is one facet of a utility’s overall asset management plan since the information gained from a CMMS guides the engineering section to determine which projects are priority projects within the utility’s capital improvement program. Likewise, it guides the operations staff to know where budgeted funds for labor and materials are to be applied.

In general, a CMMS is composed of several important elements:

- A method to prioritize work projects based on established criteria
- A standard format for tracking water operations data
- A process that assigns preventive maintenance tasks prior to becoming corrective maintenance tasks
- A format to track and trend the condition and operating history of the utility’s infrastructure
- A linkage between the CMMS and the utility’s operating platform, such as a SCADA program

As part of an asset management plan, the CMMS program will feed data into a utility’s energy management platform which will provide the necessary information and framework for the utility to manage all facets of its energy costs from how much energy is used to the unit price of energy purchased. In the early days of CMMS programs, utilities spent considerable amounts of money in start up costs to develop the computer software. However, today many proprietary CMMS programs can be purchased “off-the-shelf” that are affordable to a utility of any size.

Water Treatment

Best Practices

- Slow Sand Filtration
- River Bank Filtration
- Conventional Filtration Treatment
- Direct Filtration Treatment
- Diatomaceous Earth Filtration
- Air Stripping
- Membranes
- Ozone
- Ultraviolet Disinfection
- Desalination

While conventional treatment remains most common (coagulation, sedimentation, filtration with chlorine disinfection), many water systems use other treatment/disinfection technologies to assist them in meeting changing water quality regulations (disinfection byproducts and microbiological inactivation) and higher standards of water quality expectations from customers.

On average, water treatment uses 10 to 20 percent of total treatment and delivery energy costs for systems treating surface water (the other 80 to 90 percent is pumping costs from source to treatment and treatment to customers). While the focus should be on distribution system energy savings enhancements, for some utilities, the best energy gains may be found in optimizing treatment.

Water utilities should select the treatment processes/technologies that best correlate to achieving their energy management goals and overall system optimization. It is important that a water utility evaluate the life cycle costs, payback, and overall benefits for each treatment option. The best treatment option may utilize more energy than another option; however, when the technology is used in combination with other implemented improvements to promote an overall system optimization approach, the end result may provide overall energy reductions for the system.

While a number of newer technologies are energy intensive (reverse osmosis and desalination, for example) even these technologies are becoming more energy efficient. Alternative approaches to current treatment processes can be investigated by water utilities. For example, some plants that withdraw their water from a river could use riverbank filtration instead and eliminate their need for any of the other processes (flocculation, sedimentation, and filtration) except disinfection. A summary of various alternative treatment processes, uses, and benefits are identified below.

Slow Sand Filtration

The slow sand filtration (SSF) treatment process was first used in the U.S. in 1872 (NDWC 2000), primarily in the north east, and is the oldest type of municipal water filtration. SSF treatment works by raw water, typically surface water, percolating through a biological layer on the surface of a bed of porous sand. The biological filter, *Schmutzdecke*, develops on the surface of the sand where particles are trapped and organic matter is biologically degraded through biodegradation and bioadsorption. SSF systems typically consist of a tank, a bed of fine sand, a layer of gravel to support the sand, under drains to collect filtered water, and a flow regulator to control the filtration rate. The influent water is introduced over the surface of the sand filter and then drained

from the bottom. The sand filter typically ranges from 1 to 3 meters in thickness and consists of fine grained (0.15 to 0.35 mm) sand with a uniformity coefficient of 2 to 3 (Logsdon et al. 2002).

Slow sand filters do not require electricity to operate as the water layer, which is commonly one meter in depth, provides the head pressure. See the Pumps Section for more information on pump energy use (which is avoided entirely in this case) to determine energy savings. In order to maintain the head pressure, the water depth should remain constant. The efficiency of SSF depends on the particle size distribution of the sand, the ratio of the surface area of the filter to depth, and the flow rate of water through the filter (NDWC 2000). Compared to other treatment processes, SSF has a low installation cost and does not require the use of chemicals for the filtration process. SSFs process water at a slower rate (0.015 to 0.15 gpm/sf of bed area) as compared to 2 to 5 gpm/sf filtration rates for conventional treatment processes. Filter bed sizes can range from 200 sq ft in area for very small communities to several acres in size for large communities (NDWC 2000). SSF is a low-cost treatment option for small water systems needing to comply with the Surface Water Treatment regulations. Pilot testing is necessary to properly size and design a SSF treatment system.

Slow sand filters are typically cleaned every few weeks to a year, depending on the turbidity of the source water (NDWC 2000), by allowing the water to drain and the sand to dry and then removing the top few centimeters of sand that are clogged with biological material (*Schmutzdecke*). This layer is commonly cleaned separately, and after several cycles, the accumulated removed sand is replaced. Alternatively, SSFs can be cleaned by closing off the underdrains and stirring up the top layer of sand, releasing the biological material into the (unfiltered) water standing on top of the sand. That water can then be drained off to the side (separate mechanism from underdrains). This process is called wet harrowing. After a filter has been cleaned, its removal efficiency is much lower, as is the head loss over the filter. As biological material accumulates, the removal efficiency becomes higher and higher, as does the head loss. Eventually, unacceptably high head loss forces filter cleaning. To increase initial filter efficiency, a small portion of the removed biological material may be re-added to the filter surface (Logsdon et al. 2002).

Low water and air temperatures can reduce the effectiveness of the biological filter. Therefore, SSF in colder climates will need housing for protection. Source water turbidities above 10 NTU are not well tolerated by slow sand filters and will require pre-treatment. Removal of coliforms is 1 to 3 log units, and removal of *Giardia* and viruses is 2 to 4 log units (NDWC 2000).

River Bank Filtration

River bank filtration (RBF) is gaining in popularity for larger municipalities as pre-treatment for surface water. Riverbank filtration is an energy efficient pretreatment option available to some water utilities that can be used to meet the changing water quality regulations related to disinfection byproducts (DBPs) and microbiological inactivation and treatment of inorganic contaminants (Wang, Hubbs, and Song 2002). RBF relies on the bacteria in the native soil (alluvium) as well as the soil particles themselves along the river bank to filter the water and remove contaminants (particulates, organics, and microbiologicals). Collector wells are commonly used to withdraw water adjacent to the river and typically range in depth between 50 and 150 feet below ground surface (thus the system requires pumping to overcome 50 to 150 feet of head of water). Some water utilities that historically relied on river water have incorporated RBF as it removes the taste and odor issues that are commonly associated with treating water directly pulled from the river.

The use of collector wells allows the application of RBF to be used by medium to large water utilities since millions of gallons per day can be withdrawn and processed. Water withdrawn from the river bank is pumped to the treatment facility for post-treatment, typically including the addition of chlorine prior to entry into distribution system. Surface water with high levels of organics and total organic carbon (TOC) commonly interacts with chlorine disinfection to produce various disinfection byproducts (DBPs). Removal (secondary treatment) of the DBPs after the raw water has been treated can include energy intensive and water intensive treatment processes such as membrane filters and granular activated carbon (GAC). RBF naturally filters the organics from the raw surface water and has the potential to eliminate the production of DBPs or need for additional secondary treatment (Brandhuber 2005). Feasibility and pilot test studies are necessary to properly design a RBF system and ensure that treated water will meet applicable water quality standards or determine if any additional treatment will be necessary in order to meet all water quality standards.

For comparison, pumping water from a depth of 100 feet is equivalent to pumping across a filter or other process with a head loss of 43 psi, except of course that the river bank never needs to be backwashed or otherwise cleaned. The typical range of head loss for a rapid sand filter alone is 2 to 8 feet (not counting backwashing, which is a significant energy cost) (Spellman 2009). Although energy costs vary on a case-by-case basis, it can be demonstrated that the treatment processes in a traditional plant setup can add up to more head loss than using collection wells. As an example, Louisville Water Co. in Kentucky is currently working on a RBF project that will have a capacity of 75 MGD. By changing to RBF, the water company expects to save \$500,000 annually from reduced energy consumption. Other sites that have implemented RBF include Pembroke, NH; Jackson, NH; Cedar Rapids, IA; and Lincoln, NE. Samples of river bank filtered water from these sites had non-detectable (<1 CFU/100 ML) amounts of all measured bacteria and reduced turbidity by about 83 percent on average (Partinousei, Collins, and Brannaka).

Conventional Filtration Treatment

Conventional filtration is a process for removing particulate matter and microscopic organisms from water. It is comprised of a series of chemical and mechanical stages that condition and then ultimately filter the water. The process begins with a chemical feed addition of flocculation/coagulant aids as well as certain pH adjusting chemicals. Polyaluminum chloride (PAC) is a flocculent/coagulant that is replacing the traditional flocculents (aluminum sulfate or iron salts) in many water treatment plants. It functions more reliably over a range of temperature and pH. It also requires a lower dose and causes less pH drop than aluminum sulfate, which means lower amounts of base/caustic (such as sodium hydroxide) that have to be added to balance the pH of the water, and less sludge to be disposed of. Less base used means less base has to be manufactured and transported to the plant, with attendant lowered energy costs. Less sludge production can also lower energy costs to scrape or pump sludge out of sedimentation tanks. If sludge is transported off site, reduced sludge production also reduces transportation energy costs. PAC is more expensive than aluminum sulfate, however the lower dose required means that the two flocculent processes are fairly equivalent in cost-per-treatment. PAC acts faster than aluminum sulfate, which allows plants to use smaller flocculation and settling tanks.

Next, the chemicals are mixed quickly in a flash mix or rapid mix process for the purpose of having a uniform dispersion of the added chemicals in the water. Rapid mixing can be accomplished through mechanical means such as with propeller or turbine flash mixers, which require

energy input to operate pumps that churn and blend the water stream. There are also low energy input methods of rapid mixing such as static in-line mixing and hydraulic jumps, each of which require no outside energy input but rather use the water's own energy to accomplish the rapid mixing, thereby increasing the headloss through the rapid mixing stage (Baruth 2005).

Following the rapid mixing stage, the particles in the incoming water are destabilized through the coagulation stage. The charges on the water particles are generally all negative, and destabilizing the particles creates a condition where the particles will begin to attract to one another being oppositely charged. After coagulation, the water is gently stirred to allow the particles to gather into larger accumulated masses. This stage is called flocculation, and as with rapid mixing, there are both hydraulic and mechanical flocculation methods.

Traditional mechanical methods use paddles or blades to agitate the water and form flocs. This requires energy input. It is possible to instead use gravity powered hydraulic flocculation. Hydraulic flocculation does cause head loss, so it is only appropriate for plants where causing further head loss would not simply increase pumping needs later in the treatment. Plants at a higher elevation than the distribution system are often good candidates. Head loss varies depending on the design of the flocculator. There are significant advantages to hydraulic flocculation in that it does not require any motorized equipment, and as such saves on all of the energy and maintenance costs of that equipment. There are several types of hydraulic flocculators: some use baffles to mix the water as it flows, some use gravel beds, and the Alabama flocculators use a series of tanks interconnected by pipes. Although hydraulic flocculators are simple to maintain, they do need to be occasionally cleaned of sediment (about once a week for the Alabama flocculators, less frequently for the other kinds). Since they are not adjustable, hydraulic flocculators may not be appropriate for plants that experience very large ranges of flow or turbidity.

Information on how to size a baffle hydraulic flocculator can be obtained from AguaClara, a research group at Cornell University in Ithaca, NY. The Web site is found at <https://confluence.cornell.edu/display/AGUACLARA/Home/>.

The book, *Water Treatment Processes: Simple Options* (CRC 1995), has general and sizing information on all three kinds of flocculators, and is available as a Google Books preview: http://books.google.com/books?id=yd_sM8W8f-wC&printsec=frontcover&source=gbs_v2_summary_r&cad=0.

The book, *Coagulation and Flocculation in Water and Wastewater Treatment* (Bratby 2006), has information on sizing gravel bed flocculators and baffled flocculators, and is available as a Google Books preview: http://books.google.com/books?id=vmkNROg_ehMC&printsec=frontcover.

Two additional resources include *Water Treatment Unit Processes: Physical and Chemical* (Hendricks 2006) and *Efficiency Enhancement Using Different Coagulants: A Case Study of E.T.P.* (Singh, Shivran, and Kumar 2005).

Next, the flocculated particles are settled or separated from the water stream through a sedimentation or clarification process. High energy required processes include clariflocculator, upflow clarifiers, and solids contact slurry recirculation units. Processes requiring little to no additional energy include tube or plate settling and long, narrow sedimentation basins that operate on the Stokes Law of particulate settling.

The size (diameter), gradation, and depth of the media all have energy impacts to take into account. Also, effective backwash design and operation will reduce energy loss through the filters. Using air scour or a surface wash technology will help to break the surface of the media faster and may result in needing a shorter backwash cycle duration. Proper fluidizing or expanding the filter bed is critical for optimized treatment as well as efficient energy management. Finding the

optimum filter-to-waste duration following a backwash cycle reduces pumping costs and keeps the volume of non-revenue water to a minimum. With conventional treatment, reconfiguration is possible to allow optimization of the system. The improvements may include changing chemistry or filter media to achieve better water quality and efficiency (Getting 2008).

Direct Filtration Treatment

Direct filtration is conventional water treatment without the sedimentation stage. Flocculated water is sent straight to a filter. For systems with high quality source waters, this is an attractive option, as the community can save the construction and operation costs of a sedimentation tank (such as removing sediment, cleaning the tank, and head loss from flow through the tank) (NAS 2008). Direct filtration without coagulation is less effective at removing *Giardia* (0.5 log removal) than conventional filtration (2 to 3 log removal). With coagulation, removal efficiency for *Giardia* is 1.5 to 2 logs. Log removal for viruses for conventional filtration treatment is 1 log removal compared to 1 to 2 log removal for direct filtration (USEPA 2003). However, if the source water has high turbidity (>10 NTU), the filters will clog very frequently, resulting in an inefficient treatment method. As with conventional water treatment plants, the filters in a direct filtration plant have to be cleaned periodically by backwashing them. This is generally accomplished by pumps, which use energy as described in the Conventional Filtration Treatment section.

Diatomaceous Earth Filtration

Diatomaceous earth (DE) is the fossilized remains of a particular kind of single-celled organism (diatoms). It is mostly composed of silica. DE filters consist of about an eighth of an inch of diatomaceous earth over a septum or filter element. These filters are quite effective at removing cysts, algae, asbestos, and other similarly sized particles (3 log removal of *Cryptosporidium* and 2 to 3 log removal of *Giardia*) (USEPA 2003), however, due to their large pore size (varies, but a typical example is seven micrometers), they are not very useful for removing bacteria-sized and smaller particles.

Adding a coagulant such as aluminum sulfate or PAC to the diatomaceous earth layer, and to the influent water, can improve removal rates of bacteria, turbidity, and viruses. Loading rates are typically 1 to 1.5 gallons per minute per square foot (Fulton 2000). DE filters are not recommended for influent turbidities above 30 NTU, due to clogging. They are also not recommended for intermittent flows, as the filter cake will slough off the filter. Other than low bacteria and virus removal rates, the main disadvantage of diatomaceous earth filters is the difficulty of keeping an even layer of diatomaceous earth over the filter. Energy costs come from pumping water through the filter and occasional backwashing. The pressure drop across a diatomaceous filter is less than 30 psi (Fulton 2000). Pressure filters and vacuum filters are the two types of DE filters (Bhardwaj and Mirliss). Diatomaceous filters have the advantage of very low capital costs. Because of its simplicity (no chemical coagulation) and low capital costs, DE may be appropriate for water utilities that previously only disinfected their water, but anticipate having to add filtration. It can also be useful as a pretreatment for membrane filters.

Air Stripping

Air stripping or aeration is an effective treatment method for removing certain taste and odor causing contaminants, various organic chemicals such as dibromochloropropane and ethylene dibromide, and radon gas. Air stripping is also an effective pre-treatment oxidation stage for iron and manganese treatment processes as well as a carbon dioxide removal method prior to lime softening.

Several different air stripping technologies exist with a wide array of energy requirements. In general, multiple tray and mechanical aeration technologies have lower energy requirements as there is a lesser pressure head to overcome as compared to other technologies. Air diffusers have a varying degree of energy needed to operate based on the specific design of the facility. Standard designs place the diffusers near the middle area of the aeration tank for optimum efficiency. The deeper the diffusers are located in the tank, the more pressure head the diffusers must overcome, and therefore the more power is needed for the compressors. The diffuser units themselves have virtually no headloss.

Packed column or packed tower aeration technologies operate under the design principle that the higher the packing height, the higher the contaminant removal rate. However, the higher the packing height, the more headloss incurred in the process and the overall energy efficiency is reduced. Other packed tower aeration design considerations to be examined for energy efficiency savings include the temperature of the water, the shape and configuration of the tower media, and the layout or placement of the media in the column.

Information regarding air stripping design and energy considerations can be found in: *Water Treatment Plant Design* (Dykson 1998 and Baruth 2005); *Tech Brief: A National Drinking Water Clearinghouse Fact Sheet—Organic Removal* (NDWC 1997), available at: http://www.nesc.wvu.edu/pdf/dw/publications/ontap/2009_tb/organic_removal_DWFSOM47.pdf; and *Water Quality & Treatment Handbook* (AWWA 1999).

Membranes

Membrane processes trap particles as water flows through a filter (membrane). As with all kinds of filters, there is a tradeoff between energy required to move the water through the filter and filtration efficiency, which is mainly determined by pore size and backwash frequency. However, recent innovations in membrane technology have allowed higher removal efficiency for a given energy use. Membranes are classified according to the size of the molecules that they are able to filter; Nominal Molecular Weight Cutoff or MWCO. Different kinds of membranes have various uses (ranging from sediment filtration to microorganism removal) and there are various types for each specific use. New technologies include low-pressure membranes to reduce water and energy consumption and self-cleaning filters. Common pressure-driven membrane classifications, from largest pore size to smallest, include microfiltration (MF), ultrafiltration (UF), nanofiltration (NF), and reverse osmosis (RO). On average, low-pressure membranes (MF and UF) have lower energy requirements compared to high-pressure membranes (Chang et al. 2008). Components of a membrane systems that consume the largest fraction of energy include the feed/vacuum pump(s), backwash pump, air scour blower, and the recirculation pump (if used) (Chang et al. 2008).

Water utility managers need to choose the right membrane material and type to fit the conditions of use. Since not all contaminants can be treated with membranes, other treatment or disinfection processes may be needed as part of a complete treatment process. Water temperature

impacts the efficiency of the flux (permeate flow/membrane area), therefore it is important to maintain water temperature around 20°C to reduce energy requirements (USEPA 2005). Membranes are prone to fouling and can have chemical stability issues depending on the water parameters (pH, temperature, etc.). Commonly, pretreatment (prefiltration, chemical conditioning) is necessary to minimize fouling. The technical report *Evaluation of Dynamic Energy Consumption of Advanced Water and Wastewater Treatment Technologies* (Chang et al. 2008), published by the AwwaRF is an excellent resource for more detailed information on real performance of membrane systems. The report can be found at: <http://www.waterresearchfoundation.org/research/TopicsAndProjects/reports.aspx?Topic=EnrgyMgm>.

- *Microfiltration (MF)*—(0.03 to 10 microns)
MF membranes have the largest pore size and are excellent for pre-treatment since they remove larger particles (silt, clay, some colloids, and algae) and various microorganisms, including *Cryptosporidium* and *Giardia*. Typical feed pressure ranges between 5 and 35 psi (AMTA). Microfiltration has the highest MWCO of 100,000 Daltons or more. MF membranes are commonly used as pre-treatment for surface water due to the higher suspended solids and biological matter and easily replace rapid sand filtration. These low-pressure membranes typically have lower energy requirements compared to high-pressure membranes although this will vary based on the specific membrane and feedwater characteristics. Energy efficiency is determined largely by the membrane permeability and the backwash frequency (Chang et al. 2008). Routine back-flushing is required to remove collected material and prevent fouling with backwashing waste volumes ranging from 4 to 15 percent of permeate flow (AMTA). Other operational parameters such as air scouring will also affect energy consumption. Energy consumption is estimated at 0.1 kWh/kgal of water treated (O'Connor 2007).
- *Ultrafiltration (UF)*—(0.01 to 0.03 microns)
UF membranes have a smaller pore size as compared to MF and are excellent for pre-treatment since they remove larger particles (silt, clay, some colloids, algae), various microorganisms (*Cryptosporidium* and *Giardia*), and soluble macromolecules such as proteins and viruses. Typical feed pressure ranges between 5 and 35 psi (AMTA). UF membranes are effective to MWCO sizes of 10,000 Daltons or more. UF membranes are commonly used as a pre-treatment filtration for RO and easily replace rapid sand filtration. Routine back-flushing is required to remove collected material and prevent fouling, with backwashing waste volumes ranging from 4 to 15 percent of permeate flow (AMTA). As with MF, energy efficiency is mostly determined by membrane permeability and backwash frequency. This can be optimized through careful selection of pretreatment practices and proper membrane selection. Mackey et al. (2001) estimated energy consumption was in the range of 0.5 kWh/kgal of water treated for ultrafiltration for two treatment plants studied. Another source states consumption of 1 kWh/kgal (O'Connor 2007) and 0.5–1.0 kWh/kgal (Chang et al. 2008).
- *Nanofiltration (NF)*—(10 angstroms or less)
NF membranes are a newer membrane technology and are commonly referred to as “loose” RO membranes. The membranes are porous, but are extremely small with a MWCO between 200 and 1000 Daltons. Typical feed pressure ranges between 50 to 200 psi (Wilbert 1999). NF membranes are typically used to remove dissolved

contaminants such as hardness (Ca^{2+} , Mg^{2+}) and organics including disinfection byproduct precursors. Due to the pore size, NF membranes require non-turbid (clear) raw water. Therefore, pre-treatment with MF or UF would be necessary for turbid water. Large volumes of concentrate accumulate as compared to MF or UF and the filters require routine cleaning and periodic replacement. Energy costs are estimated at 1.8 kWh/kgal treated (O'Connor 2007).

- *Reverse Osmosis (RO)*—(MWCO is generally less than 100 Daltons)
RO membranes are non-porous filters and are excellent at capturing total dissolved solids (TDS), salt ions, F^- and Cl^- , and organics. The RO process involves applying pressure (feed pressure) that forces the water through the membrane against the natural osmotic gradient. The feed pressure results in increasing the dissolved contaminant concentrations on one side of the membrane and increasing the volume of water with lower concentrations of dissolved contaminants on the other. Typical feed pressures range between 125 and 300 psi for low pressure systems and between 350 and 600 psi for standard pressure systems; feed pressures for desalination systems are higher than for low and standard pressure systems. RO is the most common treatment for desalination of brackish water or seawater. RO removes 95 to 99 percent of the TDS, but requires clear and non-turbid water. Therefore, pre-treatment is necessary for turbid water. As with many treatment options, energy efficiency of RO can be increased by improving the efficiency of the pumps powering the system. More specifically to RO, energy efficiency can be improved by installing one of several technologies that recover excess pressure energy in the filtered water and use it to pressurize the unfiltered side of the water stream. This can yield roughly 10 percent energy savings. Additionally, increasing the removal rates of other treatment techniques used prior to RO can decrease membrane fouling and increase performance, lengthen time between cleanings, and decrease energy use.

Additional resources for various membranes and applications include: *Fundamental of Membranes for Water Treatment* (Sagle and Freeman), available for download at: <http://texaswater.tamu.edu/readings/desal/Membranetechnology.pdf>; *Membrane Filtration Guidance Manual* EPA 815-R-06-009 (USEPA 2005), available for download at: http://www.epa.gov/ogwdw/disinfection/lt2/pdfs/guide_lt2_membranefiltration_final.pdf; and *Membrane Applications in Water Treatment: U.S. Bureau of Reclamation* (Wilbert 1999), available for download at: www.epa.gov/watertrain/transient/memb_17.ppt.

Ozone

The ozone treatment process introduces ozone gas, one of the strongest disinfectants and oxidants available, into the water via a vacuum. Ozone is manufactured by passing air or oxygen through two electrodes with high, alternating potential difference (voltage). The ozone gas created will readily degrade back to oxygen and during the degradation process, a free oxygen radical is formed that is highly reactive and short lived; under normal conditions it will only survive for milliseconds. The basic elements of an ozone system include ozone generation, feed gas preparation, ozone contacting, and ozone off-gas destruction. Energy consumed by the ozone process occurs during the formation of oxygen into ozone and by operating the mixing device and cooling water pumps for the ozone generator. Energy consumption associated with the ozone generator tends to

increase with increasing ozone generation rate; however, energy required for the auxiliary systems remains relatively fixed regardless of the ozonation generation rate (Chang et al. 2008).

One of the primary benefits of this treatment process is that ozone is highly efficient as a disinfectant and can remove more waterborne pathogens including *Cryptosporidium* and *Giardia*, than chlorine. Additionally, ozone reduces concentrations of iron, manganese, and sulfur; provides no harmful residues and is maintenance free; requires no storage; and removes color, taste and odor. Furthermore, ozone can be applied at various points in the treatment train, although it is usually applied prior to coagulation.

Ozone does not have any residual effect in the distribution system; therefore, it works as a primary disinfectant and requires post chlorination to maintain a disinfectant residual. Since chlorine can generate disinfection byproducts such as trihalomethanes (THMs), which are known to be carcinogenic, ozone is becoming more popular as a primary disinfectant. It can reduce the amount of chlorine needed for post treatment which will reduce the potential for disinfection byproduct formation.

Ozone is highly unstable and must be manufactured and used onsite. The use of ozone entails higher equipment and operational cost as compared to other disinfection processes and will likely require a professional trained in ozone treatment and maintenance. To minimize system costs and maximize performance, the ozone system should be designed with an efficient injection system. Ozone's efficiency as a disinfection declines in hard water and is impacted by other water quality parameters, such as pH; therefore, the water may require pre-treatment. Information on optimizing ozone equipment and processes found in the Foundation report, *Ozone System Energy Optimization Handbook* may be downloaded at: <http://www.waterresearchfoundation.org/research/topicsandprojects/execSum/167.aspx>.

Additionally, post ozonation filtration may be necessary as ozone reacts with metals to create insoluble metal oxides. The type of disinfection byproducts ozone produces is currently being investigated. The byproducts discovered so far include aldehydes, ketones, and carboxyl acids. Energy use for ozonation is determined by the plant capacity, operating flow rate, ozone dosage, and type of feed gas system and is in the range of 0.1 kWh/kgal processed (O'Connor 2007). Typically, energy efficiency is assessed in terms of the amount of energy required to produce one pound of ozone (Chang et al. 2008). Energy savings can be realized by making sure ozone production is at or near the design concentration. Additionally, Chang et al. (2008) described optimization considerations for energy consumption associated with air-fed ozone systems and liquid oxygen-fed ozone systems and discussed work by other researchers to optimize energy consumption at ozone facilities. Three case studies are also presented that describe energy use and energy savings related to various operating strategies. The energy consumption for the ozone generators at the three facilities ranged from 3.3 kWh/lbO₃ to 8 kWh/lbO₃ produced resulting in a range of 0.03 kWh/kgal to 0.122 kWh/kgal used.

Ultraviolet Disinfection

This treatment process disinfects production water by exposure to ultraviolet (UV) irradiation. UV treatment provides excellent disinfection by inactivating all types of microorganisms including bacteria, viruses, yeasts, molds and spores. Even with low UV doses, UV inactivates chlorine resistant organisms such as *Giardia* and *Cryptosporidium*. Water utilities can easily retrofit UV into existing treatment plants and UV can be combined with other oxidants (i.e., ozone and hydrogen peroxide) to create hydroxyl radicals for removal of many other harmful contaminants.

TOC removal by UV light or ozone alone is negligible while substantial removal can be expected from a combined UV/O₃ process. Energy consumption, on average, is greater for UV systems than for chlorination systems. EPRI (1997) estimated that UV disinfection increases energy consumption by 0.07 to 0.10 kWh/kgal relative to that needed by conventional chlorination processes. Mackey et al. (2001) estimated that UV disinfection will use about 0.05 kWh/kgal to 0.15 kWh/kgal, using low pressure-high intensity and medium pressure lamp systems respectively.

The UV treatment process includes the generation of UV light in lamps by flowing electrons from an electrical source through ionized mercury vapor. Three types of UV lamps are currently available, low pressure, low pressure/high output, and medium pressure (USEPA 2009).

- *Low-pressure (LP)* lamps produce monochromatic radiation. These lamps are the most energy efficient; however, they provide relatively low-intensity radiation (40 to 85 W) resulting in the need for many lamps to treat large volumes of water, thereby reducing their energy efficiency.
- *Low-pressure/high output (LP-HO)* lamps provide a high-output (300 to 400 W) as compared to LP. Fewer LP-HO lamps than LP lamps are required to treat the same volume of water. LP-HO lamps are more energy efficient than medium-pressure lamps.
- *Medium-pressure (MP)* lamps produce polychromatic radiation. These lamps are less energy efficient because they produce 10 to 20 times higher UV output than LP or LP-HO lamps. High UV output results in fewer lamps needed, but the lamps require more energy to operate and they generate heat.

Excluding the initial purchase costs, UV treatment has been established as a low cost, environmentally-friendly treatment technology and categorized as a “green technology.” The UV process is chemical free, does not involve transport or storage as does other treatments, and the process produces no disinfection by-products (DBPs). Energy requirements vary widely, but at design flows, they can be under 0.1 kWh/kgal (O’Connor 2007). To reduce energy costs associated with UV systems, utilities might consider using sodium-sulfur battery systems to take advantage of energy pricing structures by charging the system during non-peak hours (generally at night) and then during the day, using the batteries to power the UV system (Wright et al. 2007).

Optimizing energy efficiency is accomplished through a dose control strategy that alters the number of lamps in use or the lamp power based on flowrate, level of disinfection required (dose), and water quality (Chang et al. 2008). Energy efficiency measures include having multiple UV disinfection systems or lamps in the same system in parallel that can be turned on as needed. At anything less than full design flow, a UV disinfection chamber is wasting energy. One drawback is that individual lamps are not very adjustable in their output using current technology.

Water quality parameters such as turbidity and suspended solids can lower UV transmittance by screening/shielding the UV light from the microorganisms. The presence of some organic and inorganic compounds (such as iron and calcium hardness) can also absorb UV light, lowering UV transmittance. Therefore, depending on water quality, additional pre-treatment (in excess of existing water treatment) may be required. Temperature, fouling of the lamp housing, and lamp age will also impact the energy efficiency of the UV lamps as will hydraulic conditions and UV lamp configuration (Chang et al. 2008). In general, a linear configuration is considered to be the most energy efficient to avoid emission losses due to self-absorption, reflection, and refraction (NYSERDA 2004).

There are a number of resources available to assist water utilities with the evaluation of UV treatment. These include:

- *The Multi-Barrier Assessment Tool (MBAT) and UV Disinfection Implementation Tool (UVDIT)* available from the Water Research Foundation at: <http://research.pirnie.com/AwwaRF2861/>. These tools address such issues as feasible retrofit locations for UV disinfection and implementation issues of UV disinfection at each retrofit location and how the issues can be resolved. Additionally, these tools provide estimates of the cost of various retrofit options by evaluating existing infrastructure, hydraulic limitations, water quality variability, flow variability, power source limitations, and lamp breakage issues.
- *The UV Cost-Analysis Tool (UVCAT)* co-funded by the Foundation and NYSERDA is available at: <http://www.nyserderda.org/programs/Environment/OptimizationUV.asp>. The related research and tool is described in the report *Optimization of UV Disinfection* (Wright et al. 2007). This tool was developed to provide a comprehensive evaluation of UV disinfection system performance and cost. Three types of analyses are provided: Standard Life-Cycle Cost, Lamp Replacement Interval Cost, and Advanced Life-Cycle Cost.
- USEPA's *UV Disinfection Guidance Manual for the Final Long Term 2 Enhanced Surface Water Treatment Rule*, EPA 815-R-06-007, dated November 2006 includes a variety of ways to design and set up systems for the most energy efficiency. http://www.epa.gov/safewater/disinfection/lt2/pdfs/guide_lt2_uvguidance.pdf.

Desalination

Desalination is a process by which salty water (ocean water, brackish water, or salty groundwater) is converted to fresh, potable water. Desalination is generally quite energy-intensive, and thus a potentially expensive option for water utilities. However, with high quality source water availability decreasing and desalination efficiency increasing through technological improvements, water-stressed utilities in California, the American Southwest, and parts of Florida are increasingly turning to desalination. Additionally, desalination is considered 'drought-proof,' since the ocean is the world's most reliable source of water. There are several techniques used to achieve desalination, chiefly distillation and membrane processes (such as reverse osmosis). These are generally preceded by some kind of pretreatment to remove larger particles, hardness, and organic matter and protect the desalination equipment from fouling.

- *Distillation* involves boiling seawater (often in lower pressure chambers to reduce the boiling point) to provide steam which is then condensed to produce fresh water. This is an older and more energy intensive method of desalination, and is being supplanted in much of the new construction by membrane desalination. Veerapaneni et al. (2007) provided a comparison of energy consumption for various types of distillation processes. Multi-stage flash and multiple-effect distillation consumed energy in the range of 7 to 15 kWh/kgal of water processed. Energy consumption can be reduced by lowering the ambient pressure since water boils at a lower temperature at lower pressures (i.e., vacuum distillation) (Veerapaneni et al. 2007). Although distillation is considered outmoded, there may be opportunities to use waste heat from power plants to impart

much of the required energy to boil the seawater, which can drastically reduce energy costs. Additionally, research into solar desalination, wherein sunlight is concentrated to boil seawater, is underway and could prove fruitful. That would essentially provide free power, and drastically reduce energy requirements for a desalination plant, although it might make plant construction more costly and energy intensive.

- *Membrane desalination* most commonly uses a RO membrane (seawater RO), which has pores large enough to let water through but not salt ions. Salty water has to be pressurized in order to *push* it through the membrane. This is the reverse of the way the water would flow without interference (which is from fresh, low concentration to salty, high concentration), thus it is called reverse osmosis. Over half the energy consumed for desalination is from pressuring the feed to flow through the RO membrane (Veerapaneni et al. 2007). Additional energy is consumed from the intake pumps, pretreatment, and distribution of the finished water. Reverse osmosis desalination alone uses somewhere in the range of 8 to 12 kWh/kgal (Veerapaneni et al. 2007) depending on plant size and age, salinity, temperature, permeate flow, membrane area and resistance, and the efficiency of the equipment. More energy is required as water salinity concentrations increase. Special care must be taken to reduce fouling (clogging) of the membrane, as that increases the pressure needed to push water through. Special processes, such as Internally Staged Design, are often used in new plants to control and even out flow across multiple membranes, thus decreasing fouling and required pressure. See the Reverse Osmosis Section for more information. Additional design processes to reduce energy requirements include implementing a two-pass configuration, adding energy-recovery devices (ERDs) to the feed stream, installing high efficiency pumps for intake and distribution, and utilizing low-pressure micro-filtration or ultra-filtration for RO pretreatment to reduce fouling (Veerapaneni et al. 2007). More information on ERDs can be found in the report, *Critical Assessment of Implementing Desalination Technologies* (Xu et al. 2009).

Additional work has been conducted by Cath, Drewes, and Lundin (2009) on a novel forward osmosis (FO) membrane process that utilizes the osmotic pressure differential across a semi-permeable membrane rather than hydraulic pressure differential (as in reverse osmosis). This study focused on a hybrid FO/RO process to co-treat seawater and impaired waters and found that the FO processes can be coupled with RO processes to simultaneously protect the RO membranes, recover purified water from a broad range of impaired water, and to lower the energy required for desalination of seawater.

Waste Brine (concentrated salt water) is a problematic byproduct of all desalination processes. If waste brine is dumped into the ocean, it can kill sea life due to its high salt concentrations which can be toxic. Inland, where salty groundwater is sometimes desalinated, it is even more of a problem since it will destroy the ecosystem of any freshwater receiving body. One possibility is the processing of brine into salt, through evaporation ponds or other methods. With regard to ocean disposal, brine can be blended with the output of a wastewater treatment plant or dispersed widely in the ocean to dilute out its effect. Recent research by Bond and Veerapaneni (2007) investigated technologies with the potential to reduce the cost and energy consumption for inland desalination with zero liquid discharge (ZLD). By adding several steps to the traditional ZLD approach, the researchers found that between 68 to 75 percent less energy was needed to make a kgal of product water.

Other potential problems with desalination are fish kills in the intake structure (for ocean source), generation of large amounts of greenhouse gases due to the energy intensive processes, and ground subsidence (for groundwater sources). Additionally, salty water is quite corrosive and generates scale, so plants need to be specially designed to deal with this issue.

Although water desalination is developing rapidly and improving in efficiency, manufacturer's or supplier's specifications for desalination cost, both in terms of money and energy can be wildly optimistic. Water quality (salinity and temperature), permeate flow/membrane area (flux), permeate flow/feed flow (recovery), membrane resistance, and overall efficiency of equipment are contributing factors to actual energy costs of operating a desalination facility as compared to expected costs (Veerapaneni et al. 2007). For example, the Tampa Bay desalination plant cost \$158 million to build and produces water for \$1,100 per acre-foot, as opposed to the co-developer's estimate of \$110 million and \$667 an acre-foot (Chang et al. 2008). Increased costs resulted from refurbishment to fix deficiencies. The Tampa Bay facility is the largest desalination facility in North America, capable of producing up to 25 MGD (<http://www.tampabaywater.org/watersupply/tbdesaloverview.aspx>).

Research by Sethi et al. (2009) evaluated emerging desalination technologies and configurations with a focus on product water recovery and concentrate volume minimization. In their discussion on cross-cutting aspects of energy, they noted that energy requirements for desalination processes can be reduced through development of low-pressure membranes, high-energy efficiency equipment, energy recovery devices, and optimization of operating parameters and process design. Co-generation and co-location were also discussed. Co-generation refers to a design where electricity and heat are supplied and consumed in the same system. Co-location refers to the direct connection of the desalination plant intake and/or discharge facilities to the discharge outfall of an adjacently located coastal power plant. Energy recovery devices can typically be divided into two categories: (1) devices that transfer the concentrate pressure directly to the feed stream, with an energy efficiency recovery around 96 percent; and (2) devices that transfer concentrate pressure to mechanical power and then back to feed pressure with an overall energy efficiency recovery of about 74 percent.

Water Distribution

Best Practices

- Hydraulic Modeling
- Post Flocculation
- Distribution System Piping
- Pumps
- Motors
- Variable Frequency Drives
- Pressure Reducing Valves and Inline Turbines

Water is relatively heavy; it weighs 8.34 pounds per gallon. Eighty percent of the energy directly used in water treatment and distribution is used to pump the water (EPRI 2002). As such, the approaches to energy savings in this section are twofold: increase efficiency in creating water pressure, and decrease the amount of water pressure that is needed. The former is achieved in several ways. First, improving pump efficiency to ensure pumps are operating near best efficiency points (BEP). Optimizing pump efficiency is a complex process and involves not only the pump itself but associated pump components (motors, valves, etc.) and knowledge of the complete water

distribution system characteristics. Pumps can be made more efficient by resizing them, if necessary; regular maintenance; adding variable speed or frequency drives; and upgrading motors, along with a variety of other options. Adding variable speed or frequency drives can allow pump motors to run more efficiently at lower than optimum output, especially at low pump capacities. Motors can also be replaced with more appropriately sized and efficient upgrades. For a motor or pump that is running constantly, efficiency increases of a few percent can result in large energy savings. Pump and motors should also be maintained regularly for optimum performance.

The other way to save pumping energy is to use less of it. In some cases, gravitational potential energy can be substituted for pump power (such as hydraulic flocculation). In an ideal case, where the water source is much higher than the water use, almost all of the energy needed to treat and move the water could be supplied by gravity. However, that is rarely the case, and it is not practical to completely rebuild existing water systems to match that ideal, nor is a high elevation water source usually available. More applicable is modifying or replacing treatment processes to make them more efficient users of the water pressure (see Water Treatment section).

Energy requirements to pump water can be reduced through optimization of the entire water distribution system (pipes, storage, valves, etc.) which in turn reduces the number of pumps or size of pumps needed. Improving pump efficiency or reducing energy requirements does not always require a large capital investment and at times may not require any capital investment (Budris 2008). Life cycle cost analysis is an important tool when evaluating energy efficiency improvements to the water distribution system. Many times, choosing the less expensive initial cost option may actually cost more over the life of the equipment.

Hydraulic Modeling

As water distribution systems become more complex, determining the most efficient ways to operate the system and manage energy use becomes more difficult. Hydraulic models simulate the behavior of the water system and can be used to predict the system's response to changes in system conditions. It is a tool available to test various operating and design strategies and find the most optimum system configurations for the most efficient system performance.

Hydraulic models typically are used for long-range planning and design of new systems or expansions. However, they can be used to evaluate how changes to individual system components (equipment, pipe, storage, valves) affect system responses. Modeling various scenarios provides water utility staff alternatives in system design or retrofits to maximize energy reductions. Hydraulic models serve a different purpose than an EWQMS as the hydraulic model is not often used for daily planning and daily optimization, but used to select the most efficient system configuration and equipment set-up. Developing and implementing hydraulic models requires a financial investment, take time to assemble and construct, and need adequate trained staff to operate and routinely calibrate.

It is important to keep hydraulic models current. If the model is kept current, the operator can use the model to assist with troubleshooting problems and can compare actual system data to modeled performance to identify variations or problems in the system such as closed or open valves that should not be, water line breaks, or pumping stations that are losing capacity or pressure.

Post-Flocculation in the Distribution System, Water Mains, and Storage Facilities

Improper chemical feed rates at the water treatment plant can result in the unintended consequence of the water experiencing a “second rapid mixing stage” through pumps at pump stations and other high velocity/high turbulence zones prior to entering a “second flocculation stage” such as a reservoir or water lines where the water velocities are comparatively low. It has been found that an on-going accumulation of re-flocculated aluminum hydroxides can reduce the capacity of transmission lines as well as form a blanket of flocculated particles at the bottom of a storage tank. The best way to prevent this condition is to optimize the water treatment facility and the coagulant chemical(s) dose concentrations. Overfeeding any chemical is a waste of the chemical product, an expense in extra chemical feed pumping, an extra burden to the utility’s operations staff who will be called upon to clear out the lines and clean out the bottom of the storage tanks, and a significant loss of water and energy attributed to the flushing and cleaning of the infrastructure. Overfeed conditions can be detected with on-line (ion-selective electrode) or grab sample monitoring and analysis at the water treatment plant before overfeed conditions create a problem in the distribution system.

Distribution System Piping

Overcoming head loss and friction loss in pipes are the primary causes for high pumping costs within a distribution system. Much of the head loss and frictional loss is a function of pipe diameter (flow velocity based on inside diameter). Higher flow velocity requires more energy. Pipes from the pump station to the tank/storage facility result in the most significant impact on energy use as pumps must overcome the head pressure between pressure zones (DOE 2006). As part of developing a system optimization plan or system evaluation, a water utility should evaluate its master plan or hydraulic analysis/model used in creating the master plan to determine if there are lengths of pipe that are ‘choke points’ (i.e., sections of narrow pipe as compared to the rest of the adjacent distribution system) that are causing large amounts of head loss. The distribution system can also be examined to locate the “choke points.” Correcting pipe size has potential to save up to 20 percent of pumping energy (Easton Consultants 1995).

Pipe size is important to consider when optimizing system and pumping operations. Considerable pressure can be lost in the distribution system from undersized pipes (DOE 2006). Hydraulic models can help in selecting optimum pipe size for lowest energy consumption while maintaining minimum pressures in the system. To reduce pipe costs, the goal is for a water utility to select the smallest pipe diameter (inside diameter) that provides the lowest velocities during peak demand. In pipe material selection, it is important to know the actual inside diameter (ID) as not all pipe material have the same inside diameter for the same outside diameter (OD) pipe. In addition to pipe size, the pipe layout configuration can result in pressure imbalances and increase the amount of energy required to pump water through that pipe.

The smoothness of the pipe can reduce friction loss in the system and reduce energy required to move water. The smoothness of the pipe or the roughness coefficient is commonly referred to as the C-factor. The higher the C-factor, the smoother the pipe; therefore, utilities want to maintain a high C-factor over time to maximize flow performance. The C-factor can decrease over time due to corrosion and tuberculation within the pipe which can increase energy use. Pipe linings are one option to help maintain a high C-factor. Pipe linings consist of cement lining, epoxy

coatings, or plastic sleeves. Even though a high C-factor improves pumping efficiency, pipe size (inside diameter) can have more of an effect on reducing head loss and energy loss (DIPRA 2006).

Installation of new pipe is a great opportunity to install a lining to help protect the investment. For existing piping, there are two options for improving pipe efficiency: replacement or rehabilitation. Rehabilitation via cleaning and lining may be a more cost effective option if the pipe has deposits or scaling and is structurally sound. Unidirectional line flushing programs and even pipeline “pigging” (inserting foam plugs into the line to scour the interior surface as the water pressure moves the plug through the system) can help. Lining rehabilitated pipes helps protect further deposits or scale from forming. Pipe size impacts decisions on cost/benefit of rehabilitation or replacement. Lining material should be considered carefully as some materials might reduce inner diameter more than other lining materials (DOE 2006).

Pumps

Approximately 80 percent of a water system’s energy use is associated with the processing and distribution of drinking water (EPRI 2002). Large amounts of energy are consumed by pumps for lifting and moving water. Pump efficiency is impacted by operational and system sizing requirements as well as the availability of storage capacity, piping layout, pipe size, the head pressure needed to overcome (pressure zones), and other factors. Performing an energy audit or pumping system evaluation is a proactive approach to evaluate all pumping applications and processes to determine if the pumps are properly sized for the specific application and if the pumps are working at their optimum setting for highest possible efficiency.

There are various signs that a pump or pump system is not operating efficiently, these include, but are not limited to, increased energy costs, increased maintenance and unscheduled maintenance, excessive pump vibrations, excessive heat from the pump motor, and excessive noise in the pipes. Pumps are only one component of the pumping system and for proper optimization, the water utility must look at the pumping system as a whole, including pipes, motors, valves, etc. (DOE 2006).

There are numerous approaches to take in optimizing pump operations and to address oversized and inefficient pumps. Not all approaches will involve a large capital investment and pumps do not always need to be replaced (Budris 2008). Keep in mind that different options will provide different results. The focus is to reduce energy consumption or improve efficiency. In addition to optimizing pump equipment and components, changing the pumping schedule will have the most impact on energy cost efficiency if correlated to reducing peak load demand. Pump optimization can be achieved by changing operation processes such as adding multiple smaller pumps to an application to meet changing flow demand, changing from fix-speed to variable-speed drives on pump motors, and establishing a regular pump maintenance and efficiency evaluation especially when included as part of a CMMS. The various methods of optimization are explained in more detail later in this section.

When evaluating energy efficiency improvement options, the water utility needs to incorporate a cost/benefit and life cycle costs analysis along with an evaluation of the quality of the product, any improved reliability or improved capacity utilization, and any increased productivity. Water utilities must look at a 15- to 20-year life for pump system components and how the energy savings from a more efficient pump and motor over time will provide a benefit over initial cost savings. The Hydraulic Institute’s (HI) *Pump Life Cycle Costs: A Guide to LCC Analysis for Pumping Systems*, is an available reference. Additionally, the DOE’s publication, *Improving*

Water Utility Example

Philadelphia Water Department realized a variety of energy cost reductions through a pump evaluation and modifications to pumping equipment and operations. As part of the evaluation, the water department analyzed pumping schedules and water demands in four of its high-service districts and determined that many of the pumps were not operating in optimum range. Philadelphia is in a unique situation where water demand has decreased from the 1970s and 80s due to loss of industrial customers and shifting of the urban population. In 2004, the average flow was 100 MGD less than in the 1970s (Bradley 2007). Based on their evaluation, the utility found that:

- A set up using two larger and one smaller pump only required a smaller pump and intermittent operation of one larger pump. They installed a smaller impeller in the larger pump that did not operate frequently and incurred high electric cost when in operation. The modification reduced operation of the large pump during high electric demand and saved approximately \$1,000/mo.
- Two large pumps were used all the time, and while the utility was unable to only run one pump, using both was inefficient. The utility decided to reduce capacity and head on the pumps to reduce power demand charges. They also trimmed the impellers in each pump. The utility realized \$9,400/mo in energy savings.
- Oversized pumps with VFDs were not operating efficiently due to the narrow speed-adjustment range which limited usefulness of the VFDs and low flow rates resulting in excess pump vibration. The utility replaced two larger pumps with smaller pumps. The resulting energy savings were approximately \$1,300/mo.

Pumping System Performance: A Sourcebook for Industry (DOE 2006), includes a “where to find help” section for DOE and HI resources.

Pumping System Evaluation. Since pumps work in conjunction with the pumping system, optimization and improvement may be needed for both the pump and the various system components to maximize energy reductions and energy efficiency. A water utility must make or find opportunities to evaluate pump and system performance. Optimum opportunities for a water utility to evaluate efficiency improvements are during a planned plant expansion or upgrade or while troubleshooting problems (DOE 2006). This evaluation can also occur during the development of an asset management plan. However, the water utility management may want to consider establishing requirements for annual evaluations and modeling to ensure pumps and pumping system are meeting expected efficiencies.

During an evaluation, pipe configuration and “choke points” or areas that may result in pressure drops, such as sharp bends, partially closed valves, etc. should be analyzed. Performance can be improved by ensuring that the pipe leading to the pump inlet is straight or has a minimum number of bends. Also, unnecessary headloss is added when pipe galleries in pump stations have abrupt diameter changes, such as pumping against a flange when a smooth reducer would have been a better design choice. If space constraints exist, long radius elbows should be used instead of sharp angled bends to change direction (DOE 2006). Sometimes contractors or other utility crews will open or close valves without the knowledge of the operators. Use of a hydraulic model and the adherence to a comprehensive valve turning exercise program can assist operators in comparing real operating conditions against model parameters to look for differences that might signal a problem.

Another reason to be proactive in evaluating system performance is that pump performance can decline over time as changes are made to the water system through additions of piping

or reconfigurations; and from changes in customer usage, pump component wear, and piping or pump corrosion (Bradley 2007). Furthermore, a water system evaluation may show that leaks are having higher than anticipated impacts on lowering the system pressure, which in turn increases the required amount of pumping. Detecting and fixing leaks in the distribution system can decrease the amount of pumping that is necessary to maintain system pressure in addition to decreasing the amount of water that is unnecessarily treated (see the section on Water Conservation—Water Loss Audits).

The DOE has a free software program available, the *Pumping System Assessment Tool* (PSAT), to assist water systems with evaluating existing pumping systems. The program provides estimates on existing pumping/motor efficiency, reveals peak efficiency for each pump, presents impacts based on different operating scenarios, and identifies degraded/poor performing pumps. The PSAT program relies on actual field measurement and bases pump efficiency calculations on algorithms from the Hydraulic Institute. The program can evaluate component-level performance or system-level performance. PSAT can be downloaded from http://www.pumpsystemsmatter.org/content_detail.aspx?id=112.

Additionally, a variety of software tools are available for designing pumping systems. These programs can be of great assistance in modeling and choosing amongst what can be a bewildering array of options. The DOE *Improving Pumping System Performance: A Sourcebook for Industry* publication is an excellent resource for guidelines for potential pump performance improvements.

Pump Selection and Size. The most crucial component of the water distribution system and pumping system is the pump and therefore, proper pump selection is vital for efficient and optimum operations. Rates of flow (average, peak, and variability) and pressure or head in the system must be known for proper pump selection and sizing. To ensure the pump will provide the highest efficiency, knowledge about the pumping system must be used to find the correct configuration. There are multiple pump and component combinations and the challenge is to find the most cost effective and energy efficient mix while matching the system specifications. The difficulty and complexity of the selection process increases for water systems with highly variable flow conditions as the pump selection (or multiple pump selections) must be able to meet peak flow demand and maintain high efficiency at “normal” operating conditions (DOE 2006). Due to these complexities, it is easy to oversize a pump for its “normal” operating condition.

Pump selection and sizing relies heavily on the pump performance curve and finding the pump with the BEP to match system conditions and the “normal” operating range. In the pump selection process, pump speed is an important criteria as well as impeller size as each impeller size has a unique performance curve.

Pump Optimization. Many water systems are operating with older pumping equipment and can benefit by conducting a pump evaluation. Optimizing pumps can provide substantial energy savings as high amounts of energy is wasted from operating oversized pumps and use of excess throttling or bypass valves to control flow. Oversized pumps are subject to higher wear and tear, increased maintenance, and operating conditions that can reduce useful life as a result of excess energy flow. Typically with oversized pumps, excess pressure must be dissipated which results in vibration of pumps and pipes, thus adding stress to the system that can damage pipes and valves (DOE 2006). Easton Consultants (1995) estimated that correcting oversized pumps could save 15 to 25 percent of energy costs from pumping.

Comparing the manufacturer specifications and performance curves with actual operational data is an integral part of optimizing pumps and evaluating pump efficiency. There are a variety of factors that can lead to pumps operating at less than optimal settings. These factors include:

- Improper design resulting in installed components being inherently inefficient during normal operating conditions as a result of pumps being oversized for the normal job, or changes in operating conditions
- Degradation or deterioration of components
- Improper or inefficient operation because too much flow or more head (pressure) is provided than the system requires or equipment is being operated when it is not required. Operators need to understand the effect of operating equipment at “higher-than-necessary” flows and pressures
- Generation of excess pressure by use of multiple pump systems
- Using high system pressure instead of a booster pump
- Inefficient motors (see section on Motors)

Based on the pump evaluation and efficiency/life cycle analysis, a water utility can make necessary equipment adjustments, determine if a pump needs to be re-sized or replaced with multiple pumps (which can be turned on as needed), develop pump optimization procedures, and change the pumping schedule to maximize efficiency along with other approaches. Many pump optimization options have a relatively short payback when incorporating savings from maintenance and energy costs (DOE 2006). The following describes some approaches to take if a pump is oversized or operating outside of optimum BEP range:

- *Impeller size*: Replacing impellers with smaller diameter impellers reduces tip speed and therefore reduces energy use and can bring a pump into its optimum operating range. Trimming impellers may be an option if the manufactured impeller diameters are too large or too small to match needed performance. Reducing impeller diameter by 2 percent provides an 8 percent reduction in power (4×) (DOE 2006). Smaller impeller size or trimming is a viable option for pumps operating during long periods at high flow rates where other approaches would not provide as much benefit.
- *Multiple parallel pump set-up*: Setting multiple pumps parallel in the system allows the pumps to work independently or together to meet demand flows. This configuration provides flexibility in system operation to optimize efficiency from each pump from low to peak demand periods. Identical pumps are needed to prevent domination by a larger pump. The multiple pump arrangement is a good option for high static head systems. The multiple pump arrangement also provides redundancy for maintenance or in case of pump failure. Energy savings are realized as the arrangement allows pumps to operate close to their BEP (DOE 2006). Also, through various flow conditions, systems can determine the optimum pump combination to maximize overall efficiency for savings between 10 and 50 percent on electric consumption (Easton Consultants 1995). Using multiple pumps is a “low-cost” control method (Budris 2008). The main limitation of the multiple pump arrangement is that flow changes must occur in stepwise variation. There is a potential to see a 50 percent reduction in annual costs, which mostly results from eliminating the use of throttling or bypass valves (FOE 2006).
- *“Pony” pump set-up*: This approach is beneficial for a system with a fixed-speed pump that is oversized for “normal” operating conditions, but is efficient during high peak periods or if the current pump operates intermittently. Adding a second smaller

Water Utility Example

Monroe County Water Authority (MCWA) implemented a pilot study to refurbish interior pump casings and add a coating to prevent corrosion in order to conserve energy, reduce greenhouse gases, and reduce O&M costs. Based on the positive results, MCWA received a grant from NYSERDA to research use of a ceramic epoxy coating to increase pump performance and efficiency. The initial pilot test determined that many pumps in the system were operating 20 percent below the manufacturer design curves. The initial step of the pilot study included mechanical refurbishment of the pumps by replacing valves, O-rings, etc., but only minimal improvement was seen. The second step of the pilot study entailed internal visual inspection of pumps that identified extensive tuberculation buildup on interior casings of all pumps. MCWA decided to clean the pump casings and add a NSF-approved brushable type ceramic-filled epoxy coating to preserve pumps from corrosion and enhance reduction of head loss. The pilot study showed an 8 percent improvement in pump efficiency after cleaning and applying the pump coating. On a single pump, the refurbishment and coating saved up to \$17,000 in annual energy costs. The payback period of the improvements is dependent upon hours of operation, but it is estimated that a complete payback via energy savings in less than a year.

Source: Verosky et al. 2008. *Energy Savings Through Pump Refurbishment and Coatings*. Pumps & Systems, November 2008. [Online]. Available: <<http://www.pump-zone.com/pumps/pumps/energy-savings-through-pump-refurbishment-and-coatings.html>>.

“pony” pump to the system to operate during “normal” and low-flow periods will result in improved efficiency and energy savings.

- *Controlling pump speed:* Controlling the speed of a pump can increase efficiency. Pump speed can be controlled by the addition of a VFD or multiple-speed motor. Both options result in the pump operating at the necessary speed to meet demands. More details on VFDs are outlined later in this section. The VFD option is most beneficial when a pump has continuous variations or changes in flow demand. However, VFDs must be considered carefully for use in water systems with high static head as the VFD can reduce pump speed too low or near “shut-off” conditions resulting in inefficient operation (DOE 2006). Multiple speed motors are better suited for use in systems with non-continuous flow variations as these motors only have “set” speeds; and where the need for pump “soft starts” are minimal. Additionally, if financial constraints limit capital investment, the speed on oversized pumps can be reduced with gear or belt drives; however, this process is not as energy efficient as other methods (DOE 2006).

Additionally, with any pump optimization or improvement, evaluation should be given to the pump motor (see Motor section). The motors powering pumps should also be high efficiency. High efficiency alternating current (AC) motors can be in the range of 10 percent more efficient than normal AC motors (efficiency also depends on rated output) (DOE 2006). While the savings may seem modest, it adds up quickly for pump motors that are used frequently or constantly. Furthermore, pump optimization can result by installing a SCADA system to automatically control pump operation and pumping schedules to correlate to diurnal and seasonal demand patterns.

Maintenance and Repair. Establishing and maintaining regular and preventative maintenance on pumps helps preserve pump performance, extends the life of the pump, minimizes downtime, and supports system optimization. Any pump maintenance should follow the manufacturer’s recommendations. Establishing a maintenance plan is important to maintaining a regular

maintenance schedule. The plan should include a detailed checklist for inspecting the packing, mechanical seals, bearings, motor/pump alignment, and motor condition (DOE 2006). The *American Water Works Association (AWWA) Water Distribution Systems Handbook* is a useful resource to help establish a maintenance plan and schedule and is available through the AWWA Web site: <http://beta.awwa.org/Bookstore/productDetail.cfm?ItemNumber=3955>.

After installing new pumps or components, it is a good practice to record the operation readings such as temperature, pressures, vibration, amperage, etc. Initial data can then be used to compare pump measurements over time as a proactive approach to finding or identifying potential inefficiencies (Budris 2008).

Motors

Motors control the speed of the pump and are directly tied to the efficiency of the pumping system. Motor efficiency increases if motors are operated for long periods (more than 50 percent) of time since most of the energy is expended turning on and off the motor (DOE 2006). Motors are designed to operate between 50 to 100 percent of rated load and are most efficient at 75 percent of rated load. Efficiency of motors declines when a motor is operated for extended periods below 50 percent of load (DOE Motor Challenge Fact Sheet). A water utility should develop a plan for upgrading existing motors with premium efficiency models, if not already installed, as the premium efficiency motors can provide up to 10 percent more efficiency as compared to “standard” or average motors. The plan should include purchasing premium efficiency motors for any new installations, replacements, or spares. The payback period on installing premium efficiency motors is shortened if motors are operated over 50 percent of the time (Williams and Culp 2001). The cost effectiveness of replacement of motors depends on the price of electricity, hours operated, and the price premium for purchasing premium efficiency motors (DOE 2006).

To be proactive in energy management, a water utility can conduct a motor inventory and collect operational data during an energy audit or system evaluation to use in development of a motor maintenance and replacement plan. An important component of an Energy Management Plan is the implementation of proper motor maintenance to ensure motors are operating to their highest efficiency. A plan should include monitoring of loads and run time to evaluate efficiency. Savings from implementing a motor maintenance plan can range from 2 to 30 percent of total motor system energy use (EPRI 1996 and FOE 2006). Motor maintenance plans include a set of policies and procedures to assist in managing the facility’s motors. CMMS are available as a management tool. Policies and procedures for motor repair/replacement should be based on life-cycle costing and proactive planning, including procedures for predictive and preventive maintenance planning and a motor survey and tracking program. The benefits of motor management are reduced downtime of equipment, improved productivity and efficiency, and decreased energy usage and costs.

DOE estimates that motor system optimization and optimization tools can provide substantial energy savings. *1*2*3 Approach to Motor Management*, an easy-to-use resource tool to assist with motor repair/replace decisions is available from <http://www.motorsmatter.org/>. The program provides a framework for educating water utilities and other industrial customers about best practice motor management strategies and assists in development of a motor management plan to fit the facility’s needs.

The DOE’s *Motor-Master+International* program is available to assist water utilities and industry in motor system improvement planning. The program also identifies the most cost-effective

choice when deciding to repair or replace old motors and includes energy saving calculations. The program database contains over 25,000 NEMA motors and 7,200 ICE motors. The DOE's *Motor-Master+International* software program is available for download at: www.eere.energy.gov/Industry/bestpractices/software.html. The DOE factsheet *Determining Electric Motor Load and Efficiency* can be helpful in determining if and when motors should be replaced (<http://www1.eere.energy.gov/industry/bestpractices/pdfs/10097517.pdf>).

Variable Frequency Drives

Variable frequency drives (VFDs) or variable-speed drives (VSDs) are electronic controllers that adjust the rotational speed of the electric motor (such as a pump motor) by controlling the frequency of the electric power supplied to the motor. A single VFD can control multiple motors of the same size. According to the CEC, the use of VFDs is estimated to reduce energy use by as much as 50 percent since VFDs match the motor speed to the specific energy demands needed (CEC VFD Factsheet). Therefore, energy is conserved since the drive operates at lower speeds when needed. The actual energy savings a water system may achieve will be dependent on a variety of items such as the design of the overall system, pump size, load profiles, static head, and friction. VFDs are not the best option for use in systems with high static head or pumps operating for extended periods under low flow conditions as this may result in pumps operating outside of optimum ranges (DOE 2006).

Installation of VFDs is one of the easiest energy improvements a water utility can implement. After the completion of an energy audit, water systems can determine which equipment is best suited for VFD retrofit or replacement. VFDs are being used by an increasing number of water utilities as energy efficiency measures. One of the many benefits of VFDs is the automatic adjustments which eliminate the need for mechanical devices such as flow-restricting valves or a bypass that promote the use of excess energy. A large amount of energy is wasted through the use of throttling or bypassing excessive flows and elimination of this practice can result in up to 50 percent energy reduction (depending on how often flow-restriction was used) (DOE 2006 and FOE 2006). Another benefit of installing VFDs is “soft start” of the equipment, which reduces the energy required for start up. A “soft start” reduces stress applied to the system, thus resulting in less wear and tear on motors, reducing maintenance, and increasing control of processes.

VFDs are easy to retrofit to existing equipment with three-phased electric motors, such as existing pumps and blowers with throttling devices. However, a good quality power source is needed due to alternating energy requirements (DOE 2006). As part of defining energy conservation measures, water utilities should perform a cost/benefit analysis and evaluate life cycle costs since the initial costs for VFD are typically higher than fixed-speed drives. Costs for VFDs can range from \$3,000 for small (5 horse power (hp)) models up to over \$40,000 for custom-engineered models for large utilities, plus installation costs. Despite the higher initial costs, with the potential of up to 50 percent in reduced energy use, the payback could be a few months to a few years and may be less if the electric utility offers rebates or incentives (CEC VFD Fact Sheet). Commonly, the life-cycle energy and maintenance cost savings justifies the investment.

Pressure Reducing Valves and In-line Turbines

Some water systems have significant elevation changes over their distribution areas. These systems are typically designed two ways in order to make the distribution system water pressure

uniform over the distribution area. Water is pumped into the distribution system at a lower than desired line pressure (which will become the desired line pressure at low elevations) and booster pumps are installed for lines going to higher elevations. Alternatively, water is pumped into the distribution system at higher than desired line pressure (which will become the desired line pressure at higher elevations) and pressure-reducing valves are installed for the lower elevations.

A water system designed and currently operating using the latter approach will waste some of the energy that the pumps initially put into the system through the use of the pressure-reducing valves. Instead of wasting this energy, in-line turbines can be installed to generate electricity from the excess pressure. In addition to being energy efficient, the electricity generated in this way can be competitive in price with electricity purchased from the grid. One case study (Cucamonga Valley Water District) estimated that they could produce electricity in this fashion for \$0.09/kWh at some of their more favorable sites.

There are several potential barriers to implementing this type of program. Distribution nodes where the turbines could be installed may be in somewhat remote locations, and are unlikely to be in locations where the water utility could use the generated power. So, the turbines may need grid tie-ins, which means that the utility must run expensive electric lines to the location and must face regulatory red tape related to becoming an independent power producer. The standby charges alone may be enough to discourage turbines. However, depending on location (as with the barriers), there may be renewable energy grants, credits, or subsidies available for an in-line turbine program.

If a water utility plans to take advantage of in-line turbines, it will need to either have staff familiar with sizing hydroelectric turbines or be willing to hire consultants with appropriate experience, which may be an additional constraint and cost.

For an example of hydraulic turbine sizing, see *Design Considerations for Hydropower Development in a Water Distribution System* available for download at: [http://www.hrcshp.org/cn/chshpdb/db/US/2.Design%20Considerations%20for%20Hydropower%20Development%20In%20a%20Water%20Distribution%20System\(2004w\).pdf](http://www.hrcshp.org/cn/chshpdb/db/US/2.Design%20Considerations%20for%20Hydropower%20Development%20In%20a%20Water%20Distribution%20System(2004w).pdf).

Water Conservation

<p>Best Practices</p> <p><i>Supply-Side</i></p> <ul style="list-style-type: none"> • Leak Reduction • Metering • Alternate Supply 	<p><i>Demand-Side</i></p> <ul style="list-style-type: none"> • Water Loss Audits • USEPA’s WaterSense Program • Water Efficient Devices • Metering • Commercial and Industrial Efficiency • Conservation Rate Structure • Alternate Supply
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Treating and delivering water requires substantial amounts of energy—U.S. drinking water and wastewater treatment facilities consume about 56 billion kWh per year, enough electricity to power more than 5 million homes for an entire year (USEPA WaterSense program; http://www.epa.gov/WaterSense/water_efficiency/benefits_of_water_efficiency.html). Drinking water systems use large amounts of energy for raw water extraction and conveyance, treatment, and finished water distribution and storage. Given the heavy weight of water, the majority of a water system’s

energy use goes toward pumping raw and finished water. Drinking water utilities can save energy by reducing the amount of water that must be extracted, treated, and distributed. A methodology for assessing the impact of water conservation on direct and indirect energy intensity is presented in *Greenhouse Gas and Energy Co-Benefits of Water Conservation* (Maas, 2009) and can help water utilities better understand the connection.

Many cities and drinking water utilities have developed water conservation plans and programs to reduce water use which can save on energy costs. A water conservation plan is a written document that evaluates current and projected water use; assesses infrastructure, operations, and management practices; describes actions to be taken to reduce water losses, waste, or consumption; and increases the efficiency with which water is used, treated, stored, and transmitted. Water conservation programs should holistically consider both supply- and demand-side management and conservation and evaluate alternative water supplies for potable and non-potable use. The emphasis on the supply-side is on managing and understanding available water supply, maximizing the efficiency of water supply operations, and reducing water loss from the delivery system. Conservation plans for the supply side may require additional financial resources; however, there is some potential for reduction in operating costs and recovery of lost revenues. Proper demand-side management incorporates implementing effective water loss management strategies, including performing water loss audits. Water utilities can then use the results of the audit to reduce the amount of real and apparent water loss through proactive leak detection and repair programs and accurate metering and recordkeeping. Conservation plans for the demand side (i.e., reductions in consumer usage) may result in lost revenues, though a well-designed pricing program can offset these potential losses. Other benefits associated with implementing a conservation plan include:

- Eliminating, downsizing, or postponing the need for capital projects
- Improving the utilization and extending the life of existing facilities
- Lowering variable operating costs
- Avoiding new source development costs
- Improving drought or emergency preparedness
- Educating customers about the value of water
- Improving reliability and margins of safe and dependable yields
- Protecting and preserving environmental resources

Water conservation plans will vary based on many factors including the size of the water utility. Developing a water conservation plan typically involves the following steps:

1. Establish the goals of the water conservation plan
2. Conduct a water system audit
3. Prepare a demand forecast
4. Identify and select potential water conservation measures

Elements of a conservation plan may include:

- Metering
- Water accounting and loss control
- Pricing
- Information and education programs
- Outreach developed for specific users
- Pressure management
- Water-use regulations

The water utility should develop a schedule and timetable for implementing the water conservation strategies. Implementation actions should include a timetable for securing budgetary resources, hiring staff, procurement of materials, acquisition of any necessary permits, and activity milestones.

Supply-Side Management

Supply-side management and water conservation efforts focus on reducing a utility's real and apparent water loss. Water losses originate from physical "real" losses, such as leaks and unauthorized water use, and apparent losses from inaccurate metering or recordkeeping. Water lost from water distribution systems is estimated at 1.7 trillion gallons per year at a national cost of \$2.6 billion per year (USEPA 2007). Losses of water contribute to increased energy consumption by requiring water systems to pump and treat more water than is necessary. Leak reduction, accurate, comprehensive metering, and water conservation plans, three important supply-side water conservation efforts, are described in detail below.

Leak Reduction. Identifying and fixing leaks can reduce a water system's "real" water losses. A leak can occur at any point in a water system because of a variety of causes, including pipe age, pipe material, corrosion, freeze-thaw cycle, ground settlement, and surface loads. Many times water leaks are located by visual inspection or reduced water pressure. However, the potential of significant water loss comes from small, undetectable leaks that occur for long time periods. While it is not technically or economically feasible for water systems to be completely leak-free, proactive utilities can substantially reduce system leaks.

There are 240,000 water main breaks per year in the United States (USEPA 2007). As part of an effective water loss management strategy, water systems should complete regular inspections and leak detection surveys and install leak detection equipment into the distribution system. Leak detection surveys are physical evaluations of the water system that involves using equipment, such as a listening device, to find leaks. Other leak detection methods include analysis of night flows through the distribution system, metering of specific district metered areas (DMAs), and continuous-read acoustic monitoring. Automatic meter reading (AMR) or wireless communication technologies can easily be installed with the leak detection equipment to provide real-time leak detection data. Options for reducing water loss from leaks include replacement of old, leaking pipes; repair technologies for small leaks; and pressure management. Leak detection is critical to reducing leakage—Westchester Joint Water Works in New York yielded water savings of more than 2,750 million gallons from the completion of three surveys over a 6-year period. Additional details of the surveys can be found in *Water Loss Control Manual* by Julian Thornton, 2002, pp. 241–250 (Thornton 2002).

Metering. Metering is an important component of both supply- and demand-side water conservation. Water meters are essential for supply-side management because they quantify the volume of water entering and leaving the system, which assists water utility managers to detect leaks and calculate water loss volumes accurately. The U.S. Geological Survey (USGS) estimates that as much as 6 billion gallons per day are lost to leakage, poor accounting, and other unbilled consumption (USEPA 2007). The Alliance for Water Efficiency (2009) states that “installing meters and billing accordingly is the single most effective water conservation measure water utilities can initiate.” In addition, metering unbilled connections, such as hydrants, can help a water utility determine unauthorized water use.

To ensure accuracy, water utilities must install properly-sized water meters of the correct type and that are correctly calibrated.

Alternate Supply. A significant percentage of potable water consumption is applied toward non-potable uses such as landscape irrigation, toilet flushing, and industrial processes. Because not all water applications require potable drinking water, an alternate water supply for non-potable water use can reduce the demand for treated water which translates directly to energy savings for drinking water facilities. Alternate supplies include rainwater harvesting and dual distribution systems for potable and non-potable water, which can be treated wastewater effluent.

Reducing water demand and/or increasing water supply are integral components to sustainable water management. The most effective way to reduce potable water demand is to not just use alternative water supplies to augment the water source, but use alternative water supplies to replace existing uses of potable water. Incorporating alternative water sources into water management and water resource planning allows for the conservation of limited water resources, reduces energy demand, and limits contributions to climate change.

- *Rainwater Harvesting*—Harvesting rainwater involves diverting and collecting rainwater runoff from roofs or other surfaces for immediate use or storing for later use and is a low energy water supply option. Landscape irrigation is the most common use of harvested rainwater. Additionally, harvested rainwater can be a water supply for toilets and heating and cooling systems. Rainwater can be harvested via passive or active systems. Passive systems entail contouring the landscape using berms and vegetation swales to direct and collect rainwater for irrigation of trees and vegetation. Active collection systems include a cistern or rain barrel to capture the diverted rainwater, a filtration mechanism to remove leaves and other debris before the water enters the cistern, and a pump or gravity feed set up for irrigation. One benefit of the active system is that the rainwater can be stored and used when needed. The USEPA rainwater harvesting handbook, *Managing Wet Weather with Green Infrastructure Municipal Handbook Rainwater Harvesting Policies*, available for download at (http://www.epa.gov/npdes/pubs/gi_munichandbook_harvesting.pdf) outlines the following benefits of rainwater harvesting:
 - Inexpensive water supply
 - Augments drinking water supplies
 - Reduces storm water runoff, pollution, and erosion
 - Good water quality for irrigation and non-potable uses
 - Reduces peak summer water demand (conserves water)
 - Introduces demand management for drinking water systems

Water Utility Example

Tucson, Arizona became the first city in the country to require rainwater harvesting for landscaping use. Beginning June 1, 2010, 50 percent of a commercial property's irrigation must be supplied from rainwater. In addition to cisterns, the regulations allow berms and contoured slopes to be used to direct rainwater to trees and landscaped areas (USEPA 2008).

Rainwater harvesting rules, regulations, and laws vary by state, and for states without regulation, rainwater can be categorized inappropriately as gray water or reclaimed water. This mis-categorization of rainwater can result in application of incorrect regulation or building codes and increase costs for installation. Other concerns or limitations of rainwater harvesting include public health concerns and public awareness of uses of rainwater harvesting. The per capita water use in the U.S. is one of the highest in the world and the cost per 1,000 gallons of water is relatively low as compared to other countries. Therefore, there is little incentive for implementation of water conservation mechanisms without regulation, guidelines, and water conservation programs.

- *Reuse/Reclaimed Water*—Effluent or reclaimed water is sustainable and is a key resource available to meet existing and rising water demands. The available uses for reclaimed water are dependent on the quality of the treated wastewater. Many communities already implement advanced treatment and disinfection to produce high quality effluent for urban landscaping and food crop irrigation. There are multiple uses in which reclaimed water can replace non-potable water source. The uses include:
 - Irrigation for residential and commercial landscaping
 - Irrigation for municipal uses such as parks, golf courses, and highway medians
 - Industrial use for heating and cooling and process water
 - Toilet and urinal flushing in buildings
 - Dust control and fire protection
 - Water features and fountains
 - Agricultural irrigations

Public perception and public health concerns are the main impediment to using reclaimed water and expanding the potential uses. Additionally, many states do not have regulations or guidelines for reclaimed water reuse. USEPA issued *Guidelines for Water Reuse* to provide states without reuse regulations a resource and guidance. The manual is available at: <http://www.epa.gov/ord/NRMRL/pubs/625r04108/625r04108.pdf> (USEPA 1992). The WaterReuse Association recently published a new *Manual of Practice on How to Develop a Water Reuse Program*, to assist communities in their attempts to provide a sustainable water supply. The manual describes a standardized step-by-step approach for communities to create and assess new water reuse projects. The manual along with other useful resources are available for purchase at: <http://www.watereuse.org/publications/publications-list/#row2>.

The installation of reuse distribution piping to existing users can be cost prohibitive and disruptive. The major concern with installation of dual distribution systems is that safeguards must be implemented to prevent cross-contamination; commonly the safeguards incorporate the use of color coded pipes. To assure public safety, reclaimed

water distribution systems require qualified and well trained operators to make certain reclaimed water is acceptable for the intended uses and proper monitoring is conducted.

- *Aquifer Storage and Recovery (ASR)*—ASR is a process of collecting or capturing and storing or “banking” water or excess water in an aquifer for later use. ASR is not a new practice, it has been used in the U.S. since the late 1960s (Lowry and Anderson 2006). Due to increasing strain on water supplies, ASR is a very valuable supply-side management tool to use in order to meet needs as a water utility “stores” water during abundance and takes advantage of excess supply during seasonal fluctuations (Bouwer 2007). Various water sources are available for use in ASR such as surface water, stormwater, groundwater, and reclaimed water. These sources are injected into the aquifer through injection wells, infiltration basins (percolation), or irrigation; then the water is recovered through “recovery” wells when the water is needed such as during drought periods.

Not all physical locations will be suitable for ASR as specific aquifer characteristics, such as hydraulic gradient, porosity, and permeability, are required to store the source water and allow for effective recovery. A hydrologic study and pilot study is needed to select the proper location and design as there are many conditions that must be evaluated, including hydrologic setting, land-use, geochemical, mixing, operational parameters of storage periods, volume, injection/recovery rates, and interaction with native groundwater.

ASR has several benefits over other surface storage (e.g., surface reservoir or tank), including lower costs as construction components are limited, minimal surface area needed (unless using basins), minimal environmental disturbance, and no water loss from evaporation as with surface water reservoirs. Additional geochemical benefits may exist to assist with treating of surface water or reclaimed water. State regulations, water rights, and impact to native groundwater are some common limiting factors for moving forward with ASR. The Water Research Foundation has funded several research projects on ASR and resources are available at: <http://www.waterresearchfoundation.org/research/TopicsAndProjects/topicSnapshot.aspx?topic=Sustain>.

Demand-Side Conservation

Promoting and implementing demand-side conservation can help reduce a drinking water utility’s energy consumption by reducing the volume of water extracted, treated, and distributed. There are a variety of ways water utilities can reduce their consumer demand, and programs can be tailored and combined to meet the specific needs of a water utility and its consumers. Several examples of effective demand-side conservation programs include:

- Incentive programs for the installation of water-efficient devices such as low-flow toilets, showerheads, and faucet aerators.
- Regulations and ordinances aimed at reducing water use.
- Metering water use and charging rates based on actual water consumed.
- Programs to optimize water used for irrigation, including consumer education and incentives for weather-based irrigation controllers.
- Programs to improve commercial and industrial water efficiency.

- Education and outreach on water conservation.
- Conservation rate structures.
- Alternate water supplies for non-potable water uses.

Water utilities should tailor their water conservation programs to the specific needs of their system and its consumers. In addition to saving energy, improving water efficiency can help water utilities serve growing populations while reducing the need for costly water supply infrastructure expansions. The following is a brief description of common demand-side management programs to encourage water conservation.

Water Loss Audits. Pumping, treating, and distributing water takes energy; therefore, reducing water demand, such as reducing water loss, will result in less water pumped, treated, and distributed and thus reduce energy consumption. Typical water loss at a water system ranges from 10 to 20 percent and historically was considered reasonable (Lahlou 2001). However, with aging infrastructure, concerns over water resource management, and new technologies available to improve operational efficiencies, the percentage of expected water loss can be drastically reduced. Water loss even as low as 10 percent at a multi-million gallon-per-day facility results in substantial water loss, excessive energy usage, and lost revenue. For small systems, the water loss and increased energy costs can result in an economic hardship.

Performance of a water audit is the primary way a water utility can determine or verify its volume of water loss. Water audits entail gathering details on the facility; evaluating design plans and pipeline infrastructure; listing all equipment that use water, such as conveyance and distribution lines; performing a walkthrough of the facility to look for individual processes and their water use; performing a leak detection survey on pipelines; identifying zones of low pressure; and defining areas for further investigation and improvement.

As part of water loss management, a water utility should define short-term and long-term goals to reduce water loss. These goals could include implementing active leakage control to locate unreported breaks, identifying ways to reduce the number of leaks and breaks such as pressure management, pipeline replacement programs, asset management, and implementing an automatic control system. Automatic control systems, such as SCADA, can automatically detect leaks and monitor and control pressure along the distribution system. The instantaneous knowledge of a potential leak allows for quick fixes and limits the volume of water loss.

AWWA and the International Water Association developed a free water audit software program available for water utilities that can be downloaded at: <http://www.awwa.org/Resources/WaterLossControl.cfm?ItemNumber=48511&navItemNumber=48158>.

The AWWA water audit program details a variety of consumption and losses that exist in a water system and applies a water balance approach in the analysis of a water system's data. The water balance approach provides accountability, as the quantity of water drawn into the distribution system should, in theory, equal the quantity of water taken out of the distribution system. The water audit program standardizes the approach to allow for comparisons and benchmarking of best practices which allows the systems to make meaningful assessments of water loss and to set goals.

As an additional resource, water utilities can locate comprehensive water auditing procedures outlined in AWWA's third edition M36 publication, *Water Loss Control*, which is available for purchase at the AWWA's Web site: <http://www.awwa.org>.

The Alliance for Water Efficiency (2009) indicates that some water utilities may only bill up to 50 percent or less of water treated and pumped and that the true amount of water lost by utilities is challenging due to the lack of mandates for water audits. Currently, there are no federal

regulations for water loss audits by water systems; however, several states have implemented audit requirements to promote water resource and energy management. The state of Texas was the first state to pass legislation requiring water utilities to submit water audits. The states of New Mexico, Georgia, Washington, and others have followed suit. The following is a list of Web site links to various state water audit programs.

- Texas: www.twdb.state.tx.us/assistance/conservation/Municipal/Water_Audit/Leak_Detection/WaterLossManual_2008.pdf
- New Mexico: www.ose.state.nm.us/water-info/conservation/h2o-tech-assist.html
- Georgia: www.northgeorgiawater.com/html/204.htm
- Washington: www.doh.wa.gov/ehp/dw/programs/wue.htm

USEPA's WaterSense Program. WaterSense is a partnership program sponsored by the USEPA that seeks to “promote water efficiency and enhance the market for water-efficient products, programs, and practices” (<http://www.epa.gov/watersense/basic/index.htm>). The WaterSense label helps consumers identify quality water-efficient products and certification programs. Labeled products must meet certain water efficiency and performance criteria, such as performing on par or exceeding their less efficient counterparts and being roughly 20 percent more water efficient than average products. Final WaterSense specifications have been developed for irrigation professionals, lavatory faucets, and toilets. Specifications for pre-rinse spray valves, showerheads, water- or sensor-based irrigation control technologies, urinals, and single-family homes are currently in draft form or under development.

Replacing inefficient devices with WaterSense devices can lead to substantial energy savings. USEPA WaterSense estimates that if 1 percent of American homes replaced their older, inefficient toilets with WaterSense labeled models, the country would save more than 38 million kWh of electricity—enough to supply more than 43,000 households with electricity for one month (http://www.epa.gov/WaterSense/water_efficiency/benefits_of_water_efficiency.html). Water utilities and their customers can use WaterSense's free online calculator (<http://www.epa.gov/watersense/calculator/index.htm>) to calculate the water and consumer energy savings associated with installing WaterSense labeled faucets and toilets.

Water utilities and other businesses can partner with WaterSense to encourage water efficient behaviors and the purchase of water-efficient products. Partnering utilities are referred to as “promotional partners,” promoting and sharing information about the program. Becoming a WaterSense partner has many benefits for utilities, including strengthening water-efficiency outreach, national recognition as a leader in water efficiency, increased exposure through placement on the WaterSense Web site, and free tools and resources to promote WaterSense and water efficiency.

Water-Efficient Device Incentive Programs. Installing water-efficient devices, such as WaterSense-labeled products, can substantially reduce water demand. To encourage the use of these devices, water utilities can distribute devices, provide rebates or vouchers, directly install devices, or provide incentives to manufacturers of the devices, who then reduce the price of the devices. Devices typically featured in incentive programs include low-flow showerheads, washing machines, dishwashers, clothes washers, aerators, and toilets. Low-flow toilets, in particular, can significantly reduce household water use. Utilities can develop incentive programs for both residential and commercial customers.

Metering. Installing water meters allows water utilities to bill customers based on actual water use, rather than a flat rate. Billing based on usage creates an economic incentive for customers

to conserve water and has been found to be the single most effective water conservation measure a utility can initiate, according to the Alliance for Water Efficiency (<http://www.allianceforwaterefficiency.org/metering.aspx>). Meters require careful management, and the correct size and type of meters is necessary for accurate measurements.

Water utilities may want to consider installing submeters to multi-family residential units and forming a partnership with electric providers regarding incentives for reduced energy/water use. Installation of submeters ties in with conservation practices as a way of showing individual water consumption. Depending upon the ability of the water utility's software billing, submeters provide potential for billing submetered water use to further promote conservation. Submeters also provide a beneficial tool for commercial and industrial customers so that they can monitor water consumption of various processes to find ways to reduce consumption and costs. AMR technology is gaining popularity with water utilities as the remote reading capabilities reduces time to read meters and has other benefits in addition to allowing for tracking and monitoring real-time water consumption. Collection of real-time consumption data may lead in the future to water systems applying real-time prices if they choose. Real-time metering and billing may be an option for the highest water users, such as industrial or commercial users, to provide incentives for conservation and reduced use during peak demand periods. Submetering and real-time pricing complicates the billing process and may be a barrier to some water utilities that do not have billing software or staff expertise to implement these measures.

Optimize Irrigation. Water utilities can help customers optimize water used for landscape irrigation by providing educational materials and incentives for weather-based irrigation controllers. These controllers automatically adjust irrigation schedules based on temperature, rainfall, soil moisture and/or evapotranspiration measurements, ensuring that plants are only watered when necessary. One study showed that of the "Smart Controllers" (soil moisture sensor (SMS) controllers, evapotranspiration (ET) controllers, and rain sensors RS) evaluated, all reduced the water application needed to maintain acceptable turf qualities (M.C. McCready, et al., 2009). Reductions in irrigation water ranged from 0 to 74 percent for SMS based treatments, 25 to 62 percent for ET based treatments, and seven to 30 percent for RS based treatments. Another study showed that ET controllers averaged 43% water savings compared to a time-based treatment without a rain sensor. S.L. Davis, et al. 2009).

Commercial and Industrial Water Efficiency. To improve water efficiency at industrial customers, water utilities can offer technical audits complete with recommendations for improving the water efficiency of industrial processes. Incentive programs for commercial and industrial customers can also be developed and can offer incentives for water-efficient devices such as low-flow toilets, aerators, high-efficiency irrigation systems, and automatic controls for cooling towers.

A 2005 study by the California Urban Watershed Conservation Council found that water conservation surveys at commercial, industrial, and institutional buildings could lead to water use reduction between 11 and 29 percent, depending on the type of survey conducted.

Conservation Rate Structures. Water utilities can promote water efficiency and create economic incentives for customers to conserve water through conservation rate structures. Researchers agree that residential demand for outdoor uses is more elastic than for indoor uses and that water demand is more responsive to price over the long term. The most effective conservation rate structure is an increasing block rate structure, in which the cost per unit of water increases as the customer uses more. To be an effective conservation rate structure, a large portion of the charges must be based on the quantity of water the customer consumes and the rates must be

sufficient to encourage conservation. However, this must be balanced with the needs of the water utility to recover fixed costs.

A water budget rate structure is a variation of the increasing block rate structure in which the blocks are based on the determined efficient level of water use, or water budget, for each consumer. The water budget is based on one or more consumer characteristics such as number of occupants, lot size, or evapotranspiration requirements of the landscape. While water budget rate structures can effectively encourage water conservation, they can be difficult to implement, as they require sophisticated billing systems and customer-level data that may not be readily available. Recent research by Mayer et al. (2008) provides additional insight into water budget-based rate structures including implementation costs and conservation savings.

A seasonal rate structure can also promote water conservation. In this rate structure, water rates vary by season, reflecting temporal differences in the cost of providing water, which increases during the summer for many utilities due to increased demand. Seasonal rates can be especially effective at promoting outdoor water conservation, which typically account for almost two-thirds of residential water demand. A seasonal rate structure is similar to peak-load pricing structures commonly used by electric and communication industries, among others. Related to seasonal rate structures, drought pricing is sometimes implemented by water utilities in times of drought. Under drought pricing, water rates are temporarily raised, which encourages consumer conservation and helps water utilities avoid revenue shortfall.

In implementing conservation rate structures, a water utility will need to balance the costs of saving water and energy against the potential for reduced revenues. Water utilities may want to consider establishing rate stabilization funds to address the potential reductions in revenue as a result of conservation and prevent the need to increase rates.

Alternative/Renewable Energy Sources

Best Practices

- Solar Power
- Wind Turbines
- Geothermal
- Lake/Ocean Water Cooling
- Micro-Hydro Generation

The term “renewable energy” refers to sources of energy that are regenerated by nature and are sustainable in supply. Renewable energy projects involve the installation of devices and/or systems that generate energy (e.g., electricity or heat) or displace energy use through the use of renewable energy resources. Examples of technologies include: photovoltaics, active or passive solar systems, hydropower, hydroturbines, geothermal, and wind turbines. The most notable difference between renewable energy projects and other ECMs is that renewable projects supply energy rather than reduce the amount of energy used. Renewable energy projects also tend to have lengthy ROIs. As such, projects to implement ECMs should be initiated before projects to implement renewable energy technologies. Measuring the energy supplied allows for a simplified approach to measuring savings that is not possible with energy efficiency projects. Like many projects, the performance of most renewable energy technologies depends on the environmental conditions, such as solar radiation or wind speed. Several of these technologies are discussed in more detail in the following sections.

Solar Power

The sun's heat and light provide an abundant source of energy that can be harnessed in many ways. There are a variety of technologies that have been developed to take advantage of solar energy. These include concentrating solar power systems, passive solar heating and daylighting, photovoltaic systems, solar hot water, and solar process heat and space heating and cooling.

Solar power can be used in both large-scale applications and in smaller systems for the home. Businesses and industry can diversify their energy sources, improve efficiency, and save money by choosing solar technologies for heating and cooling, industrial processes, electricity, and water heating. Homeowners can also use solar technologies for heating and cooling and water heating, and may even be able to produce enough electricity to operate "off-grid" or to net meter extra electricity to the utilities, depending on local programs. The use of passive solar heating and daylighting design strategies can help both homes and commercial buildings operate more efficiently and make them more pleasant and comfortable places in which to live and work.

Concentrating Solar Power. Utilities and power plants are taking advantage of the sun's abundant energy resource and offering the benefits to their customers. Concentrating solar power systems allow power plants to produce electricity from the sun on a larger scale, which in turn allows consumers to take advantage of solar power without making the investment in personal solar technology systems. The three main types of concentrating solar power systems are: *linear concentrator*, *dish/engine*, and *power tower systems* (NREL 2008a).

Linear concentrator systems collect the sun's energy using long rectangular, curved (U-shaped) mirrors. The mirrors are tilted toward the sun, focusing sunlight on tubes (or receivers) that run the length of the mirrors. The reflected sunlight heats a fluid flowing through the tubes. The hot fluid then is used to boil water in a conventional steam-turbine generator to produce electricity. There are two major types of linear concentrator systems: parabolic trough systems, where receiver tubes are positioned along the focal line of each parabolic mirror; and linear Fresnel reflector systems, where one receiver tube is positioned above several mirrors to allow the mirrors greater mobility in tracking the sun (NREL 2008a).

A dish/engine system uses a mirrored dish similar to a very large satellite dish. The dish-shaped surface directs and concentrates sunlight onto a thermal receiver, which absorbs and collects the heat and transfers it to the engine generator. The most common type of heat engine used today in dish/engine systems is the Stirling engine. This system uses the fluid heated by the receiver to move pistons and create mechanical power. The mechanical power is then used to run a generator or alternator to produce electricity (NREL 2008a).

A power tower system uses a large field of flat, sun-tracking mirrors known as heliostats to focus and concentrate sunlight onto a receiver on the top of a tower. A heat-transfer fluid heated in the receiver is used to generate steam, which, in turn, is used in a conventional turbine generator to produce electricity. Some power towers use water/steam as the heat-transfer fluid. Other advanced designs are experimenting with molten nitrate salt because of its superior heat-transfer and energy-storage capabilities. The energy-storage capability, or thermal storage, allows the system to continue to dispatch electricity during cloudy weather or at night (NREL 2008a).

Passive Solar Power. Today, many buildings are designed to take advantage of the sun's natural resource through the use of passive solar heating and daylighting. The south side of a building always receives the most sunlight. Therefore, buildings designed for passive solar heating usually have large, south-facing windows. Materials that absorb and store the sun's heat can be built into the sunlit floors and walls. The floors and walls will then heat up during the day and

slowly release heat at night, when the heat is needed most. This passive solar design feature is called *direct gain* (NREL 2008a).

Other passive solar heating design features include *sunspaces* and *trombe walls*. A sunspace (which is much like a greenhouse) is built on the south side of a building. As sunlight passes through glass or other glazing, it warms the sunspace. Proper ventilation allows the heat to circulate into the building. On the other hand, a trombe wall is a very thick, south-facing wall, which is painted black and made of a material that absorbs a lot of heat. A pane of glass or plastic glazing, installed a few inches in front of the wall, helps hold in the heat. The wall heats up slowly during the day. Then as it cools gradually during the night, it gives off its heat inside the building (NREL 2008a).

Many of the passive solar heating design features also provide daylighting. Daylighting is simply the use of natural sunlight to brighten up a building's interior. To lighten up north-facing rooms and upper levels, a *clerestory*—a row of windows near the peak of the roof—is often used along with an open floor plan inside that allows the light to bounce throughout the building (NREL 2008a).

Photovoltaics. Solar cells, also called photovoltaics (PV), convert sunlight directly into electricity. Solar cells are often used to power calculators and watches. They are made of semiconducting materials similar to those used in computer chips. When sunlight is absorbed by these materials, the solar energy knocks electrons loose from their atoms, allowing the electrons to flow through the material to produce electricity. This process of converting light (photons) to electricity (voltage) is called the *photovoltaic (PV) effect* (NREL 2008a).

Solar cells are typically combined into modules that hold about 40 cells; about 10 of these modules are mounted in PV *arrays* that can measure up to several meters on a side. These *flat-plate* PV arrays can be mounted at a fixed angle facing south, or they can be mounted on a tracking device that follows the sun, allowing them to capture the most sunlight over the course of a day. About 10 to 20 PV arrays can provide enough power for a household; for large electric utility or industrial applications, hundreds of arrays can be interconnected to form a single, large PV system (NREL 2008a).

Thin film solar cells use layers of semiconductor materials only a few micrometers thick. Thin film technology has made it possible for solar cells to now double as rooftop shingles, roof

Water Utility Example

The town of Rifle City, CO is installing two photovoltaic solar panels near Hwy 6. When completed, the combined solar energy systems will be one of the largest in the United States, providing 0.6 megawatts of power to the Colorado River raw water pump station at the Rifle Pond and 1.72 megawatts to the Rifle Regional Wastewater Reclamation Facility. It is the largest in the state of Colorado. While the solar panels at the raw water site will supply 90 percent of its power, only 60 percent of the power for the wastewater plant will come from the sun. At night, the system will be switched back to the power grid. The solar energy systems are being built by SunEdison, one of the largest solar energy providers in the country, with headquarters in Maryland. In addition to the energy benefits, another benefit is the cost, which is zero to the city of Rifle. Under an agreement with the city, SunEdison will finance, install, and maintain the two systems, while the city will purchase the solar electricity over a 20-year contract period, which should save taxpayers on utility rates. Rifle officials say that during the first 20 years in operation the zero-emission systems combined will offset more than 152 million pounds of carbon dioxide that would have been emitted during the production of electricity from fossil fuels.

tiles, building facades, or the glazing for skylights or atria. The solar cell version of items such as shingles offer the same protection and durability as ordinary asphalt shingles (NREL 2008a).

Some solar cells are designed to operate with concentrated sunlight. These cells are built into *concentrating collectors* that use a lens to focus the sunlight onto the cells. This approach has both advantages and disadvantages compared with flat-plate PV arrays. The main idea is to use very little of the expensive semiconducting PV material while collecting as much sunlight as possible. But because the lenses must be pointed at the sun, the use of concentrating collectors is limited to the sunniest parts of the country. Some concentrating collectors are designed to be mounted on simple tracking devices, but most require sophisticated tracking devices, which further limit their use to electric utilities, industries, and large buildings.

The performance of a solar cell is measured in terms of its efficiency at turning sunlight into electricity. Only sunlight of certain energies will work efficiently to create electricity, and much of it is reflected or absorbed by the material that makes up the cell. Because of this, a typical commercial solar cell has an efficiency of 15 percent—about one-sixth of the sunlight striking the cell generates electricity. Low efficiencies mean that larger arrays are needed, and that means higher cost. Improving solar cell efficiencies while holding down the cost per cell is an important goal of the PV industry, National Renewable Energy Laboratory researchers, and other DOE laboratories, and they have made significant progress. The first solar cells, built in the 1950s, had efficiencies of less than 4 percent.

Wind Turbines

Windmills have been used for pumping water or grinding grain for hundreds of years. Today, the windmill's modern equivalent—a *wind turbine*—can use the wind's energy to generate electricity. Wind turbines, like windmills, are mounted on a tower to capture the most energy. At 100 feet (30 meters) or more aboveground, they can take advantage of the faster and less turbulent wind. Turbines catch the wind's energy with their propeller-like blades. Usually, two or three blades are mounted on a shaft to form a *rotor*. A blade acts much like an airplane wing. When the wind blows, a pocket of low-pressure air forms on the downwind side of the blade, the low-pressure air pocket then pulls the blade toward it, causing the rotor to turn. This is called *lift*. The force of the lift is actually much stronger than the wind's force against the front side of the blade, which is called *drag*. The combination of lift and drag causes the rotor to spin like a propeller, and the turning shaft spins a generator to make electricity (NREL 2008b).

Wind turbines can be used as stand-alone applications, or they can be connected to a utility power grid or even combined with a photovoltaic (solar cell) system. For utility-scale (megawatt-sized) sources of wind energy, a large number of wind turbines are usually built close together to form a *wind plant*. Several electricity providers today use wind plants to supply power to their customers (NREL 2008b)

Stand-alone wind turbines are typically used for water pumping or communications. However, homeowners, farmers, and ranchers in windy areas can also use wind turbines as a way to cut their electric bills (NREL 2008b).

Small wind systems also have potential as distributed energy resources. Distributed energy resources refer to a variety of small, modular power-generating technologies that can be combined to improve the operation of the electricity delivery system (NREL 2008b).

Geothermal

Many technologies have been developed to take advantage of geothermal energy—the heat from the earth. This heat can be drawn from several sources: hot water or steam reservoirs deep in the earth that are accessed by drilling; geothermal reservoirs located near the earth’s surface, mostly located in western states, Alaska, and Hawaii; and the shallow ground near the Earth’s surface that maintains a relatively constant temperature of 50° to 60°F (NREL 2009a). In 2007, geothermal was the fourth largest source of renewable energy in the U.S. Today the U.S. has about 3,000 MW of geothermal electricity connected to the grid. Geothermal energy generated 14,885 gigawatt-hours (GWh) of electricity in 2007, which accounted for 4 percent of renewable energy-based electricity consumption in the U.S. (including large hydropower). The U.S. continues to produce more geothermal electricity than any other country, comprising approximately 30 percent of the world total (Blodgett and Slack 2009). The geothermal energy within the Earth is estimated as equivalent to 42 million Megawatts of power. This is a vast resource potential available as 1 Megawatt can meet the power needs of approximately 1,000 people.

This variety of geothermal resources allows them to be used on both large and small scales. A utility can use the hot water and steam from reservoirs to drive generators and produce electricity for its customers. Other applications apply the heat produced from geothermal directly to various uses in buildings, roads, agriculture, and industrial plants. Still others use the heat directly from the ground to provide heating and cooling in homes and other buildings through use of a ground-source heat pump (GSHP; NREL 2009a). Low-grade geothermal energy is available throughout the United States from a depth of 2 to 200 meters (MIT 2006) since the ground has a relatively constant temperature year round. GSHPs take advantage of Earth’s temperature at shallow depths for heating and cooling to replace conventional equipment. The ground temperature is warmer than the air during the winter and cooler than the air in the summer. The process incorporates using a set of pipes buried underground at a shallow depth to allow the flow of fluid or groundwater through the pipes. In winter, water (or another fluid) is circulated through a shallow pipe system, where it collects heat from the earth. It then transfers the heat through a heat exchanger to warm the building and provide hot water. In summer, when the groundwater temperature is lower than that of ambient air at the surface, the system works in reverse to cool building spaces. Any differences among the design and actual operating conditions results in less efficient equipment (MIT 2006). Even though the infrastructure costs can be expensive, the reduction in electricity used can result in a payback within 20 years. MIT (2006) stated that GSHPs have potential of up to 75 percent savings in electrical consumption per unit of heating or cooling.

Most power plants generate electricity using steam. The steam rotates a turbine that activates a generator, which produces electricity. Many power plants still use fossil fuels to boil water for steam. Geothermal power plants, however, use steam produced from reservoirs of hot water found a couple of miles or more below the Earth’s surface. There are three types of geothermal power plants: *dry steam*, *flash steam*, and *binary cycle* (NREL 2009b).

- *Dry steam* power plants draw from underground resources of steam. The steam is piped directly from underground wells to the power plant, where it is directed into a turbine/generator unit. There are only two known underground resources of steam in the United States: the Geysers in northern California and Yellowstone National Park in Wyoming, where there’s a well-known geyser called Old Faithful. Since Yellowstone

Water Utility Example

The Washington Suburban Sanitary Commission (WSSC) is now powered by wind. According to the USEPA, WSSC is the #1 local government direct purchaser of clean, renewable energy in the United States. In the spring of 2008, the Commission began its use of green power. A total of 14 wind turbines are spinning on a farm in southwestern Pennsylvania, generating 70,000-megawatt hours of power a year. That power is running one-third of WSSC's water and wastewater operations.

While the use of wind power is growing more common, WSSC's wind power purchase is anything but common. Instead of buying renewable energy certificates or RECs, WSSC has opted to purchase green power directly from a wind farm. This not only means a tremendous savings for WSSC's customers, but also demonstrates its commitment to improve air quality by reducing greenhouse gas emissions.

WSSC is paying a fixed price for 85 percent of the wind farm's output over the next 10 years. With this agreement, WSSC expects to save about \$20 million in energy costs over the length of the contract. By using wind power, WSSC is reducing greenhouse gas emissions by about 90 million pounds a year.

is protected from development, the only dry steam plants in the U.S. are at the Geysers (NREL 2009b).

- *Flash steam* power plants are the most common. They use geothermal reservoirs of water with temperatures greater than 360°F (182°C). This very hot water flows up through wells in the ground under its own pressure. As it flows upward, the pressure decreases and some of the hot water boils into steam. The steam is then separated from the water and used to power a turbine/generator. Any leftover water and condensed steam are injected back into the reservoir, making this a sustainable resource (NREL 2009b).
- *Binary cycle* power plants operate on water at lower temperatures of about 225° to 360°F (107° to 182°C). These plants use the heat from hot water to boil a *working fluid*, usually an organic compound with a low boiling point. The working fluid is vaporized in a *heat exchanger* and used to turn a turbine. The water is then injected back into the ground to be reheated. The water and the working fluid are separated during the whole process, so there are little or no air emissions (NREL 2009b).

Small-scale geothermal power plants (under 5 megawatts) have the potential for widespread application in rural areas, possibly even as distributed energy resources. Distributed energy resources refer to a variety of small, modular power-generating technologies that can be combined to improve the operation of the electricity delivery system (NREL 2009).

Lake/Ocean Water Cooling

Employing cold lake or ocean water is similar to using the geothermal energy of the Earth for heating and cooling. The process consists of drawing the cold water at the bottom of a lake or at depth from the ocean into a system of pipes through a heat pump or heat exchanger. Through the heat exchanger, the cold lake or ocean water cools the air or water flowing through a closed loop system to the customers' cooling units. The use of the cold water removes the need for "refrigeration" as a way of reducing energy consumption. The water source is typically returned to the ocean or if a lake is the potable water source, the water, after being used for cooling, is sent to a water treatment plant.

Toronto has reduced energy consumption by 90 percent as compared to using conventional chillers. The Deep Lake Water Cooling system draws water from the lake through intake pipes and water flows to heat exchangers to transfer energy from cold water to a chilled water supply loop. The water is supplied through a closed loop system to multiple buildings. After the water flows through the loop, the water continues on to the surface water treatment plant. The heat exchangers installed are expected to have double the life expectancy as compared to conventional cooling systems.

Honolulu is implementing a process (seawater air conditioning) to use ocean water to cool buildings instead of using fossil fuel-based air conditioning units. The system is designed to intake water from an approximately 1,600 foot depth that will have a temperature around 45°F. The ocean water will be used to cool fresh water circulating through a closed loop system through buildings in downtown Honolulu. The ocean water will be returned to the ocean at a much shallower level and be diffused to ensure proper mixing.

Micro-Hydro Power Generation

Hydroelectric power or “hydropower” is a common source of commercial electric power through a large-scale system utilizing energy of flowing water stored behind large dams. Prior to widespread availability of commercial electric power, small-scale or micro-hydro power was a common power source to operate machinery in manufacturing, grain mills, and the logging industry. Today, micro-hydro power is a term applied to hydro power systems generating up to 100 kW of electricity. These systems capture energy of flowing water and convert the energy to electricity through generators or tie into on-site power stations.

Various hydropower sources or capture are available to municipalities and water utilities—surface water intake feed through pipelines or pressure reducing zones, at a reservoir dam or spillway, or diversion of river to a “conveyance” channel. Water flow powers a turbine sending energy to a generator for conversion to electricity. Depending on the size or number of locations, micro-hydro power has the potential to provide adequate power to supply system operations. The benefit of hydropower is that no “fossil-fuels” are consumed and therefore, there are no air emissions. Depending on the water source for the power generation, there is a need to ensure the source is continuous and flow rates can be maintained (high and low flow).

There are several water utilities utilizing the micro-hydro power technology. These systems include—Mohawk Valley Water Authority, Utica, NY; Mancos Water Reservoir, Mancos, CO; Durango, CO—Lemon Reservoir, Bayfield, CO; and Lee, MA (Green Hydro-Generation). An energy audit of the Lee, MA water treatment facility identified additional hydroelectric potential that is available through utilizing the flow through a pressure reducing station (surface water intake feed).

Water Utility Example

In July 2009, the Tuscaloosa City Council authorized a company to study the feasibility of installing electricity-producing micro-turbines at certain sites along the water distribution system. Mayor Walt Maddox will execute the agreement with Green Hydro-Generation LLC, a company with expertise in the technology. Possible locations for the micro-turbines are at the Lake of Tuscaloosa dam, spillway, aerators, and the raw water feed line that carries water to the water treatment plant.

Financial Assistance

Best Practices

- DWSRF and CWSRF
- ARRA-GPR
- Financial Incentives
- NYSERDA Programs
- State Funding Programs

Implementing energy efficiency measures typically requires a capital investment from the water utility. Fortunately, there are many opportunities for water utilities to receive financial assistance for projects that reduce their energy consumption.

- The Drinking Water State Revolving Fund and Clean Water State Revolving Fund (DWSRF and CWSRF, respectively) can provide low-interest loans for a variety of energy efficiency and water efficiency projects, which in turn reduce energy use. Examples of fundable projects include on-site production of power, energy audits, equipment upgrades, leak detection equipment, meter installation, and installation of water efficient devices.
- Many energy utilities offer financial incentives, such as rebates and reduced energy rates, for customers that purchase energy efficient equipment or implement energy efficiency management practices.
- Water utilities can use energy performance contracting, an innovative financing mechanism that allows systems to install energy conservation measures without paying up front—installation costs are repaid out of guaranteed energy savings.
- NYSERDA and other state funding organizations offer a variety of financial assistance programs including shared-cost energy efficiency studies, incentives for efficiency measures and renewable energy projects, and loan funds to reduce the cost of installing equipment to improve efficiency and promote the use of alternate energy sources.

Water utilities should explore the financial assistance programs available to meet the specific energy efficiency needs of their system. Utilities should recognize that they may need to use a combination of incentive programs and funding sources.

Drinking Water and Clean Water State Revolving Funds

The Drinking Water and Clean Water State Revolving Funds (DWSRF and CWSRF, respectively) function like banks to provide affordable financing for drinking water and water quality projects. The CWSRF was established by the Clean Water Act to provide funding for water quality projects, including point source, nonpoint source, and estuary projects. The DWSRF was established by the Safe Drinking Water Act 1996 Amendments as a financing mechanism to help communities provide safe drinking water.

Federal and state contributions capitalize both funds in all 50 states and Puerto Rico. The states use these funds to make low- or no-interest loans for drinking water and water quality projects. Loan repayments are then cycled back into the funds to be loaned out again. Both publicly and privately-owned community drinking water systems and nonprofit non-community drinking water systems are eligible for funding under the DWSRF program. Eligible CWSRF loan recipients may

include communities, individuals, citizens' groups and non-profit organizations. Specific project eligibility and available funding varies by state, so potential assistance recipients should contact their state DWSRF or CWSRF representative.

A range of water efficiency and energy efficiency projects are eligible for funding through the SRFs. Eligible water efficiency projects include:

- Installation of water meters
- Installation or retrofitting of water-efficient devices, including appliances, plumbing fixtures, and irrigation equipment
- Incentive programs such as rebates, vouchers, and public education
- Installation of dual pipe distribution systems

The SRFs can also fund projects to improve energy efficiency at drinking water utilities. Eligible projects include:

- Utility energy audits
- Retrofits or upgrades to pumps or treatment processes
- Leak detection equipment
- On-site production of clean power
- Replacement or rehabilitation of pipe

In addition, the DWSRF allows states to set aside up to 31 percent of their federal capitalization grant to fund various drinking water programs. Several states use these set-asides to help water utilities and their customers use water more efficiently through the following programs:

- Leak detection
- Water audits
- Development of water conservation plans
- Development and implementation of incentive programs, and
- Development and implementation of water conservation ordinances and regulations.

American Recovery and Reinvestment Act of 2009—Green Project Reserve

The American Recovery and Reinvestment Act of 2009 (ARRA) provided an additional \$2 billion in funding for the DWSRF programs to use to ensure safe drinking water and to finance green infrastructure investments at drinking water utilities. The ARRA requires that a minimum of 20 percent of the capitalization grant received by each state be applied towards “green” drinking water projects to address “green infrastructure, water and energy efficiency improvements, or other environmentally innovative activities.”

USEPA has specified that some types of green project reserve (GPR) projects are entirely and explicitly green and by their nature meet the goals of the GPR. These types of projects are defined as “categorical” green projects. Many traditional drinking water projects are not inherently “green,” but may incorporate green components. In order for non-categorical projects to qualify towards the GPR, a “business case” is required to support how the project meets the goals of the GPR. A business case quantifies the benefits of the project (energy savings) and cost savings.

Drinking Water SRF energy efficient projects qualifying as “categorical” include:

- On-site power generation using wind, solar, hydroelectric, geothermal, etc.
- Leak detection equipment
- VFDs on electric motors
- Energy audits

Drinking Water SRF energy efficiency projects that require a “business case” and justification include:

- Retrofit or replacement of pumps and motor with high efficiency models
- Total pump system optimization
- Replacement or rehabilitation of distribution lines
- SCADA systems
- Alternative treatment options (e.g., high-efficiency reverse osmosis)
- Other projects not listed under categorical

Funding for GPR projects for both drinking water and clean water was included in the FY-2010 appropriations bills.

Financial Incentives Provided by Electric and Gas Utilities

Some energy utilities supply rebates or other financial incentives for customers that purchase energy efficient technology or introduce energy efficient management practices. These incentives can include reduced energy rates, rebates for the purchase cost of equipment, assistance in energy audits, and monthly bill credits. Because not all energy utilities offer incentives and the programs that are offered vary, interested water utilities should contact their energy provider for details about available programs. Water utilities use large amounts of energy, so efficiency gains can help water systems save on energy costs. Utility programs to discount energy-efficient equipment can help reduce upfront costs of retrofits or replacements and augment the benefits of energy efficiency projects.

The following are examples of energy utility incentive programs from around the country.

- The southwest offers a number of examples of energy efficiency rebate programs offered by energy providers. Austin Energy, for example, provides rebates for energy efficient motors and variable frequency drives, among other products. The Texas-New Mexico Power Company offers incentives for the installation of many energy efficient products, and CPS Energy offers rebates on high-efficiency motors and innovative energy efficiency installations. In Nevada, the Sure Bet program provides incentives and rebates for equipment replacement and retrofit.
- In California, regulations require that utilities provide incentives for conservation and efficiency. San Diego Gas and Electric offers a number of flexible options for energy efficiency incentives, including bill credits and support for equipment retrofits. Southern California Edison organizes its incentive programs to correspond directly to the energy savings of a given project. Pacific Gas and Electric provides demand response, solar energy, and self-generation incentives as well as energy saving tips.

- Utilities across a number of states offer rebate programs for high-efficiency motors and pumps. In Iowa, Interstate Power and Light offers the Business Energy Efficiency Rebate Program that provides a customizable rebate tailored to a particular business. In Ohio, Dayton Power and Light offers the Business and Government Energy Efficiency Rebate Program with discounts on motors and pumps, and custom rebates for innovative energy efficient projects. Progress Energy offers a similar program in the Carolinas.
- In Massachusetts, the Cape Light Compact offers the Commercial, Industrial and Municipal Buildings Energy Efficiency Rebate Program, which provides rebates for variable frequency drives and other energy efficient equipment.

The U.S. Department of Energy hosts a Database of State Incentives for Renewables and Efficiency, which includes all federal, state, and utility-level programs to encourage energy efficiency. This can be found at <http://www.dsireusa.org>.

Energy Performance Contracting

Energy performance contracting (EPC) is an innovative financing technique that water utilities can use to install energy conservation measures without paying up front capital expenses. In EPC, the initial costs of installing energy efficiency measures are borne by the performance contractor and repaid through cost savings from the reduced energy consumption. EPC is often accompanied by guaranteed energy savings (e.g., that the savings will be sufficient to finance the project). Energy Service Companies (ESCOs) such as the New York Power Authority (<http://www.nypa.gov/about.html>) perform EPC and typically provide comprehensive services, including design and specification of new equipment, installation, energy audits, and long-term monitoring and verification of project savings. There are different types of contracts within EPC, but Guaranteed Savings Agreements are most commonly used for public sector projects.

In a performance contract, the ESCO will tailor energy conservation measures to the specific needs of the facility. Conservation measures provided through EPC can include:

- Water conservation measures, including replacement and upgrade of inefficient fixtures, installation and assessment of water meters to ensure the correct size and meter type are installed, and leak detection
- Lighting upgrades
- Building envelope improvements including insulation, roofs, and window upgrades
- Replacement of heating, cooling, and ventilation systems
- Development and implementation of energy management systems and controls
- Development of water and energy tracking systems
- Installation of renewable energy sources

NYSERDA Programs

NYSERDA is a public benefit corporation established in 1975 by the New York Legislature to identify solutions to the State's energy challenges in ways that benefit the State's economy and environment.

Water and wastewater treatment facilities in New York State consume more than 3 billion kWh of electricity per year. NYSERDA offers programs designed to assist municipalities in making sound energy decisions about process and equipment retrofits and upgrades. These programs include support for customized energy evaluations and studies, capital incentives for the installation of commercially-available energy-efficient equipment, support for developing and demonstrating innovative technologies and processes, the Focus on Water and Wastewater program, and incentives for grid-related PV and wind energy systems.

FlexTech Program. The Flexible Technical (FlexTech) Assistance program provides funding for customized facility evaluations to identify cost-effective energy efficiency measures. Evaluations are performed by pre-qualified engineering firms on a cost-shared basis. Based on the needs and complexity of the facility, technical assistance services provided through FlexTech can include:

- Feasibility studies
- Detailed analysis of specific energy efficiency projects
- Process improvement
- Rate analysis, load shapes, and energy service aggregation
- Development of long-term capital budget strategies for upgrading or energy-intensive replacing equipment
- Retro-commissioning of energy efficiency measures in existing buildings

Information on the FlexTech program is available through the following link: <http://www.nysesda.org/programs/flextech.asp>.

Existing Facilities Program. NYSERDA's Existing Facilities Program offers incentives to implement a variety of energy efficiency measures at existing facilities. Under this program, municipalities can choose their contractor or energy service company. Eligible energy efficiency projects include pre-qualified incentives for small-scale projects such as lighting, motors, VSDs, and HVAC projects, and performance-based incentives for large-scale efficiency projects. There are several categories of performance-based incentives, including electric, gas, process energy, and demand response incentives.

Information on the Existing Facilities Program is available through the following link: http://www.nysesda.org/Programs/Existing_Facilities/default.html.

Municipal Water and Wastewater Research, Development, and Demonstration Program. Offered on a bi-annual cycle, the Municipal Water and Wastewater Research, Development, and Demonstration program offers municipal water and wastewater utilities cost-shared funding to develop, demonstrate, and pilot test innovative energy efficient processes and technologies.

Priority areas have included:

- Helping municipalities address regulatory pressures to decrease nutrients in wastewater
- Developing innovative ways to disinfect water
- Optimizing performance to improve efficiency and increase wastewater treatment capacity

Electronic copies of final project reports can be accessed through the following link: <http://nysesda.org/programs/Environment/muniwwtReports.asp>.

Focus on Water and Wastewater. The Focus on Water and Wastewater program provides water and wastewater operators and elected officials with the knowledge and resources necessary to successfully identify and implement energy efficiency improvement projects. Various outreach materials have been developed including:

- *Best Practices Fact Sheets* describing energy-efficiency projects in a case study format
- *A Best Practices Handbook*
- *Energy Checklists* for identifying simple opportunities for energy reduction

Materials and resources developed through the Focus on Water and Wastewater program can be accessed through the following link: <http://water.nyserdera.org>.

Incentives for Grid-Related Photovoltaics and Wind Energy. NYSERDA also offers financial incentives to install on-site solar electric and wind systems. The *Solar Electric Incentive Program* offers incentives for the installation of new solar electric or photovoltaic systems through pre-qualified installers. Incentives are also available for new wind generation systems. The value of the incentives varies depending on the customer type and system size. Information on these incentives is available through the following link: <http://www.powernaturally.org/>.

Other State Funding Programs

There are several federal Web sites that detail the state-by-state incentives, rebates, and funding mechanisms available for energy efficiency improvements, including assessment and installation of renewable energy systems. DOE has two resources available to help locate funding for energy efficiency improvements and renewable energy:

- *Federal Energy Management Program (FEMP)* is a very useful and informative Web site and has information describing financing mechanisms.
- *Energy Efficiency and Renewable Energy (EERE)* contains information on a variety of energy efficiency measures and provides link to the Database of State Incentives for Renewable and Efficiency (DSIRE).

Wisconsin. The Focus on Energy (FOE) is a program for both residents and businesses that promotes the installation of energy efficiency and renewable energy projects. The mission of the program is to help manage rising energy costs, encourage “in-state” economic development, and reduce greenhouse gas emissions through controlling the state’s growing demand for electricity and natural gas. FOE provides a variety of resources and financial incentives to help residents and businesses implement the projects.

- *General Incentives* are available for purchasing and installing energy efficient lighting, motors, compressed air and HVAC equipment, along with custom projects for building upgrades or improving processes and programs for maintaining equipment. Incentives are also available for evaluating the feasibility of proposed energy efficiency projects.
- *Tax Incentives* through federal and state programs are available for installing energy efficient equipment, adopting renewable energy measures, and implementing overall energy efficiency improvements.

- *Renewable Energy Incentives and Grants* are available to assist with site evaluations and feasibility studies and installation of renewable energy systems for solar, wind, and biomass projects.

More information is available at: <http://www.focusonenergy.com/Default.aspx>.

California. The CEC has extensive information regarding resources on climate change, energy efficiency, renewable energy, and funding options. CEC helps local governments, schools, public colleges, and hospitals identify and implement energy efficient practices.

- *State Loan Program* for cities, special districts, schools, hospitals to help fund energy efficient lighting, HVAC, Energy Management Systems, pumps and motors, cogeneration systems, and renewable energy. There is a loan maximum of \$3 million with 3 percent fixed APR for 15 years.
- *Consumer Efficiency Rebates* programs are listed through the “Flex Your Power” Web site (<http://www.fypower.org/>). The Web site outlines the various rebates available to residential, commercial industrial, institutional, and agricultural customers.
- *Municipal Agreements* have been developed between local governments in partnerships. See <http://www.fypower.org/> for more details on the various existing agreements.

The California Solar Initiative (CSI) is governed by the California Public Utilities Commission (CPUC). The program was transferred from CEC to the CPUC in 2006. Incentives are provided through the state’s energy providers, Pacific Gas & Electric, Southern California Edison, and San Diego Gas & Electric. The program provides incentives for solar installations based on the expected performance for small systems and for larger systems (>30 kW) incentives are based on actual performance over the first five years. The CSI has a budget of \$2.167 billion for use between 2007 and 2016. More information can be found at: <http://www.gosolarcalifornia.ca.gov/csi/index.html>.

Texas. The State Energy Conservation Office (SECO) has a goal to reduce energy costs and maximize efficiency. SECO works with residents, businesses, educators, and local governments and offers a variety of funding, support, and education programs. Several of the programs are described below.

- *LoanSTAR* revolving loan program is available to fund energy-efficiency projects for state and government agencies, schools, and hospitals. Eligible projects include installation of lighting, HVAC, EMS, solar, wind, and geothermal heat pumps. The financial assistance program has saved taxpayers \$200 million.
- *Energy Efficiency* program to assist schools and local governments to set up and maintain energy-efficiency programs including conducting energy assessments, energy management training, workshops, and providing technical support.
- *Energy Management Services* is a program to reduce energy and utility expenditures in state-owned facilities through the construction of “state-of-the-art” energy and utility information systems, and implementation of energy procurement, along with other services.
- *Innovative Energy* program supports renewable energy and sustainable building practices by providing training and education to residents and communities, along with increasing awareness of financing options and available incentives.

More information is available at: <http://www.seco.cpa.state.tx.us/programs/>.

Partnerships

Best Practices

- Federal Government
- State Government
- University
- Energy and Water provider
- Trade Associations and Other Business Networks

There are many opportunities for water utilities to engage in partnerships to pursue energy efficiency. The partnerships take two forms: (1) public sector partnerships that provide information, technical expertise, and financial support, and (2) fee-supported industry partnerships and trade groups that provide a network of industry connections and knowledge for subscribers. Public sector partnerships provide a no-cost way for water utilities to learn about available management practices and efficient technologies, and to begin tracking and improving their energy efficiency. These partnerships can be created with the Federal and State governments and with the public university systems. Trade associations and business networks provide alternative partnership opportunities for water utilities that would like to gain exposure to other organizations. Both kinds of partnerships encourage the transfer of knowledge and energy efficient technology, and water supply utilities can use these partnerships to expand their understanding of energy efficiency and support their implementation of energy efficiency plans.

Through partnerships, drinking water utilities can learn about and implement energy efficient management practices and technologies at low cost. Utilities can share information about the most effective ways to increase energy efficiency, and experts can train a wide scope of water utility operators. These partnerships are described in more detail in the following sections.

Federal Government Partnerships

The Federal Government organizes partnerships with water utilities through the USEPA and DOE. These voluntary partnership programs provide training, technical information, and goal-setting for utilities in order to reduce energy use.

USEPA's ENERGY STAR[®], WaterSense, and Green Power programs all feature partnership opportunities for water utilities. The ENERGY STAR[®] program offers energy efficiency training and performance tracking, and encourages utilities to promote energy efficiency in their communities as well as in their operations. The Green Power Partnership encourages partners to purchase power from renewable sources and thus reduce their carbon footprint. The WaterSense Partnership promotes water efficiency, which has a direct impact on energy savings.

The ENERGY STAR[®] program, in particular has introduced a number of water and energy efficiency tools that can be used by drinking water utilities. By tracking water use alongside energy use, utility operators will better understand how the two resources relate to one another. Water utilities can participate in the ENERGY STAR[®] Challenge, USEPA's national call-to-action to improve the energy efficiency of America's buildings and facilities by 10 percent or more. Participants are encouraged to:

- Design commercial buildings to be energy efficient
- Measure and track water and energy use

- Develop a plan for energy improvements
- Make energy efficiency upgrades
- Help spread the energy efficiency word to others
- Become an ENERGY STAR® Partner

Water utilities can partner with the ENERGY STAR® for Buildings and Plants program. The partnership commitment includes measuring, tracking, and benchmarking the system's energy performance; developing and implementing a plan to improve the system's performance, including adopting the ENERGY STAR® strategy; and educating the utility staff and the public about the utility's partnership and achievements with ENERGY STAR®.

Water utility management can utilize USEPA's *Portfolio Manager*, an interactive energy manager tool that allows users to track and assess their water use in a secure online environment. *Portfolio Manager* can help systems in the following ways:

- *Manage energy consumption.* Utility operators can streamline energy, and track key consumption, performance, and cost information for all the system's buildings.
- *Rate building energy performance.* The Commercial Building Energy Consumption Survey is conducted every four years and compares participants to others in their peer groups.
- *Set investment priorities.* This valuable tool can help operators understand the relative costs associated with a given level of performance.
- *Verify and track progress of improvement projects.* *Portfolio Manager* can generate a Statement of Energy Performance for each building which summarizes important energy intensity, CO₂ emissions, and gross floor area.
- *Gain USEPA recognition.* Utilities can use *Portfolio Manager* to share their data and best practices with USEPA.

Target Finder is a related tool that works in conjunction with *Portfolio Manager* and helps users establish energy performance targets for design projects and major building renovations. Operators can also participate in ENERGY STAR®'s free online training via live Web conferences, animated presentations, pre-recorded trainings, and self-guided presentations.

The DOE administers the Industrial Technologies Program and Federal Utility Partnership Working Group. These programs encourage energy efficiency through management techniques and the adoption of new technology. The Industrial Technologies Program encourages utilities and other partners to increase energy efficiency by 25 percent over ten years and offers a Best Practices Training program for many different aspects of energy efficiency at locations around the country. The Federal Utility Partnership Working Group develops strategies to implement cost-effective energy efficiency and water conservation projects through utility incentive programs at federal sites.

The Federal Government can provide networks and contacts on a national scale for utilities interested in energy efficiency. The voluntary programs run by USEPA and DOE seek to achieve measurable results through incentives, training, and technology transfer. These partnerships can be a valuable and inexpensive way for utilities to become engaged in energy efficiency projects and learn about new products and strategies from energy experts.

State Government Partnerships

Some state governments provide energy efficiency partnership opportunities with water supply utilities. These partnerships provide utilities with expert knowledge on energy efficiency, new technologies, and management practices. Due to substantial energy use, state governments can achieve significant energy use reductions by concentrating on a small number of utilities.

All state governments are different, however, and not all states provide energy efficiency partnership programs. Benefits provided by the energy efficiency programs differ by state. Interested water utilities should seek out the appropriate state agency to determine if there are partnership opportunities available and the potential benefits of the program. Although there is variability in individual programs, many state partnership programs offer the following benefits:

- Facility surveys to identify energy efficiency opportunities
- Information about new energy-efficient technologies
- Effective management practices to reduce energy consumption
- Contractor identification to encourage the installation and use of available energy-efficient technologies
- Training from energy efficiency experts

University Partnerships

Many universities seek to increase energy efficiency on campus and in their surrounding communities, and a few partner with local water utilities to share knowledge and expertise. These partnerships provide universities the opportunity to apply research and ideas to working water utilities, and the utilities benefit through reduced energy costs. Although there are few well-documented partnerships of this kind, the following examples provide promise for collaboration between water suppliers and universities across the country.

- In California, many water utilities have joined Flex Your Power, a state-wide effort to promote energy efficiency. A few public universities in California are also involved in the effort, and the universities and water suppliers are able to join together to increase energy efficiency.
- The Massachusetts Energy Efficiency Partnership is a collaborative effort between the University of Massachusetts and Massachusetts electric utilities. The partnership encourages energy efficiency in commercial and industrial applications through knowledge and technology transfer.
- Washington State University offers an Industrial Services program that provides training, assessments, and support for energy efficiency for little or no cost to companies in the Pacific Northwest. The program applies knowledge and technology from a university setting to working industrial sites, benefiting the university through experience and greater research opportunities and industry through energy savings.

There is significant opportunity for growth in partnerships between water utilities and universities, and the programs above can provide a model for future partnerships.

Energy and Water Provider Partnerships

Substantial water and energy savings are possible from water conservation (Nelson et al. 2007). Based on the connection between water and energy, an increasing number of water and energy utilities are forming partnerships to minimize their customer's water and energy consumption and ultimately implement measures to reduce greenhouse gas emissions. Partnerships provide benefits to both utilities as electric utilities looking for ways to reduce operating costs and greenhouse gas emissions and water utilities looking for ways to reduce overall operating costs and improve efficiency. Additionally, through a partnership, the utilities can combine resources and share the costs of funding and marketing the programs. Partnership work as many of the customers are common between utilities and information can easily be shared. Challenges include record keeping, processing rebates, identifying responsibilities, and disagreement on methodology (Dickson 2009).

Several of the water and energy partnerships established across the United States are described below.

- California Public Utilities Commission has numerous references regarding measures for achieving energy savings from water conservation and efficiency. References are available at: <http://docs.cpuc.ca.gov/energy/electric/energy+efficiency/waterenergyworkshopsa0701024.htm>.
 - Pacific Gas & Electric has formed multiple partnerships with water utilities and communities in efforts to reduce energy costs and conserve water.
 - Southern California Edison has implemented several “Water-Energy” pilot programs through partnerships. These programs include low-income direct install of high-efficiency toilets, industrial water efficiency programs, “Express” water efficiency programs, water conservation programs, and “Green Schools/Green Campus” programs.
- In the state of Washington, Puget Sound Energy has partnered with various water providers to provide rebates and programs for commercial kitchen pre-rinse spray valves and commercial clothes washers among other equipment.

In the state of Colorado, Xcel Energy and Denver Water formed a partnership with NAIOP (the Commercial Real Estate Association) to improve energy and water efficiency of the office buildings, warehouses, and other commercial real estate. Denver Water customers use more than 225,000 acre-feet of water each year; 20 percent consumed by commercial users. Both Xcel Energy and Denver Water offer a diversity of rebate programs to assist business with efficiency improvements.

Trade Associations and Other Business Networks

Water utilities can take advantage of industry knowledge about energy efficiency by joining trade associations and other business networks that encourage the sharing of knowledge and experience among members. While these associations often charge a subscription fee, they provide an opportunity for businesses to learn about energy efficient technologies and practices, and arrive at low-cost options for greater energy savings. Trade associations can provide links across many

aspects of energy efficiency, including energy utilities, equipment manufacturers, installation specialists, and water utility operators.

Each trade association pursues a distinct agenda and provides different benefits. Some encourage discussion between managers about effective energy-saving techniques, while others concentrate on connecting equipment manufacturers with interested utility operators. After joining an energy efficiency trade association, water utilities can expect to broaden their contacts and can gain from the knowledge and experience of others.

Some trade associations, such as the Consortium for Energy Efficiency and the U.S. Green Building Council, have a national scope, while others have a smaller scope. There are regional associations, such as the Midwest Energy Efficiency Alliance, and state-level organizations, such as the Massachusetts Energy Efficiency Partnership. The National Association of Local Government Environmental Professionals provides an opportunity for water utilities to connect with local government officials, from town employees to big-city administrators, and implement successful environmental programs. Water utilities can expect different contacts from local partnerships versus national programs, but both kinds of organizations provide an opportunity for water utility operators to learn about energy efficiency.

CHAPTER 4 CASE STUDIES

OVERVIEW

Fifteen utilities agreed to participate in this project to provide case study examples of real-world energy efficiency practices. These case studies were selected to represent geographical diversity as well as a range of utility sizes and practices. A full spectrum of efficiency practices was identified and utilities were selected to provide information across the range of practices. The case studies were designed to:

- Provide a background on the water system and a history of the energy issues
- Identify the type and size of the best practice, process, or technology being evaluated
- Discuss the changes implemented and the results
- Document any particular staff expertise or IT needs specific to implementing the practice, process, or technology
- Document the lessons learned
- Provide a conclusion
- Provide a list of resources
- Identify utility contact information

In addition, a Case Study Information Table template was completed for each case study to allow consistent information to be collected and shared with the UKWIR coordinator for inclusion in the international best practices compendium. A brief one-page summary of the case study overview and findings was also prepared for use in the international compendium. A copy of the each of the final case study templates is found in Appendix A.

CASE STUDIES

[Table 4.1](#) lists the various best practices identified in each case study and groups those by each major category of energy efficiency practice and across the categories of management practice, raw water, treatment, and distribution.

American Water, NJ

Management Tools	Plant Improvements and Management Changes	Water Treatment	Water Distribution	Water Conservation	Alternative/Renewable Energy Sources	Financial Assistance	Partnerships
	✓		✓	✓	✓		✓

Table 4.1
Case study energy efficiency best practices

Energy efficiency practice		Management practice	Raw water	Treatment	Distribution	
Management Tools	EWQMS	LVVWD				
	Energy Management Plans/Systems	AAWTS CWW CRWD				
	Monitoring Industrial Water Use				CRWD	
	Staff Training	CWD				
	Plant Improvements and Management Changes	Lighting	AW			
		Fleet Management	AW AWU1			
HVAC		AAWTS LVVWD				
Rate Structures		CWD MCWA QWD SCWA CWW				
SCADA		CRWD CWW LVVWD SCWA VW				
Long Range Planning		CRWD				
Water Treatment		Ozonation			AAWTS	
	Desalination			WBMWD		
Water Distribution	Hydraulic Modeling				MV/GVWD	
	Pump Optimization				AW AWU CWD LVVWD MV/GVWD MCWA QWD	
	Motors/VFDs				AAWTS CRWD MCWA	
	Gravity Feed		AWU1 MV/GVWD	AWU1		

(continued)

Table 4.1 (Continued)

Energy efficiency practice		Management practice	Raw water	Treatment	Distribution
Water Conservation	Alternative Supply	WBMWD			
	Reducing Leaks				AW LVVWD
	Incentives and Rebates	WBMWD			AWU2
	Conservation Programs	WBMWD			AWU2
Alternative/ Renewable Energy Sources	Solar	AWU1 AW WBMWD		NJAW	LVVWD
	Wind	AW	CWD		
	Hydroturbines				MVWA
	On-Site Generation	CWW			
	Recycled Water	WBMWD			
Financial Assistance	State Agencies	MCWA MVWA NJAW QWD			
	Energy Providers	AWU1 CRWD CWW MCWA MV/GVWD SCWA WBMWD			
Partnerships	National	AW			
	Regional	AWU2 QWD			
	Energy Providers	CRWD CWW MCWA MV/GVWD WBMWD			

AW = American Water

AAWTS=Ann Arbor Water Treatment Services

AWU1 = Austin Water Utility

AWU2 = Austin Water Utility

CRWD = Cedar Rapids Water Department

CWD = Cleveland Water Division

CWW = Columbus (GA) Water Works

LVVWD=Las Vegas Valley Water District

MV/GVWD=Metro Vancouver/Greater Vancouver Water District

MVWA=Mohawk Valley Water Authority

MCWA = Monroe County Water Authority

NJAW = New Jersey American Water

QWD = Queensbury Water District

SCWA = Suffolk County Water Authority

VW=Village of Waterloo

WBMWD=West Basin Municipal Water District

Background on the Water System and History of the “Issue”

American Water was founded in 1886 and owns or operates over 870 water treatment facilities and 270 wastewater facilities in 32 states and Canada. It is the largest investor-owned (private) water and wastewater provider in North America.

With 85 to 99 percent of water treatment plant electric consumption incurred by pumping (raw water and well pumps, high service pumps, filter backwash pumps, and booster pumps), American Water realized it could reduce electric consumption at its facilities through improved system and pump efficiency, and reduction in non-revenue water (NRW)—water “lost” before reaching the customer.

In addition, as electric costs continue to increase and concerns are growing over the environmental impact of electricity and other fuels with regard to global climate change, American Water has taken an opportunity to “do its part” in reducing its environmental impact. The primary driver in improving energy efficiency, reducing water loss, and reducing environmental impact is that climate changes will have a direct impact on future water quantity and quality and poses a threat to the efficient stewardship of water as an essential resource.

Type and Size of the Process or Technology Evaluated

American Water’s GHG emissions come from purchased electricity (mainly for pumping), fuel for fleet vehicles, fuels for engine-driven pumps and generators, and minimal emissions from HVAC and process emissions. Approximately 92.3 percent of GHGe are indirect through electrical use, 3.5 percent is from vehicle use, and the remainder is from other sources (see [Table 4.2](#)).

To promote energy efficiency and reduce the environmental impact through reduced GHGe, American Water has established a strong Environmental Policy, and joined the USEPA Climate Leaders program in January 2006. The Climate Leaders program was created in 2002 and is an industry-government partnership to develop long-term, comprehensive corporate climate change strategies. Through participation in the program, American Water pledges to reduce and inventory its corporate-wide GHGe.

The benefits to voluntary monitoring and reducing GHGe include:

- Enhanced “green” image/reputation;
- Decreased expenses by changes in capital expenditure (CapEx) investment and operational enhancements;
- Prepared for eventual regulations;
- Management of risks associated with global warming; and
- Improved operational investment.

American Water’s Environmental Policy is important to the company as it contributes to and relies on the quality of the physical environment, thus making environmental management fundamental to the business. Each operating unit (subsidiary) of the company carries out its operations in a manner that limits the impact on the environment. The Environmental Policy requires the following:

- Compliance with all relevant environmental laws, regulations, and standards.
- Sustaining the environment through responsible business practices that promote environmental stewardship with a holistic approach to the prevention of pollution.

Table 4.2
Energy use and GHG emissions for 2008

2008 GHGe inventory emissions source	Emissions tCO ₂ e*	Emissions (%)
Direct emissions		
Stationary combustion [†]	34,198	4.0
Mobile sources [‡]	30,294	3.5
Process/fugitive [§]	59	0.0
Refrigerant**	1,334	0.2
Subtotal	65,885	7.7
Indirect emissions		
Electricity	791,080	
Subtotal	791,080	92.3
Total	856,965	100.0
Required supplemental information		
Total stationary–biomass CO ₂	324	

Source: American Water.

*tCO₂e = metric tons of equivalent amount of carbon dioxide

†Natural gas, diesel, and fuel oil

‡Fleet

§Biogas leakage from wastewater treatment plant anaerobic digesters

**Leakage of air conditioning refrigerants

- Ensuring effective and efficient use of natural resources (water, energy, and land), including electricity. Use of energy can contribute to climate change which could impact the availability and quality of water resources. The policy also emphasizes minimizing the impact of capital investments on resource consumption.
- Implementation of an Environmental Management Plan.

Change(s) Implemented and Results

USEPA's Climate Leaders Program. American Water was the first water utility to join the USEPA Climate Leaders program. By joining, American Water showed its commitment to pursuing and implementing sustainable practices. The partners in the program commit to significantly reducing their impact on the global environment by setting and achieving a long-term GHG reduction goal. These Climate Leaders set the standard in GHG management. Through the program, the partners commit to the following:

- Setting corporate-wide GHGe reduction goals, to be achieved in 5–10 years;
- Developing a corporate-wide inventory of the six major GHGs;
- Developing a corporate GHG Inventory Management Plan (IMP); and
- Reporting inventory data annually and documenting progress toward the reduction goal.

American Water has now completed the first three phases of the program: created an IMP, developed a corporate-wide GHGe inventory, and set a GHGe reduction goal. On December 2, 2009, the USEPA announced American Water's Climate Leaders Partners Goal at the annual Climate Leaders Partner meeting. American Water set a goal of reducing its GHGe intensity by 16 percent by 2017.

The IMP is a stand-alone document that provides a step-by-step description of how American Water conducts its high-quality, corporate-wide inventory of its GHGe. The IMP includes seven major sections:

- *Partner Information*: company name, address, and inventory contact information;
- *Boundary Conditions*: organizational and operational boundary descriptions;
- *Emissions Quantification*: quantification methodologies and emission factors;
- *Data Management*: data sources, collection process, and quality assurance;
- *Base Year*: base year adjustments for structural and methodology changes;
- *Management Tools*: roles and responsibilities, training, and file maintenance; and
- *Auditing and Verification*: auditing, management review, and corrective action.

American Water utilizes three primary databases to capture its energy, water, and fuel consumption data. Monthly electricity, natural gas, and stationary fuels data is stored in an Itron database managed by American Water's Energy Manager staffperson. Monthly water production data is stored in an Operating Parameters Database, and mobile fuel purchases are stored in a database maintained by Automotive Resources International.

Energy Efficiency Strategies Associated With Environmental Policy. American Water has evaluated and implemented various strategies to increase energy efficiency and "green" opportunities at its water treatment facilities. The focus has been on reducing NRW, performing energy audits to identify the highest electric-consuming facilities, identifying best locations for operational enhancements, and incorporation of "green" power. The primary operational enhancement was found to be improving pumping efficiency. Based on American Water and industry averages, the water industry can improve its GHGe intensity by as much as 20 percent by improving average pump wire-to-water efficiency.

- *Reducing NRW*—through reducing water loss (real and apparent losses) within the facilities (i.e., leak detection), American Water can reduce its electrical consumption through decreased pumping. American Water is not unlike most water utilities in the country in having a significant need to replace aging infrastructure. In recent years, two efforts have been used to address NRW: a significant increase in main replacement rate and an increased effort in leak detection and repair. Those efforts have stopped the increase in the NRW rate, but have not decreased it. Analyses to date indicate that leakage-related NRW will not decrease significantly until the average distribution system pipe age goes below 75 years.
- *Pump Optimization*—through performance of energy audits and evaluating pump efficiency, American Water realized there was a significant opportunity to improve energy efficiency by improving pumping operations. The recommended pumping efficiency improvements include optimizing efficiency through trimming or replacing impellers and bowls, sand blasting and recoating pump wetted parts, installing VFDs or soft starters, and installing new high efficiency pumps and motors. To ensure that

pump efficiency is maintained, American Water performs routine pump efficiency, vibration, noise, and thermal tests to identify early signs of degradation of pump and motor efficiency.

American Water developed a *Pump Efficiency Testing Plan* that includes testing wire-to-water efficiency and power factor, determining desired and required future pump operating ranges, determining/designing the recommended improvements, programming CapEx to make improvements that meet Asset Investment Strategies, and recording and monitoring results. As part of verifying the *Pump Efficiency Testing Plan*, American Water first defined the scope of work and then determined the test locations. American Water used its Itron energy management database and determined that its largest 48 facilities were responsible for 50 percent of American Water's total annual electricity use. Pump testing is currently underway at these facilities and is expected to be completed by December of 2010. These results will be used by corporate engineering planning and design staff to identify those pump improvements that will yield the highest energy/carbon savings. The improvements will be designed and constructed over a six-year period. The pump performance and energy use will be monitored annually to quantify the net energy and carbon savings resulting from the pumping improvements.

- *Operational Enhancements:*
 - *Energy efficient lighting*—even though lighting contributes less than 0.5 percent of American Water's electric use, it still provides an excellent opportunity to reduce electric consumption. American Water took advantage of free lighting audits at two plants and will replace T-12 fixtures with T-8 fluorescent fixtures in 2010. The return on investment for these two projects ranged from 57 percent to over 80 percent with a payback of less than 2 years. Energy use at these facilities will be monitored and evaluated for six months following the installation of the new fixtures. If successful, American Water plans to roll the program out across all its systems.
 - *Fleet management*—upgrading fleet vehicles is an important way to reduce fuel consumption and reduce the environmental impact of GHGe. American Water has replaced 27 of its 3,653 fleet vehicles (0.7 percent) with hybrid vehicles. They have not purchased more due to the price premium added to each vehicle and the lack of available truck “hybrids” (60 percent of the fleet are trucks). In addition, American Water has established a “no-idle” policy and is evaluating the potential of incorporating the Ford Eco-Boost cars and trucks into the fleet (beginning in 2010). The Eco-Boost engine is projected to boost fuel economy by 20 percent, decrease GHGe by 15 percent, and costs up to \$2,000 additional per vehicle, as compared to \$5,000 for “hybrids.” While these hybrid vehicles have reduced the energy and carbon intensity over the vehicles they replaced, replacing 0.7 percent of the fleet with hybrid vehicles has not resulted in a measureable decrease in annual fleet fuel purchases.
- *Green power generation*—there is significant potential in reducing electric consumption and GHGe through installing “green” power (i.e., solar, wind, biomethane) or purchasing “green” power. American Water has already installed solar power generating facilities at two of its water treatment plants; a 698 kilowatt (kW) system at New Jersey American's Canal Road plant and a 100 kW system at New Jersey American's

Raritan-Millstone plant. Together, these two solar PV installations produced over 818,000 kWh of electricity in 2008 and saved 425 tCO₂e. With tax incentives available, installation of renewable sources is a viable option for the company.

- *Green power purchase*—American Water purchases green power (wind energy) at its Yardley, PA facility. In 2008, American Water purchased approximately 1.4 million kWh of wind power. In the Climate Leaders GHGe protocol, truly green power has a GHGe factor of zero. Thus, this green power purchase decreases American Water’s annual GHGe.

Special Staff or IT Needs or Other Considerations

Corporate officers and senior management must be the drivers behind establishing environmental goals to reduce GHGe and promote “green” as being good for business. To properly manage, track, and inventory GHGe, a utility must invest in appropriate databases and management of the databases that may entail hiring outside experts. Additionally, all staff must be dedicated to implementing the environmental policies and reducing the utility’s environmental impact.

Lessons Learned

It is important to provide services in a manner that prevents pollution, enhances the environment, and promotes sustainability. There is a corporate and social responsibility for reducing the impact on the environment since climate change poses a threat to the efficient stewardship of water as an essential resource. There are multiple issues impacting the water industry that can result in variations of GHG intensity and must be considered when establishing goals for reducing GHGe. These include:

- Changing water quality standards that may require changes or additions to water treatment by adding additional processes such as UV, ozone, or membranes. These additional treatment methods require an increase in electric consumption.
- Changes or variations in water source and/or purchased water, including variations in usage.
- Increases in volume to wastewater treatment because, on average, wastewater treatment is approximately 10 percent higher in energy intensity than water treatment.
- Impacts of pressure management on the distribution system since increased pressure increases energy intensity and energy requirements.

Conclusion

Optimizing energy use is a way to save money, promote corporate responsibility (environmental stewardship), reduce the utility’s impact on environment, and improve sustainability (prepare for future generations). There are multiple solutions to reduce GHGe such as reducing pumping through reducing NRW and promoting water conservation, pressure management, pump efficiency/system efficiency improvements, improved fleet management, upgrading lighting and HVAC, and energy audits. Water utilities contribute to GHGe and they are also recipients of

the effects of climate change (water resources and water supply variations). By joining USEPA's Climate Leaders program, American Water can integrate climate change strategies based on state, regional, and international GHG accounting schemes.

Ann Arbor Water Treatment Services, MI

Management Tools	Plant Improvements and Management Changes	Water Treatment	Water Distribution	Water Conservation	Alternative/Renewable Energy Sources	Financial Assistance	Partnerships
✓	✓	✓	✓				

Background on the Water System and History of the “Issue”

The Ann Arbor Water Treatment Services (AAWTS) obtains surface water from the Huron River and treats it at two water filtration treatment facilities. AAWTS operates four dams on the Huron River—two without hydroelectric power generating facilities (Argo and Geddes Dams) and two with hydroelectric power generating facilities (Superior and Barton Dams). The first water filtration treatment facility was constructed between 1938 and 1949 and has a 22 MGD capacity. The second water filtration treatment facility was constructed between 1966 and 1975 and has a capacity of 28 MGD. Both facilities are considered conventional filtration treatment with rapid mixing, flocculation, sedimentation, and filtration in addition to disinfection treatment. Each plant has two stages, primary and secondary. The water is softened in the primary stage and the water is recarbonated (pH adjustment) in the secondary stage.

The AAWTS also operates and manages the City's water distribution system, which is comprised of five pressure districts within the City. The City has a main reservoir supplying the core of the City's finished water storage. Three reservoirs, four pump stations, and two elevated tanks are located in the outer pressure districts. The water distribution system is comprised of over 439 miles of water pipe. The City operates 60 facilities from the source water collection and treatment locations to all sites within the water distribution system. In 2005, The City spent \$4.5 million on energy—about 1.6 percent of a \$288 million annual budget.

Energy use and the cost of purchasing energy has long been a concern of the City of Ann Arbor but to install cost-saving measures and construct energy-efficient facilities, initial capital investment funds are needed. Utility and Public Works budgets typically do not have a large cash reserve from which to draw to fund these kinds of projects.

In 1981, Ann Arbor first began to promote energy conservation in all City buildings. By 1988, the City's municipal bonding authority provided a \$1.4 million energy bond to implement efficiency measures at thirty different City facilities. The payments for this ten-year bond have been generated through energy cost savings. In 1998, the final payment on the Energy Bond was made. Energy Bond payments of over \$200,000/year had been included in the annual City budget for each of the previous ten years. Instead of discontinuing the budget item, it was reduced by 50 percent to \$100,000 for the next five years and used to establish a Municipal Energy Fund. The Energy Fund is self-financed by taking funds saved through energy efficiency measures and reinvesting the funds into new energy saving projects. The City requires facilities using the Energy

Fund to pay back 80 percent of the funded project's estimated energy savings for five years commencing with the first year the facility/energy saving measure is in operation. The Energy Fund is administered by the City's Energy Office under the supervision of a three-person board. The Board approves funding, implements projects, and often serves as a project manager. The Energy Office provides the Board with information from energy audits. The Board also receives applications for Energy Fund money from the City's facility managers. The Board has the responsibility to review all applications and make final decisions on what projects to fund each year. Funding decisions are based on the project's potential to save energy, its educational value, and the planned facility.

Type and Size of the Processes and Technologies Evaluated

The City of Ann Arbor takes pride in being on the leading edge of energy efficiency in terms of creative projects and project funding. All City branches have embraced the concept of energy efficiency, including the AAWTS. City managers, treatment plant supervisors, plant operators, and distribution system operators all contribute to a collective resource pool of ideas that lead to innovative projects and improvements. Several of these innovative ideas are captured in the four projects described below.

Ozonation Optimization. AAWTS operates an ozone disinfection system as a primary disinfection treatment process. The high energy costs of producing ozone led AAWTS to investigate whether manipulating the water conditions would result in water that is easier to treat with ozone and thereby uses less energy for the ozonation process. Prior to any full-scale construction, AAWTS conducted a pilot study to see if changing the water chemistry could result in lowering the energy demand for operating the ozone system. The pilot study results showed that depressing the pH of the water with carbon dioxide before ozone application and then raising the pH with caustic soda after ozone treatment improved the efficiency of the ozonation process and reduced its energy needs.

Demand Management System. AAWTS has set up an operations system that allows operators to view real-time power usage (kWh) at any treatment or pumping facility. The system is treated like a working operations guide for the operator who must stay inside of pre-determined energy setpoints unique to each treatment facility and pumping station. At any given time, operators are able to schedule and time the sequencing of certain process operations to best accommodate the lowest energy rates that the utility can purchase.

High Efficiency Motor Replacement. Over the last few years, AAWTS has replaced motors and pumps at the water treatment plant for several processes (backwash water, plant pumping, etc.). AAWTS has plans to also upgrade pumps and pump stations in the distribution system with high efficiency pumps and motors. In general, replacing single speed motors is an efficient way to reduce electrical demands (and thereby reducing electrical costs). Single speed motors are generally set to operate in the higher ranges. But as the demand for the pumping capacity decreases, the single speed motor does not perform as efficiently as it would in the high range. Variable speed or variable frequency motors allow the motor to run efficiently at a lower speed.

Computerized Air Handling System. Heating and cooling large air spaces can be a very expensive, inefficient operation. AAWTS recognized that this large on-going expense could be lowered if the system was centrally controlled. AAWTS' heating systems are powered by natural gas which has a volatile price history.

Change(s) Implemented and Results

The projects described below have effectively reduced energy consumption and energy costs at AAWTS. The resulting benefits are monitored and analyzed against operational and training costs as well as other direct and indirect costs. Quantifying the results is critical to fully understand the success (or lack of success) of these efforts.

Ozonation Optimization. Operating the ozonation disinfection system under the depressed water pH conditions has reduced the ozone generation energy costs. It is difficult for AAWTS to quantify the savings since the ozone process has only been operated with the depressed pH process since the pilot study was done prior to the completion of the ozone plant. The energy savings costs from less ozone generation must be balanced against the added costs of the chemicals used to depress and then raise again the pH, as well as the chemical pumping costs.

Demand Management System (DMS). DMS allowed AAWTS to switch to off-peak hour pumping for the distribution booster pump stations and the backwash water pumps at the water filtration treatment plants. The off-peak hour pumping at the booster pump stations allows AAWTS to buy power at a lower rate by avoiding on-peak surcharges. The DMS is not able to reduce AAWTS's overall energy consumption from its power company; however. The advantage of the DMS is to shift energy purchases to alternate off-demand times and thereby save the amount of ratepayer money spent on energy. To fully understand the large picture of what impact demand management has on energy efficiency, one would need to expand the scope to include the power company and its savings in energy production to meet lesser peak energy demand because customers like AAWTS are shaving their peak energy demands. In general, AAWTS estimates that it is able to shift enough on-peak energy demands to off-peak times to realize a 15 to 20 percent savings on its monthly energy bill.

Use of Variable Frequency Drives. In most cases, variable frequency drive (VFD) motors replaced older motors. In other cases, multiple smaller-capacity pumps and motors were used where once one large pump and motor was used. The capital investment for VFDs and multiple pumps and motors can be larger than single speed motors, but AAWTS estimates the payback time on the investment to be about 5 years which is significantly less than the useful life of the pump and motor.

Computerized Air Handling System. AAWTS installed a computer system to control the operation of the heating, ventilation, and air conditioning system. The utility selected a Windows-software package from Siemens at a capital cost of \$18,000 based on an upgrade to a previous DOS-based system already in place.

Special Staff or IT Needs or Other Considerations

Since the ozonation plant was built after the decision was made to adjust the water chemistry to save energy, AAWTS had never operated the treatment facility differently. Therefore, the operators have always been trained to depress and then elevate the pH accordingly. No special provision has been needed for staff training.

The Demand Management System requires an interface with the water treatment plant and distribution system pumping SCADA system which is part of the proprietary software package. No other special provisions were necessary.

Replacing old pumps and motors with high efficiency equipment is part of AAWTS' "energy master plan." All levels of the organization contribute to the compilation of the plan.

The computer software used for operating the air handling system is a proprietary product from Siemens. Siemens was selected due to that company’s purchase of a smaller company that had placed a DOS-based but far less robust system in place earlier. The Siemens system amounted to a large upgrade of the previous system.

Lessons Learned

- Improving energy efficiency is a constantly evolving process. Although the utility believes the conditions leading to the decision to optimize the ozone disinfection system are relatively unchanged in the last 15 years, AAWTS is conducting a new pilot study in 2009 to confirm results of the original study. For instance, AAWTS is interested in exploring how much impact a higher price for bulk caustic soda has on the optimization formula and whether or not any changes need to be made to the feed concentrations and how often these changes should be made. AAWTS believes the pilot study is essential prior to making any full-scale changes in its process.
- The keys to making the Demand Management System work are the quality of the operators driving the process and allocation of sufficient resources for operator training and development of standard operating procedures. AAWTS spends a considerable amount of time training operators to understand and use the system and to anticipate needed operational changes. Operator and management input continues to be important in developing the on-going operating procedures.
- AAWTS has seen multiple benefits from replacing inefficient pump motors. Besides the immediate benefit of energy cost savings, the improved management of pumps and motors can result in a longer useful asset life.
- A big component of AAWTS’s efforts to reduce heating and energy costs is insulating the utility from fluctuations in natural gas prices. These prices can be volatile and vary with demand, seasonally, and due to several domestic and international economic indicators with little warning to customers like water utilities.

Conclusion

Like many utilities today, AAWTS is in the early stages of realizing just how to conserve energy and lower energy costs. As the utility continues to implement energy savings strategies, it will continue to develop metrics to document the savings achieved. Currently, AAWTS is focusing attention on attainable goals to lessen the cost for purchasing power.

Austin Water Utility (1), TX

Management Tools	Plant Improvements and Management Changes	Water Treatment	Water Distribution	Water Conservation	Alternative/Renewable Energy Sources	Financial Assistance	Partnerships
	✓	✓			✓	✓	

Background on the Water System and History of the “Issue”

The city-owned Austin Water Utility (AWU) provides water and wastewater services to a service area of 538 square miles. Raw surface water from the Colorado River is treated using a traditional lime softening treatment process and disinfection. AWU operates two water treatment plants with a combined 285 million gallons per day (MGD) maximum capacity serving 200,000 connections and two wastewater treatment plants with a 135 MGD combined capacity serving 187,000 connections. The water system includes over 3,500 miles of mains, 45 booster pumping stations, and 167 million gallons of finished water storage capacity. A new water treatment plant, WTP4, is currently being designed and is projected to be in operation in 2014.

AWU customers currently use an average of 50 billion gallons of water and generate an average of 33 billion gallons of wastewater per year. The peak summer demand is approximately 220 MGD, and the average winter demand is approximately 100 MGD. In 2008, the utility consumed a total of 210 million kWh in electricity for all its activities; 1.6 percent of Austin Energy’s total deliveries. AWU’s energy consumption is directly related to the climate. For wet and cool years, fewer gallons of water are consumed as compared to hot and dry years. With less demand, less energy is required to treat and distribute drinking water. However, the past two years 2007–2008 and 2008–2009, the climate has been hot and dry and AWU’s energy consumption has increased.

The City of Austin adopted the *Austin Climate Protection Plan (ACPP)* in 2007 that directed the city’s departments and publicly-owned utilities to begin taking action on reducing GHG emissions, with an ambitious set of goals for the year 2020:

- Save 700 megawatts (MW) of electricity;
- Produce 30 percent of energy needs with renewable energy; and
- Have all municipal activities be carbon-neutral (no net GHGe).

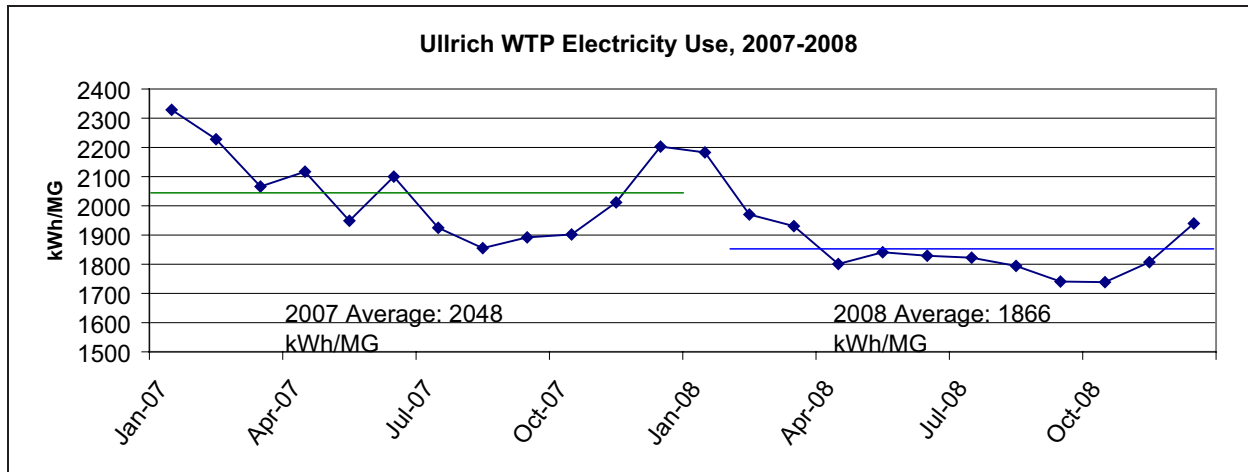
Type and Size of the Process or Technology Evaluated

To meet the goals of the *ACPP*, AWU is expanding its water conservation, energy efficiency, and renewable energy programs. The efforts at AWU will be an important factor since water and wastewater treatment and conveyance are energy intensive processes and the water and wastewater utilities are both directly and indirectly responsible for generating significant amounts of GHGe. As a start to reaching the energy reduction goals outlined in the *ACPP*, AWU is utilizing the expertise of AWU’s workforce to identify process and operational improvements that can be carried out within existing budgets.

AWU conducted an inventory of GHGe in 2007 as an initial step to identify processes at its facilities that had the potential to reduce energy consumption. One of the most direct ways to reduce energy consumption associated with AWU operations is through water conservation. Therefore, AWU is utilizing its well-developed water conservation program in addition to incorporating operational improvements to meet the goals set in the *ACPP*.

Change(s) Implemented and Results

The initial energy efficiency improvements incorporated by AWU include operational changes at the Ullrich Water Treatment Plant, blower repairs at the South Austin Regional Wastewater Treatment Plant (WWTP), seasonal process changes at the Walnut Creek WWTP, fleet



Source: Austin Water Utility.

Figure 4.1 Electricity consumed plant-wide per million gallons of water treated

management, and on-site energy generation. Through these combined energy efficiency strategies (water and wastewater), AWU realized an estimated 4.5 percent reduction (\$700,000 savings) in energy use and GHGe from 2007 through 2008. In addition, AWU has incorporated energy efficient design into a proposed new water treatment plant (WTP4). The specific energy efficiency improvements presented in this section focus on AWU’s drinking water facilities, fleet management, and on-site energy generation.

Optimizing Pumping at the Ullrich Water Treatment Plant. In 2007, AWU staff noticed elevated energy use in its raw water pumping despite a recent pump upgrade. After reviewing the issue with operations staff, it was determined that operators had been trying to avoid switching pumps in an effort to save the energy spikes associated with pump starts and stops. Instead, staff was ‘throttling’ pumps to achieve the desired flow rate. While throttling does avoid a pump change, it is also an inefficient mode in which to run a pump. When pumps were left throttled for extended periods, the benefits of avoiding a pump switch were ultimately offset by the inefficient operation. In order to improve energy efficiency, the new procedure includes optimizing the switching of pumps and minimizing the use of “throttling” as a flow control mechanism. For 2008, the change in pumping operation reduced energy use by 5,000 megawatt hours per year (MWh/yr); an 8 percent reduction in energy consumption. Greenhouse gas emissions were reduced by 2,500 metric tons carbon dioxide equivalent per year (tCO₂e/yr). The reduction in energy consumption correlates to a savings of \$400,000 in annual energy costs with minimal capital investment. [Figure 4.1](#) shows the electricity consumed (kWh) plant-wide (including treatment, raw, and finished water pumps) per million gallons treated.

Water Treatment Plant 4. AWU has begun incorporating energy life-cycle costs into the design and decision-making of relevant capital improvement projects (CIP). This is evident in the design phase of the WTP4. AWU relies on impoundments along the Colorado River (of Texas) for its water supply: the current two treatment plants draw water from the river’s Lake Austin; up until the recent past it also drew from Town Lake, downstream of Lake Austin. The new treatment plant will draw water from Lake Travis, upstream of—and higher than—Lake Austin. AWU is capitalizing on the higher source elevation with additional design elements to reduce overall pumping

energy requirements: the new treatment plant's elevation and location will allow gravity flow from its clearwells to further reduce the combined raw and finished water pumping energy requirements, and the new 84-inch transmission mains greatly reduce headloss. AWU estimates that the Lake Travis water source, new transmission mains, and new treatment plant location will reduce by over 50 percent the energy needed to supply water to a part of the city that is growing and currently uses almost 25 percent of the AWU system pumpage requirements. Accordingly, system-wide energy use and GHG emissions will be approximately 13 percent lower than if the same amount of water were delivered from the existing system (Lake Austin water source). The projections estimate a savings of 20,000 MWh of electricity and 10,000 tCO₂e/yr. In addition, AWU is incorporating Leadership in Energy and Environmental Design (LEED) design elements into the plant buildings.

Fleet and Equipment Fuel Use. AWU has approximately 250 vehicles that average 5.4 mpg. The existing diesel fleet is currently operating on B20, a blend of 20 percent diesel. AWU incorporated modifications to the fleet vehicles and equipment fuel use into its climate protection strategies. These modifications include:

- Replacing traditional vehicles, when possible, with hybrid and/or biofuel-capable vehicles. This change could result in a reduction of 600 tCO₂e/yr, with a more modest reduction in total fuel use from the hybrid vehicles' improved efficiency.
- Replacing idling diesel vehicles to power equipment with non-combustion engine truck-mounted power units. Many utility vehicles, such as television inspection trucks that are used to examine pipes for leaks, are typically powered by the truck's idling engine. Because the power units provide power only on demand, AWU expects them to reduce overall energy use.
- Reducing vehicular trips (from field to office) through use of wireless communication for various data retrieval (maps, permits, etc.).

On-Site Energy Generation. AWU is working with Austin Energy to establish renewable energy generation through a solar photovoltaic system at the AWU's Glen Bell Service Center. The system will incorporate a 135 kW solar photovoltaic array on the roof of the building and is expected to generate 300 MWh/year and reduce 150 tCO₂e/yr.

Special Staff or IT Needs or Other Considerations

Currently, AWU's climate protection strategy does not require any specialized staff. AWU has relied on the expertise of the current workforce (management, engineers, and operators) to identify process and operational improvements and design improvements for the new WTP4. In order to meet the ambitious goals outlined in the ACPP, all AWU staff will need to work together to find solutions and energy efficiency improvements.

Lessons Learned

AWU's tracking of energy consumption at the Ullrich plant for more than a decade helped highlight the elevated consumption rates and led to the operational change in pumping. AWU is continuing to identify and formulate additional energy efficiency strategies. AWU has learned the importance of historical data evaluation, energy consumption, monitoring, data analysis, and effective database management to implement new programs and practices. The utility understands that

it will take time to optimize processes. Additionally, the utility is embarking on both asset management and business intelligence initiatives to improve data gathering, integration, and analysis.

Conclusion

Tracking plant efficiency, as in the case of the Ullrich plant improvements, has helped AWU identify and implement energy efficiency improvements and reduced its overall energy consumption and GHGe. As AWU plans for future capital improvements, as in the case of WTP4, the use of energy life-cycle costs in design and decision-making may lead to further efficiency gains. Through the implementation of a new climate protection strategy, AWU is looking beyond process efficiencies and is addressing energy use in its fleet and buildings, and is developing its own renewable power generation capacity.

Austin Water Utility (2), TX

	Plant Improvements and Management Changes	Water Treatment	Water Distribution	Water Conservation	Alternative/Renewable Energy Sources	Financial Assistance	Partnerships
Management Tools				✓			✓

Background on the Water System and History of the “Issue”

The City of Austin has permitted water rights to divert 325,000 acre-feet of water per year from the Colorado River for municipal use. The raw surface water is treated using a traditional lime softening treatment process and disinfection. Austin Water Utility (AWU) operates two water treatment plants with a combined 285 million gallons per day (MGD) maximum capacity and serves 200,000 connections over 310 square miles. The water system includes approximately 3,600 miles of mains, 45 pump stations and local booster pumping stations, and 167 million gallons of finished water storage capacity.

With a 25-year history (see text box) of implementing water conservation measures, AWU is a leader in demand-side management. Many lessons have been learned and AWU continues to evaluate, modify, and expand its water conservation efforts to sustain the water supply and manage its water resources during periods of drought. AWU’s water conservation program began in 1983 in response to increased demand from a growing population and concern over the impact on the water supply. The water conservation program began with emergency demand management measures setting mandatory restrictions on outdoor water use and has continued to evolve in response to changing customer needs, emerging technologies, political concerns, and available resources. AWU manages the water conservation and reclaimed water efforts through its Water Conservation Division (WCD).

In the summer of 2009, exceptional drought conditions causing a decrease in the water supply and an increase in demand forced AWU to implement Stage II water restrictions, limiting outdoor watering to one-day per week, among a number of other restrictions. The day preceding the Stage II watering restrictions, AWU incurred its largest ever peak daily demand of 226 MGD.

Major Milestones of Conservation Program

- 1983—Emergency Water Conservation Ordinance approved.
- 1985—Commercial Water Conservation Retrofit Ordinance adopted for retrofit of showerheads and toilets with dams.
- 1991—Ordinance passed prohibiting installation of toilets flushing more than 1.6 gallons per flush.
- 1992—Toilet replacement program instituted.
- 1999—Ordinance passed prohibiting water waste.
- 2006—Resolution approved setting a goal of reducing peak-day water use by 1 percent per year for 10 years and creating the Water Conservation Task Force (WCTF).
- 2007—City Council approved a resolution adopting the WCTF conservation recommendations.
- 2008—Plumbing code changes implemented to improve conservation efforts (January 1).
- 2009—Stage II watering restrictions implemented.

Type and Size of the Process or Technology Evaluated

Historically, AWU’s water conservation program has included incentives for residential and commercial customers to install water efficient fixtures and equipment, services to reduce demand for a variety of water use (indoor, outdoor, and leakage), educational and outreach programs, and regulatory measures.

To continue promoting water conservation and manage water resources to meet long-term supply needs, the City Council, on August 24, 2006, approved a conservation goal of reducing peak-day water use by 25 MGD within 10 years (or 1 percent per year peak-day reduction). The City Council also created a Water Conservation Task Force (WCTF) with a goal of drafting a policy document to detail ways to achieve this conservation goal. The WCTF considered costs and feasibility of implementing various water conservation strategies and developed a policy document that was adopted by the City Council in May 2007 that included:

- Indoor strategies (plumbing fixtures, metering, cooling towers);
- Landscape irrigation strategies (irrigation system efficiency, landscape design, watering schedules, rainwater collection); and
- City and utility strategies (leak repair, water reuse program, rate structures, public education).

Change(s) Implemented and Results

AWU has implemented a variety of conservation programs over the last 25 years. The more recent changes adopted by the city and implemented by AWU incorporate operational and management changes and demand- and supply-side approaches to supply and capacity issues.

WCTF Measures Implemented Since 2007. The WCTF policy, adopted in 2007, provided strategies for providing peak-day savings of an estimated 32 MGD, which exceeds the City’s conservation goal of 25 MGD. Of the 23 measures recommended in the policy, there are three water-related WCTF measures that are estimated to provide the largest individual peak-day savings. These measures are described in the [Table 4.3](#) and sections below.

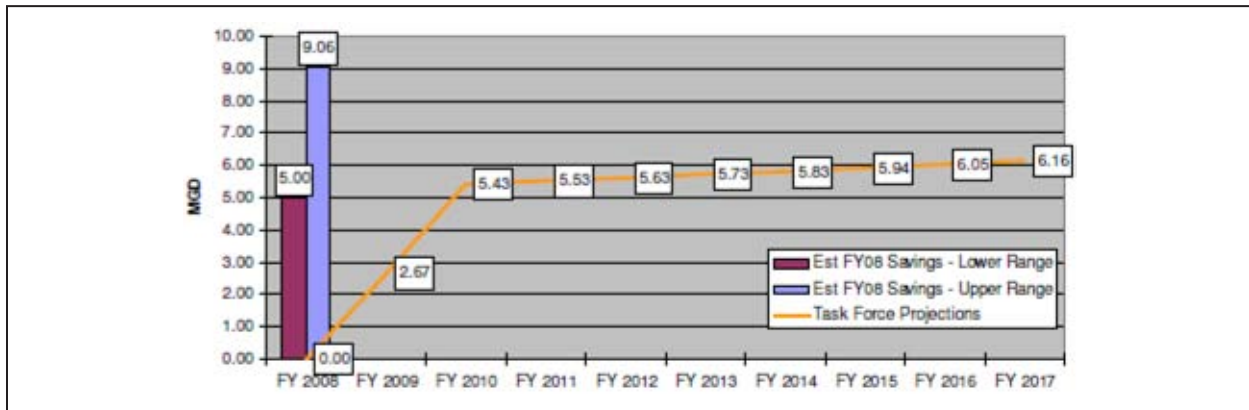
AWU estimates it uses an average of 2400 kilowatt hours per million gallons (kWh/MG) for water treatment and distribution at an average cost of \$0.08 per kWh. The potential cost savings

Table 4.3
Water conservation measures and savings

Water conservation measure	10-Year peak demand savings goal	FY 08 actual savings
Enhanced water use management	6.15 MGD	5.0 to 9.0 MGD
Reclaimed water use	5.95 MGD	2.5 MGD*
Adjust conservation water rates	5.0 MGD	Effective 11/2009

Source: Austin Water Utility.

*Projects cited by WCTF not built yet, but reclaimed peak day water use increased by approximately 2.5 MGD from FY 07 to FY 08.



Source: Austin Water Utility.

Figure 4.2 Savings from summer watering schedule

related to the 25 MGD peak-day savings conservation goal (or 15 MGD average reduction) is approximately \$1,000,000 per year.

Enhanced Water Use Management. The ordinance, effective October 1, 2007, limits watering to two days per week year-round for commercial and multi-family customers and from May to September for residential customers. Additionally, the ordinance prohibits daytime watering and water waste and sets forth progressive restrictions to respond to increased demand or decreased supply. Savings to date are shown in Figure 4.2. The low-end estimate of 5 MGD savings of water over five summer months translates to an estimated 1800 megawatt hours (MWh) and \$150,000 savings each year.

Reclaimed Water Use. In May 2007, the City Council approved a resolution adopting the WCTF recommendations for aggressive water conservation measures, including several water reclamation projects that are currently underway to build a reclaimed water storage tank and add reclaimed water transmission lines. Reclaimed water projects are expected to reduce peak demand by 5.95 MGD over 10 years. In FY 2008, reclaimed customers used 1.63 billion gallons of reclaimed water, compared to 1.17 billion gallons in the FY 2007 base year. This equates to an estimated peak day potable water system reduction of 2.5 million gallons for FY 2008. Use of reclaimed water for FY 2009 is estimated at 2.0 billion gallons.

Conservation Water Rates. AWU has implemented an inclining block rate structure to provide an incentive for high water users to conserve. It provides a mechanism to reduce the bills for customers that are at or below the average water use rate. A fifth block residential rate went into

Additional Improvements Realized From the WCTF Policy

- AWU hired additional staff and made organizational changes that have increased participation in the water conservation programs while decreasing the costs per gallon saved. Specific changes include reduced time processing rebates, 300 percent more irrigation audits conducted, and a four-fold increase in participation of toilet rebate programs.
- In 2008, AWU partnered with 3-1-1 to give customers a 24-hour venue to report water waste complaints. Complaints have increased dramatically.
- Enhanced efforts to reduce distribution system water loss including resources to respond to leaks and breaks.

effect in November of 2009 for usage of over 25,000 gallons. The rate structure is not changed for commercial or industrial customers.

Existing Programs (not including WCTF measures). AWU's existing water conservation program includes:

- *Incentives/rebates to residential and commercial customers to install water efficient equipment.* This includes toilets, washing machines, plumbing fixtures, and rainwater harvesting barrels. Commercial customers may apply for up to \$100,000 per project to install water-saving equipment or to complete reuse projects for water from manufacturing or cooling processes. The limit was increased from \$40,000 to \$100,000 in 2008. Programs like the toilet and washing machine rebates provide water savings and energy savings beyond the estimated 2400 kWh/MG, as well as reduce wastewater (estimated to be on average roughly equal to water's 2400 kWh/MG). In the case of washing machines and dishwashers, end-use energy consumed directly by customers for onsite heating and pumping can be reduced. Using available literature, AWU estimates that, per unit of water, end-use energy may actually exceed AWU's own energy use.
- *Educational and outreach programs.* AWU educates the public on the importance and practices of water conservation through TV, radio, and print advertising, a well-designed Web site, press releases, and other public outreach efforts. AWU partners with the Lower Colorado River Authority and Cedar Park to promote the Texas Water Development Board-developed Water IQ campaign. The division participates in community events, and hosts a speakers bureau available for neighborhood and community group presentations.

Special Staff or IT Needs or Other Considerations

To ensure proper management of conservation measures, the utility has trained staff on the importance of water conservation and hires staff with backgrounds in water resource management. Additionally, adequate staff is required to ensure the programs operate smoothly, such as hiring staff to perform the irrigation audits. Successful implementation of water conservation measures requires a partnership approach with cooperation of the water utility, building code enforcement department, energy companies, and large-scale customers.

Lessons Learned

- Careful and comprehensive planning is critical for successful program implementation. Theoretical savings projections measured against actual savings achieved should be reviewed and confirmed to ensure that programs are cost-effective.
- Representatives from the broader community should be included in the planning process.
- It is important to evaluate programs regularly to validate savings projections, and to phase out programs that are not working or are no longer needed.
- What works well for one water provider may not work for another. It is necessary to plan new initiatives carefully, continue to evaluate results, and tailor programs as needed to achieve measurable reductions in water demand.

Conclusion

During its 25-year water conservation history, AWU has learned through trial and error and has continued to expand and modify conservation approaches. AWU continues to evaluate new tools and water saving methods, and build new partnerships. The City’s water conservation efforts have contributed to a substantial reduction in per-capita water use even with continued population growth. Between 1984 and 2008, the city’s population grew 82 percent; however, water use only increased 51 percent. The City has found that water conservation provides multiple benefits including extending water supplies, lowering bills for customers, reducing operational costs and environmental impacts from pumping and treatment (energy consumption and greenhouse gas reductions), and improving management of infrastructure investment. Water conservation efforts are never finished and more water conservation efforts can always be realized.

Cedar Rapids Water Department, IA

Management Tools	Plant Improvements and Management Changes	Water Treatment	Water Distribution	Water Conservation	Alternative/Renewable Energy Sources	Financial Assistance	Partnerships
✓	✓		✓			✓	✓

Background on the Water System and History of the “Issue”

The Cedar River is the source of the Cedar Rapids drinking water supply. The water source is classified as groundwater under the direct influence of surface water. Raw water is extracted from the sand and gravel deposits along the Cedar River from 46 shallow vertical and 4 horizontal collector wells and treated at two conventional lime softening treatment plants. The Cedar Rapids Water Department (CRWD) is in the process of adding ultraviolet disinfection to the treatment train to meet new water quality standards. The two treatment plants have a combined designed capacity of 65 million gallons per day (MGD). The system meets an average demand of 38 MGD and a peak demand of 51 MGD. The system has a 23 MG finished water storage capacity.

Of the average demand, 25 percent is from residential and commercial customers and the remaining 75 percent is from multiple wet milling grain processing plants and other industries that require high volumes of potable, food-grade water.

In the early 1990s, the water utility's industrial customers expressed concerns about increasing water costs and inquired about ways to allow them to maintain a competitive edge and maintain their own low operating cost. Due to the high percentage of industrial water use, CRWD did not want to lose the businesses due to high water rates and operating costs. To address these concerns, CRWD began implementing various energy efficiency measures.

Type and Size of the Process or Technology Evaluated

CRWD performed a walk-through audit of the water system to understand how and where energy was being used in the water system. Based on the system evaluation, CRWD implemented an extensive program to monitor, analyze, and evaluate energy consumption throughout its system. The first energy program established was tracking and analysis of electric usage. From there, the CRWD Energy Efficiency Management Program began to take shape. Through the 1990s, CRWD integrated the following energy conservation measures into the water utility's management and operations:

- Monitoring industrial water use.
- Monitoring peak demand power, power factor, and power usage.
- Tracking and analyzing electricity usage.
- Using variable speed/frequency drives (VFDs) for high service, well pumps, and booster pump stations.
- Participating in its power provider, Alliant Energy's interruptible program.
- Participating in the city-wide energy management system.
- Initiating a water and wastewater facility energy audit conducted by the local electric utility.

Change(s) Implemented and Results

Over the past 15 years, CRWD has established a variety of energy conservation measures and continues to expand its efforts. These initiatives are discussed in the following sections.

Monitoring Industrial Water Use. To help address industrial customers' concerns and questions on water use and rates, CRWD implemented a program that allows the largest water users to monitor their own water consumption. The monitoring program works by using a TeleData interface module on the City's water meter that provides continuous, real-time consumption data to the industry's automatic control system. CRWD provides and installs the interface module at no cost to the customer. The interface module also transmits a daily history of water consumption via telephone line to CRWD. The real-time water consumption data helps the customer to optimize water usage which in turn reduces the system's peak demands and its associated costs. The information also helps utility operators track water usage, identify water main breaks and leaks, and keep meters in working order. Additionally, the interface module allows CRWD to take meter readings remotely.



Source: Cedar Rapids Water Department.

Figure 4.3 Use of a SCADA system

Monitoring Peak Demand Power, Power Factor, and Power Usage. The electricity rate structure is primarily demand based, with varying rates for peak vs. off-peak usage, and summer vs. winter usage. It includes credits for power factor and participation in the interruptible rate program as described below, and allows a substantial energy cost adjustment that varies monthly to cover Alliant Energy’s variable costs.

In 2000, the CRWD began to establish internal goals for reducing electric demand rates in the form of monthly “caps” or maximums. This program has provided the most benefit for improving system efficiency because it has provided utility operators with an increased awareness of energy conservation and system optimization measures. Before this “cap” was established, the operators were not conscientious of the energy used by the various equipment and would operate pumps inefficiently such as, operating multiple pumps during peak rate periods then shutting off pumps during off-peak periods, sending water to multiple parts of the City when pumping could be staggered between the different segments, operating inefficient well pumps, starting and stopping equipment frequently, and leaving valves throttled more than necessary. Now, with the “cap” in place, the operators think about and make conscious decisions regarding which equipment (pumps, wells, etc.) to operate depending on the needs. The cap is reviewed and modified monthly by utility management and posted for the operators. A normal summertime cap reaches 5000 kilowatts (kW), and a wintertime cap reaches 3500 kW.

In order to properly manage peak demand usage, real-time electricity data is collected with CRWD’s extensive network of primary and secondary electric meters throughout the system, including the two water treatment plants, wells, booster stations, tanks, and other system facilities. There are three primary meters and over 20 secondary monitoring points (submeters) that monitor electricity use for specific equipment, wells, and processes. The electric meters are used in-line with the power utility’s (Alliant Energy) electric meters to measure electricity consumption at the same point. The meters and submeters feed real-time electricity usage data to the SCADA system, which is then displayed on the operator’s control screen. The SCADA system displays electricity

consumption (kW), voltage, and power factor for each of the three primary meters and the combined total.

The presentation of this data (see [Figure 4.3](#)) allows the operators to continually monitor electricity usage to ensure the “cap” is not exceeded. The real-time electricity data on the operator’s computer screen changes color as the “cap” on electric demand is being reached. The first warning occurs when electricity usage is within 400 kW of the “cap.” The display turns red if the “cap” is reached. This visual representation is a reminder to the operator to properly monitor and evaluate the operating equipment and to make necessary adjustments to ensure the “cap” is not exceeded. Adjustments made to reduce peak demand can include turning on generators and/or direct drives during peak demand periods, shutting off non-essential equipment, and operating different wells or pumps.

As a further benefit of monitoring real-time electricity usage, Alliant Energy provides incentives for customers to improve their incoming power quality by installing power factor (PF) correction capacitors. Cedar Rapids has achieved an average power factor of 98 percent over the period covering FY 06–FY08 resulting in a total cost savings of \$117,000 over that time. PF deductions are based on a baseline of 90 percent, with deductions given for every percentage point over 95 percent, and penalties charged for every percentage point under 85 percent. The electricity rate is calculated as percent over 90 \times Net Demand Charge for the month (i.e., for a 98 percent power factor, the calculation would be 0.08 \times Adjusted Net Demand Charge).

Tracking and Analyzing Electric Usage. The utility’s SCADA system program was upgraded in 2008/2009 and now allows storage of data for an “unlimited” timeframe compared to the previous one-year limit. The SCADA system includes a historian program that provides graphics and trend lines of data that allows CRWD staff to more easily track electric usage. In addition to using SCADA, CRWD incorporates the electric data into Excel spreadsheets for monthly evaluation. The most common electric data trend used by CRWD is the analysis of the kWh per million gallons pumped (see [Table 4.4](#)). Data is analyzed for trends to see if there are problems with electric billing, metering, or operation of equipment. Additionally, the data is used to help troubleshoot problems, and was recently used to help in the design of a new pump station. Furthermore, the tracking and analysis of electric data is an important tool used to report cost savings to management.

Using Variable Frequency Drives (VFDs) for High Service and Booster Pump Stations. Due to CRWD’s finished water storage capacity (23 MG) and average demand of 38 MGD, the water system operates 24-hours a day at various pumping rates. To help reduce pump cycling and improve the system’s energy efficiency, CRWD has installed VFDs on many of the water system pumps. The VFDs have contributed to energy savings by matching pump speed to flow demand, which reduces excessive pump cycling. A large amount of energy is consumed with cycling pumps on and off. The VFDs will also reduce wear and tear on the pumping system, thus reducing maintenance costs.

CRWD is currently constructing a new pump station that will replace eight old high service pumps with six new high efficiency pumps. The two largest pumps will include VFDs. Additionally, electric submetering will be installed to allow for tracking the new pumps’ electric consumption.

Interruptible Electric Rate. CRWD participates in Alliant Energy’s interruptible rate program in which participants agree to curtail their power demand upon request in order to help Alliant Energy meet its peak demand. In exchange, the participants benefit through negotiated rates that allow significant cost savings. When contacted, each participating customer has 2 hours to curtail electric consumption to the contracted level. When requested, CRWD turns off equipment such as the centrifuges, dehumidifiers, back wash pumps and recirculation pumps from the

Table 4.4
Analysis of annual water and electrical usage and costs

	Daily average finished water pumpage (MGD)	Total electrical usage (million kWh)	Annual electrical cost	Annual cost per kWh	Cost per million gallons pumped	kWh per million gallons pumps	Percent of off-peak hours electrical usage
FY94	30.4	21.4	\$965,275	\$0.05	\$87.1	1928	58.2
FY95	31.6	21.7	\$964,234	\$0.04	\$83.7	1884	60.4
FY96	33.9	24.3	\$1,116,989	\$0.05	\$90.4	1908	61.6
FY97	35.5	23.1	\$1,124,797	\$0.05	\$86.9	1736	59.9
FY98	35.5	22.7	\$1,076,917	\$0.05	\$83.2	1707	60.2
FY99	34.8	22.5	\$1,024,726	\$0.05	\$80.6	1725	60.3
FY00	35.8	23.0	\$997,402	\$0.04	\$76.3	1757	60.4
FY01	35.7	23.4	\$1,042,876	\$0.04	\$80.1	1800	60.8
FY02	35.7	22.5	\$906,936	\$0.04	\$69.7	1728	59.7
FY03	34.4	24.9	\$1,023,261	\$0.04	\$81.5	1981	61.6
FY04	36.5	24.9	\$1,020,409	\$0.04	\$76.5	1861	61.2
FY05	36.7	23.4	\$1,076,712	\$0.05	\$80.3	1750	60.7
FY06	37.8	25.1	\$1,274,936	\$0.05	\$92.4	1952	60.5
FY07	38.0	25.7	\$1,315,486	\$0.05	\$94.8	1838	61.4
FY08	38.1	23.3	\$1,228,095	\$0.05	\$88.4	1678	61.2

Source: Cedar Rapids Water Department.

backwash basin, and reduces lighting to a minimum. For the period of FY06–FY 08, CRWD achieved electrical savings of \$344,000 by participating in the interruptible program. If the participant does not meet the contract limits, they face significant penalties up to and including being taken off the program.

CRWD is able to participate in the interruptible rate program because of its available standby power that consists of an assortment of generators, (400 kW–1800 kW), and pumps equipped with diesel and natural gas powered direct drive units.

Energy Management System. A City Government department-wide Energy Management System (EMS) was initiated by City employees in 2001 to collectively manage energy use at 22 major facilities and conduct real-time monitoring of electricity usage. The EMS resulted in approximately \$447,000 savings per year through 2007. Unfortunately, the majority of the municipal buildings incorporated into this project were damaged or destroyed during a flood in 2008. As part of the rebuilding and refurbishment process, the City has set a goal of re-establishing an energy management plan. This new plan has three major components—energy reduction in the form of electricity, natural gas, and vehicle fuel; building reconstruction incorporating Leadership in Energy and Environmental Design (LEED) standards; and evaluating the potential for converting waste to energy. CRWD and the City’s wastewater department are leading the development of the new EMS since they account for up to two-thirds of the municipal departmental energy usage.

Special Staff or IT Needs or Other Considerations

Reliable communications and a user-friendly SCADA system are critical for operating a complex system over a wide geographic area. CRWD staff includes a SCADA System Manager,

two Instrumentation and Control technicians, and one full time electrician. Communications to the wells, plants, and tanks is achieved using multimode and single-mode fiber optic lines, Ethernet radio, Ethernet cabling, and hardwire lines. The above mentioned staff is responsible for the daily maintenance and upkeep of all of these forms of communication. In addition, CRWD works closely with the local electrical utility to evaluate the connected load, energy efficiency improvements, rebates for installing energy efficient equipment, and for service work to the system.

Lessons Learned

CRWD has learned a variety of lessons in the process of implementing its energy management programs over the past 15 years:

- A water utility can never have too many meters or submeters. The collection of accurate electric data is an important component of the program.
- It is vital to allocate adequate resources for staff training and equipment maintenance.
- With a large industrial customer base, CRWD must stay competitive with utility costs to retain existing customers as well as entice new customers to locate to the service area.
- It is critical that water utility staff to make a personal commitment to carry out energy conservation goals and use the available technology to meet these goals.
- It is critical to work closely with the local energy providers to optimize energy usage as well as maximize energy conservation rebates.
- Stewardship of all natural resources is critical and conserving energy is an important component of protecting resources for current and future generations.

Conclusion

CRWD has undertaken considerable efforts to improve energy efficiency as a way to reduce costs and control water rates for its customers. Energy conservation measures have increased staff knowledge, accountability, and commitment to the utility's energy management program. A key component of this program is the ability to collect, track, and analyze real-time energy consumption which allows for further system optimization.

By participating in the Alliant Energy's Power Factor and Interruptible Rate Programs, CRWD has realized approximately \$150,000 per year in cost savings. In addition, they realize an estimated savings of \$15,000 per year through peak demand monitoring. Furthermore, energy efficient features of the new pumping station are estimated to offset \$30,000 per year in increased energy costs from the new UV reactors.

Cleveland Water Division, OH

Management Tools	Plant Improvements and Management Changes	Water Treatment	Water Distribution	Water Conservation	Alternative/Renewable Energy Sources	Financial Assistance	Partnerships
✓	✓		✓				✓

Background on the Water System and History of the “Issue”

The City of Cleveland water supply system has grown over the centuries from very modest beginnings. The earliest settlers of Cleveland relied on individual water supplies such as springs, wells, and cisterns. Early in the 19th Century, town pumps were constructed in central locations for residents to collect water for their homes. As the demand for water grew, more wells and springs were developed and the Cuyahoga River was added as a source. Health officials expressed concerns for the quality of the water sources as pollution from sewage and early industrial development increased. Lake Erie was first tapped as a source of water in the mid 19th Century with intakes only a few hundred feet from the shoreline. However, the highly polluted Cuyahoga River and other discharges along the shoreline contaminated Lake Erie water near the shoreline. So, the quest for clean water drove the City to develop an intake structure farther from the shoreline.

The intake structure, or “crib” as it is called, is located just over five miles offshore in Lake Erie. The original intake was built in the early 1900s with major upgrades occurring in the 1940s and 1950s. Tunnels were constructed to pipe the water from the crib to the pumping station inland from the shore.

The Cleveland Water Division (CWD) built its first water filtration treatment plant in 1917—the Division Avenue Water Filtration Plant (later renamed the Garrett A. Morgan WTP). In 1925, the Baldwin Water Treatment Plant was constructed, and then two other water treatment plants were added in the 1950s—the Nottingham WTP in 1951 and the Crown WTP in 1958.

As post-war expansion impacted the Cleveland area in the middle 20th Century years, the CWD expanded as well to serve drinking water to surrounding communities either by wholesale contracts or through direct customer supply. Today, the quartet of water treatment facilities has capacity to produce more than 540 million gallons per day (MGD) of water. As the system expanded so, too, did the demand on power needed to supply water across long distances. Electric costs increased as the treatment plants produced more water and pump stations delivered more water to a larger distribution system. To address these concerns, CWD investigated ways to keep the production cost and the transportation cost of water as low as possible in order to keep the wholesale and retail water rates at an affordable level. CWD focused on energy efficiencies at the water treatment facilities and at the pumping stations to yield immediate energy (and cost) savings.

Type and Size of the Process or Technology Evaluated

The CWD implemented several energy savings strategies at various levels of the organization. Personnel changes that impacted the Division of Water as well as the entire City organization were critical in shaping organization-wide attitudes and commitment to energy savings. Other strategies involved operational changes that improved energy efficiency through buying less expensive power and using less power. Finally, CWD realized energy savings by making capital investments in infrastructure that will pay the utility back in a specified time through energy cost savings.

Operation Optimization. Training operators to manage the pumps and pumping stations in the most efficient manner helps CWD meet energy cost savings goals. CWD has an on-going process of developing a mindset in operators to embrace standard operating procedures (SOPs) for routine water process operations. As of 2009, CWD estimates that training is currently about 10 to 20 percent complete and will be 100 percent complete by 2011. The core features of SOPs for the

pump/pump station electrical optimization are conducting thermal analyses, vibration tests, and pump test setting analyses. From these SOPs, operators will be expected to:

- Know and understand the operating range of the pumps and make routine operational changes in the pumping procedures based on the temperature and specific gravity of the raw water being pumped.
- Know and understand a pump's power range based on kilowatt hour efficiencies balanced against real-time vs. theoretical water flow and water pressure. From the comparisons, an operator will know which of several different pumps will be the correct pump(s) to use in a specific operating scenario.
- Know how historical events have impacted electrical demands. Historical events with documented performance information include the loss of any major facilities, water main breaks, and significant weather events.
- Be familiar with the overall "water operations script" for operating pumps and pumping facilities, and know how specific activities (routine maintenance work, construction projects, etc.) and system information (power and water capacity demands, water quality, etc.) affect daily operations. CWD is reviewing both internal approaches as well as proprietary software which will allow the utility to create a real-time operations overlay plan which cycles through optimum scenarios on a constant 30-minute interval rotation.

Installing Wind Turbines on the Lake Erie Intake Crib. The City's intake structure for the water treatment plants was once near the shore of Lake Erie. However, the City moved the intake away from the impacts of the nearby heavily polluted tributary rivers of Lake Erie, by constructing an intake structure several miles off shore in Lake Erie. The original intake was built in the early 1900s with major upgrades occurring in the 1940s and 1950s. The City began to explore alternate methods to power its intake structure so far out into Lake Erie and at the same time began to think regionally about an alternate form of energy. The potential of harnessing the strong, constant wind currents ever present offshore became a regional focus for Cleveland. The City of Cleveland, the Cleveland Public Power utility, and Green Energy Ohio established a partnership to study, pilot, and construct a wind tower on the end of the crib. In addition to generating enough power to supply the intake structure's needs (and eliminating costly maintenance upkeep for an electrical line from the shore out to the end of the crib), the tower will serve to collect data from which future decisions will be made regarding the feasibility of harnessing wind power regionally.

Off-Peak Energy Consumption at the Pumping Facilities. CWD is very aware of the large energy demand of filter backwash pumps, air scour blowers, and pumps. Typically, most operations like backwashing a filter or filling a distribution system reservoir from a pump station are initiated on an as-needed basis. That is, the facilities are placed on-line when the demand calls for the service. To reduce the amount of energy purchased in the peak power demand period, CWD investigated the feasibility of deferring as many on-demand functions as possible to off-peak power demand periods. In 2008, CWD began a pilot project to look at off-peak use of power to perform these process operation tasks.

Replacing Older Pumps and Motors With Energy Efficient Pumps and Motors. Most of a water utility's energy costs are associated with pumping water. Pumps and motors operate most efficiently when operating under optimum conditions (capacity for specific head pressure and motor horsepower). While CWD selects pumps and motors that fit the optimum conditions, not

all pumps and motors are operated in those zones. So, in addition to selecting a pump and motor that truly fits the given conditions, CWD also selects the most efficient pumps and motors through construction and purchase specifications. CWD has decided that it makes sense from an efficiency perspective to operate pumps at the demand and capacity needed for a specific application.

Change(s) Implemented and Results

Many of the City's energy savings strategies are only now beginning to be implemented or are still planned for the future. These strategies range from acquiring energy from new "green" sources to replacing aging equipment with more energy efficient equipment to determining how to balance peak energy demand times and therefore lower the cost of purchasing energy. The current status of these various initiatives are described below.

Operation Optimization. Currently, the data set to document the electrical power savings resulting from this measure is not very robust, but progress is being made toward the goal of establishing the data set. The City estimates that without the operating software, the City may realize energy savings between 5 to 7 percent. With the operating software, the City is anticipating being able to save between 10 to 15 percent of its energy costs.

Installing Wind Turbine Power. Full implementation of this measure has not taken place as of November 18, 2009, although the City has installed a 60-meter tower on the crib. The tower serves as a fully functioning wind monitoring station complete with one wind turbine and several data collection sensors. The City estimates that long-term use of wind power for the region could begin in 5 to 10 years with the construction of up to five 5-Megawatt turbines at a cost of \$80 million (in 2009 dollars).

Off-Peak Energy Consumption. As a result of the pilot study, the water treatment plant operators have switched to initiating backwash pumps and air scour blowers during the hours of 12 AM (midnight) to 8 AM in order to realize the energy rate savings of off-peak power operations.

Pump and Motor Efficiency. By operating more efficient pumps and motors, CWD estimates the energy cost savings can be as much as \$10 million over 5 years. CWD has been specifying new efficient pumps when pump stations are rehabilitated or rebuilt or when pumps and motors are at the end of useful service lives and need to be replaced. Additionally, when a large pump is to be replaced, it can often be more efficient to install two smaller pumps as replacements if space and demand allow. Another way to make an existing pump more efficient is to trim the impellers or add variable frequency drives.

Special Staff or IT Needs or Other Considerations

Operation Optimization. In addition to the purchase of the proprietary software, CWD must train its operators to be able to understand and implement the procedural changes identified in the optimization strategy.

Installing Wind Turbine Power. Special considerations must be made for safety training of the operators and maintenance staff working on the tower and turbines.

Off-Peak Energy Consumption. No special staff or training is needed beyond typical operational procedural training of shifting "day operations" tasks to "night" shift tasks.

Pump and Motor Efficiency. No special staff or IT needs are required.

Lessons Learned

- **Operation Optimization.** Utilities can often underestimate the labor involved in training staff properly to accomplish tasks inside of new operating procedures. CWD has found that even though the cost is higher and the time period to implement the changes is lengthened, a comprehensive training schedule that covers several years and involves all operations staff is most desirable.
- **Installing Wind Turbine Power.** The high capital costs to start construction on this project make implementation very difficult to predict. Waiting for the economic climate to improve and for CWD to gather the necessary funds to commence construction has taken longer than originally anticipated.
- **Off-Peak Energy Consumption.** Effective communications and planning are keys to implementing operational changes that affect both day and night shift operators and supervisors. For example, off-peak pumping adds responsibilities to night shift operators that were formerly assigned to the day shift.
- **Pump and Motor Efficiency.** Specifying high efficiency pumps and motors in CWD's construction standards and specifications is truly the key to success with this strategy.

Conclusion

The CWD has long been a leader in treatment innovations and optimization, and has expanded its efforts to include energy savings and energy optimization. CWD continues to implement and refine its energy savings strategies given the availability of capital dollars for construction investments; the current status of the national, regional, and local economies; and the training efforts exercised by CWD to have all of its operations staff working under a mindset and a suite of standard operating procedures that target energy efficiency throughout the water system.

Columbus Water Works, GA

	Plant Improvements and	Water Treatment	Water Distribution	Water Conservation	Alternative/Renewable Energy Sources	Financial Assistance	Partnerships
Management Tools	Management Changes						
	✓				✓	✓	✓

Background on the Water System and History of the “Issue”

The Columbus Water Works (CWW) utility in Georgia first constructed a water filtration plant in 1915 and has since made numerous upgrades and changes to the original treatment facility. The source water for the water filtration plant is Lake Oliver, an impoundment on the Chattahoochee River. In 1956, CWW added wastewater service and in 1964 completed its first wastewater treatment facility.

Several years ago, CWW realized it could be more efficient, and identified specific projects in three main areas. CWW first realized that the size of the labor workforce could be trimmed down to focus attention on core utility functions. Next, the utility believed that the quantities of treatment chemicals being used could be reduced based on a thorough analysis. Finally, the utility

had become concerned over the rising cost of electrical power and decided to proactively respond with energy and energy cost savings measures.

CWW participated as a partner in an Awwa Research Foundation (now the Water Research Foundation) project *Strategic Planning and Organizational Development* to aid utilities in developing a strategic planning framework that can be modified and adapted to the utility's specific needs. CWW used the research methodology to develop its own strategic plan including an asset management program. CWW identified 80 different tasks, 15 of which were considered priority items that needed to be addressed before the program could be further implemented. The water utility also participated in the Water Research Foundation's project *Best Practices in Energy Management* in order to share its cost savings management, conservation, and implementation strategies with other water systems.

Managing the utility's energy needs was just one of the key elements in the strategic plan. To manage the utility's energy demands, sources, and costs, CWW developed an *Energy Management Program*. Objectives of the program include establishing a results-oriented procedure to ensure that energy-saving operating practices are incorporated in its daily routine; using advances in technology to efficiently analyze, control, forecast, and monitor facility operations; making cost-effective facility improvements that promote efficient and environmentally responsible energy use; and procuring energy that takes full advantage of alternative electric rates. The purpose of this program is to minimize overall energy-related costs and expenses to enhance the economic and service performance of Columbus Water Works.

Type and Size of the Process or Technology Evaluated

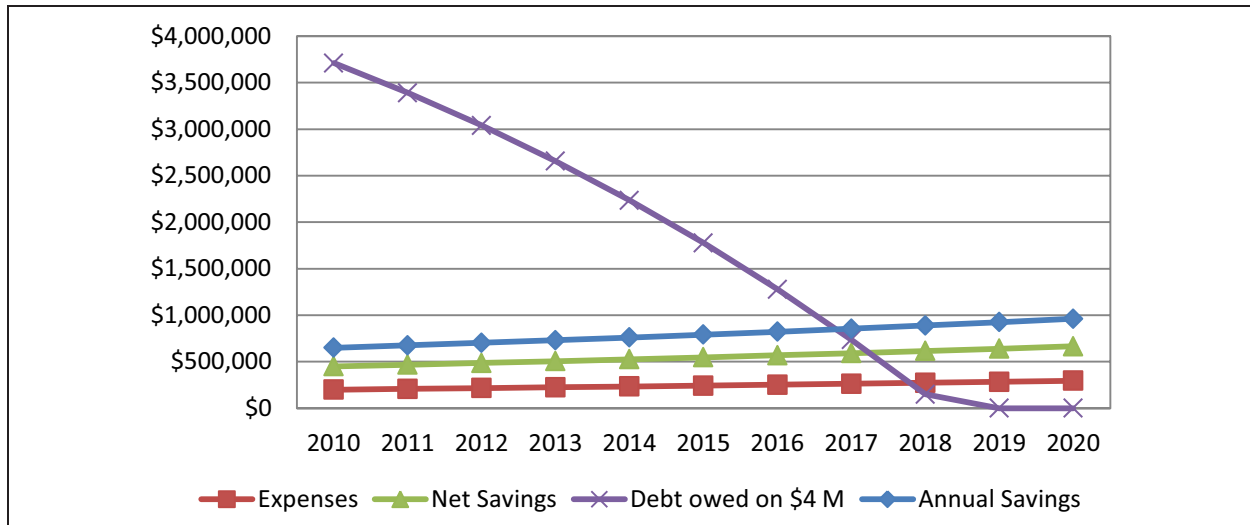
CWW uses its *Energy Management Program* to guide and direct projects and activities that will achieve the organization's objectives. To accomplish the objectives, CWW established several goals for the utility:

- Carry out an ongoing energy-monitoring program at each facility that measures the results of how efficiently energy is being used and seek to apply the most favorable and/or flexible electrical rate structures.
- Maintain the lowest net electric power cost possible by implementation of the *Energy Management Program* and utilizing applicable measures to reduce energy costs.
- Review facility operations and evaluate equipment performance on a continuing basis to identify cost-savings opportunities.
- Optimize operations with the use of new technology and advanced computer applications.
- Use equalized-storage operating practices and economical pumped-storage capabilities to optimize energy costs for pumping operations.
- Modify or replace treatment and pumping equipment where the cost savings payback is justified.
- Use time-of-day power use strategies that seek to optimize the facilities' electric load profile and minimize electricity costs.
- Educate and train staff on the potential impacts and costs of electric power usage associated with various treatment processes and operating strategies.
- Minimize adverse environmental impacts and conserve energy when planning for and implementing changes in the operation of the CWW system.

Change(s) Implemented and Results

To achieve the goals stated in CWW's *Energy Management Plan*, the utility developed a list of key programs and projects to undertake:

1. Produce an *Energy Management Information Manual* that is easily read, understood, and updated. The manual can be used as a reference, and to train staff to implement proper energy efficiency practices and take advantage of power rate structures. Also, it will provide guidelines on managing next-day power demand on a daily basis at CWW facilities based on current-day estimated cost curves and established standard operating procedures (SOPs).
2. Evaluate available alternative rate structures, negotiate favorable terms and conditions, and optimize facility operations to take advantage of the most favorable rate structures. CWW and its energy provider, the Georgia Power Company, have developed a unique "partnering" relationship that has allowed CWW to significantly reduce its power cost by negotiating more favorable pricing structures. Georgia Power Company cooperates by providing various scenarios of cost impacts and assists CWW in choosing the best rate structure that matches the CWW mode of operation. "Real-time pricing" and "day-ahead pricing" for example, have allowed CWW to realize hundreds of thousands of dollars in cost savings over the last several years. An additional feature of this program involves CWW's ability to shave connected load during high-cost hours of energy production. CWW operates on a customer base load of 70 percent of total load. During hours when power costs are the highest (sometimes reaching as much as \$1.75 per kWh), if CWW can shave connected load to less than 70 percent, then the power company will pay CWW for the savings. During 2002, one day alone amounted to a savings of \$35,000.
3. Perform energy audits and power-use profiling of major energy sources to identify areas that have the greatest savings potential.
4. Use Supervisory Control and Data Acquisition (SCADA) and computerized neural networking capabilities to continuously monitor, control, and prioritize loads and energy usage. Targets for electric power demands, discharge pressures, tank elevations, etc. are established to improve operational decision-making and enable power shedding. The SCADA system is used to monitor and limit power usage on large equipment. It works by comparing running equipment power consumption against a matrix of allowed power consumption within the plant at any given moment. The control logic has all of the large power equipment listed and how much power each piece consumes. It adds any of the running equipment power consumption together and will not allow any equipment to be started that would exceed the maximum allowable limit. The limits are set to minimize power usage during peak times and cannot be changed by the operator as the logic is password protected. In a partnership arrangement, CWW and the Georgia Power Company developed a pilot program for integrating new power demand software directly with the plant operating system. This enables CWW to program the plant operating system so that it automatically calculates total connected load at any point in time and prevents an operator from increasing the base demand load without prior approval of the plant manager. During a recent



Source: Columbus Water Works, GA.

Figure 4.4 Annual savings using on-site power generation with repayment of \$4 million investment

- incident when the pilot program was in operation, CWW saved \$85,000—money that would have been wasted in the absence of this new process.
- Evaluate the feasibility of on-site generators at the water treatment plant that enable peak shaving operations to decrease electric demand and energy consumption during peak periods. The generators have yet to be placed into service, but CWW has a capital cost investment of \$4 million. The utility has a contract with Cummins to operate the generator facility for 5200 hrs/year. The operations and maintenance expenses are estimated to be around \$200,000 per year, but the annual savings from the generators are expected to be about \$650,000 per year for a net savings of \$450,000. Assuming a 4 percent interest rate, the \$4 million capital investment could be recovered within 10 years (see [Figure 4.4](#)).
 - Develop and implement a Motor Policy that encourages the use of high-efficiency motors and incorporates life-cycle cost analysis when sizing, purchasing, maintaining, repairing, or replacing motors and motor starters. CWW inserted this language into all of the utility’s construction specifications and standards.
 - Evaluate water treatment plant processes to determine whether advances in technology or changes in capacity requirements offer short-term payback opportunities to improve treatment and energy-use efficiencies.
 - In 1995, CWW worked with the Georgia Power Company to modify the way the utility is billed for electrical power. CWW converted the electrical meters that service the water treatment plant and the river pump into one meter that serves both facilities. CWW was able to realize considerable cost savings by not having an “extra” meter. Additional cost savings factors include water demand, electric power demand, and negotiated rates based on power consumption.

Since 1995, CWW has realized over \$4 million in savings from implementing a variety of energy reduction strategies for both drinking water and wastewater including “cost avoidance” measures and actual lower energy usage. The majority of the energy cost savings for drinking water has been the result of “cost avoidance” by utilizing the various programs and efforts outlined in the *Energy Management Program*.

Special Staff or IT Needs or Other Considerations

CWW trains its staff in energy efficiency and energy conservation. Operators have the ability to review SOPs and the Electrical Power Billing and Usage Analysis, a manual of electrical use developed by an engineering consulting firm for the utility. From the manual, operators have all the tools they need to achieve the optimum energy performance from the CWW facilities.

Lessons Learned

Many of the projects that CWW has initiated for energy reduction purposes are still evolving as staff learn how to implement the energy-saving strategies identified in this case study report. One on-going task for staff is to develop metrics beyond cost comparison to evaluate energy savings strategies. In general, the utility would have liked to have invested more time and effort in the use of “sophisticated software” that would perform “smart” decision-making functions for pump operations and pumping sequences.

Conclusion

CWW has a long history of being a leader in the drinking water industry including incorporating energy conservation initiatives and practices into utility operations. As the utility continues to implement and refine its energy savings strategies, it will continue to develop robust metrics to document the energy savings that are achieved. Currently, CWW is focusing attention on attainable goals to lessen the cost for purchasing power as well as opportunities to lessen energy consumption.

Las Vegas Valley Water District, NV

Management Tools	Plant Improvements and Management Changes	Water Treatment	Water Distribution	Water Conservation	Alternative/Renewable Energy Sources	Financial Assistance	Partnerships
✓	✓		✓	✓	✓		

Background on the Water System and History of the “Issue”

The Las Vegas Valley Water District (District) receives most of the water it treats from Lake Mead. The balance, 11.7 percent in 2009, was pumped from ground-water wells. In 2009 the maximum day consumption was 429 MG. Available storage in District reservoirs is 916 MG. The District serves 1.3 million people in a service area that includes metro Las Vegas, areas of

unincorporated Clark County, Blue Diamond, Coyote Springs, Jean, Kyle Canyon, Laughlin (Big Bend Water District), and Searchlight.

Raw water is drawn from Lake Mead and treated by the Southern Nevada Water System (SNWS). Lake Mead had a surface elevation of just less than 1,100 feet at the end of July, 2010. The District has 36 reservoirs and tanks, 51 pumping stations, 76 production wells capable of producing 175 million gallons of water per day, and more than 4,100 miles of water transmission pipelines. Seven facilities generate electricity from on-site solar array panels.

The District is divided into 19 pressure zones that range from elevations 1,845 feet to 3,665 feet. The various zone reservoirs are filled at night using water delivered by SNWS to nine receiving points. Lifting water to these elevations results in electricity being a large portion of the District's annual budget. Energy costs for fiscal year 2009 were \$14.7 million, about 30 percent of the Operations Department's budget.

Type and Size of the Process or Technology Evaluated

The District has implemented a variety of programs to improve energy efficiency. They cover a wide spectrum of practices including management tools, HVAC, renewable energy, pump performance and optimization, leak detection, and efficient use of reservoir storage. These programs are described in more detail below.

Energy and Water Quality Management System (EWQMS). The District has built its own EWQMS system based on concepts developed by EPRI and the Foundation. The EWQMS program is used to optimize water quality, storage levels, and available pump efficiencies to achieve the lowest energy cost per MG of water delivered, while maintaining water quality.

Solar Energy. The District has installed 3.1 MW of solar panels at seven of its reservoir sites to supplement peak electrical loads.

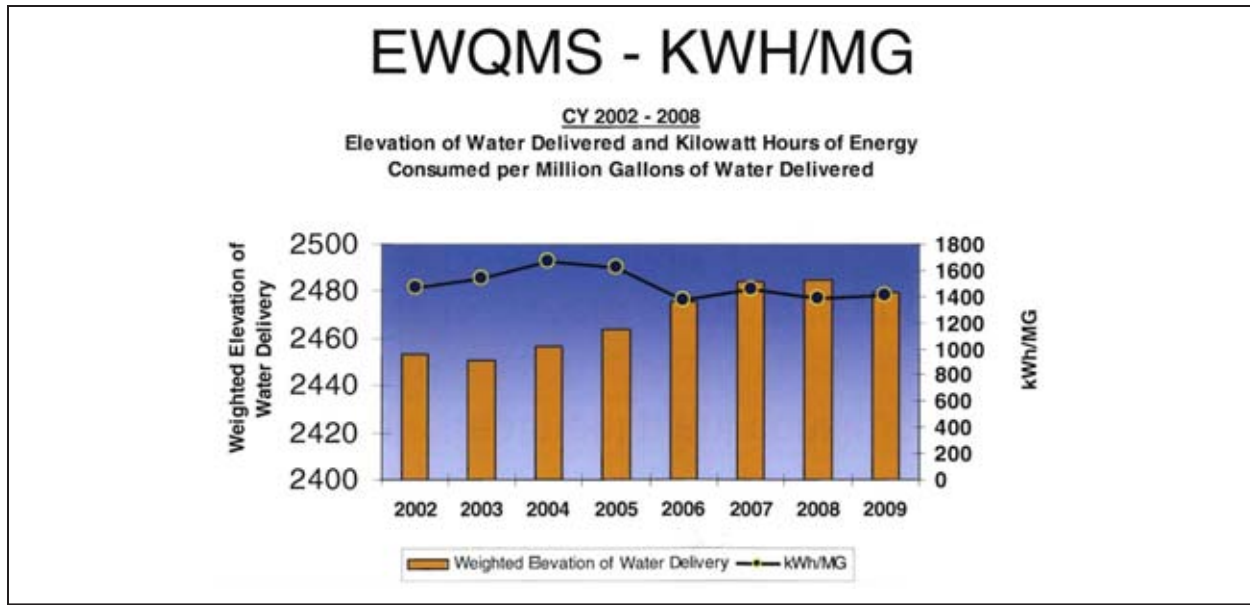
SolarBee® Reservoir Mixers. Most of the zone reservoirs have mixers to reduce stratification and improve water quality. The old style mixer was very high maintenance and used 10 HP motors. These have been replaced with SolarBee® mixers that draw only 1/20 HP.

Minimize Reservoir Storage. Monthly reservoir storage tables have been produced using minimum storage required for fire safety, demand, and water quality. These tables are used to minimize the pumping required per day. For example the reservoirs might be nearly full in the summer and only half full in the winter.

Building Temperatures. Almost all District pump station buildings are not staffed. Building temperatures are monitored by the SCADA system, and alarms have been set to monitor temperatures when maintenance work is finished, such that summer-time building temperatures are kept at the highest temperature possible without damaging equipment but not for human comfort.

Pump Performance Monitoring. Pump performance data such as flow, pressures, and energy are monitored by the SCADA system and stored in a process-information history database for future analysis. The District uses the pump performance data to evaluate pump performance which greatly reduces the need for expensive on-site pump testing. The District then compares the net present value (NPV) of pump performance degradation to the NPV of pump repair cost to determine which pumps are economically justified to repair.

Well Pump Optimization. Because of varying pumping water levels throughout the Las Vegas Valley service area, there can be significant differences in energy cost to deliver water. Not only does the water level vary by location, but also through the well pumping season. To determine the most cost effective wells, the District monitors production and energy consumption for each



Source: Las Vegas Valley Water District.

Figure 4.5 kWh/MG compared to delivery elevation centroid 2002–2008

well. The data is then used to determine which combination of wells will deliver the lowest energy cost per MG.

Water Loss. The District has a comprehensive leak detection program using the Permalog™ Logger System and traditional acoustic leak correlators. The Permalog™ units listen at night for leaks and then radio alarms to a monthly patrol vehicle. Acoustic geo-phones and/or leak correlators are then used to verify and locate the actual leak.

Change(s) Implemented and Results

Energy and Water Quality Management System (EWQMS). Figure 4.5 shows how the overall energy per MG (kWh/MG) has been reduced since 2006 even though the delivery elevation centroid has increased. Since 2007, the energy cost per acre-ft has decreased from \$132/acre-ft (1,574 kWh/acre-ft) to \$111/acre-ft (1,318 kWh/acre-ft).

Solar Energy. The District uses at least 50 percent of the 3.1 MW solar power generated onsite while the remaining energy is returned to the grid. For the 12 month period ending June 20, 2010, the District received over \$1.2 million in solar return credits.

SolarBee® Reservoir Mixers. The 34 installed SolarBee® mixers have resulted in saving \$65K per year in maintenance, and \$115K per year in energy cost.

Minimize Reservoir Storage. Any water pumped to a reservoir will eventually be used, however as the reservoir level is increased the pumps have to work against higher head which increases pumping costs. Tables have been developed to indicate ideal levels based on usage, security level and time of year.

Building Temperatures. By maintaining pump-station buildings that aren't staffed at temperatures suitable for equipment (90 degrees F in the summer) instead of human comfort levels, the District estimates its 2009 savings to be nearly \$125K.

Pump Performance Monitoring. In 2009, booster pump performance was analyzed for all pumps over 5 years old. For each pump, the potential annual energy savings was calculated based on measured efficiency compared to as new efficiency. The potential annual efficiency savings were then compared to the estimated rebuild cost. Pumps were prioritized for repair based on simple payback. Rebuilding 7 top priority pumps resulted in over \$30K/year in energy savings. The 10 year net savings (including repair cost) are projected to be \$103K.

Well Operation Optimization. In 2009, choosing to operate the lowest energy cost per MG wells has saved the District nearly \$115K (12 percent) compared to the same period in 2008.

Water Loss. The cost of the water leak detection program has been \$2.7M. This includes the data loggers, vehicles, and staffing. The program is expected to have a 15-year payback based on reduced water and associated reduced energy consumption.

Special Staff or IT Needs or Other Considerations

These projects have all been accomplished using District staff. Some additional training has been necessary to learn new systems or equipment. SCADA and process-information historian data have been essential tools for monitoring and analyzing process data.

Lessons Learned

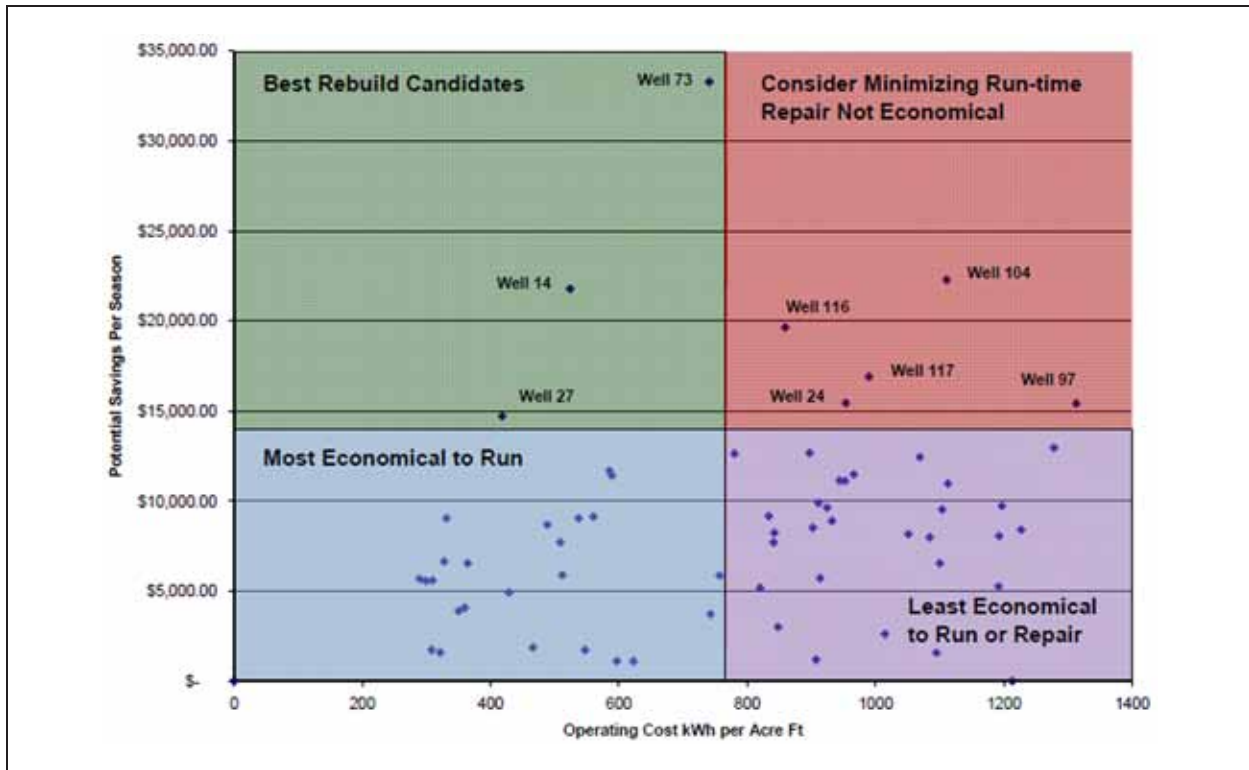
SCADA systems generate enormous amounts of data. To make use of this data requires operations, engineering, and database management skills. It is therefore essential that the engineers, operations, and IT people communicate what needs to be measured, and how the results should be calculated.

Focus on the objective—deliver quality water at the lowest overall cost. For years the District measured individual booster pump and well pump performance and made repair decisions based on pump performance degradation. The objective was to have the most efficient pumps, which is not necessarily the same as delivering quality water at the lowest cost. For example, the booster pumps all have comparable lifts, so having more efficient pumps will indeed achieve the objective. However, since the well pumps have significantly different pumping water levels, the most efficient pump may still be the most expensive to operate. By focusing on the objective, it was determined the best well-pump optimization method was to simply run the wells that had the lowest energy use per MG produced. Individual well pump performance is still evaluated and a performance/operating cost matrix (Figure 4.6) is used to determine which well pumps would be the most beneficial to repair.

Good ideas can come from anywhere/body in the organization. Don't dismiss an idea as foolish, or accept an idea as being great without evaluating it further. When possible, make decisions based on lowest life-cycle cost between alternatives.

Conclusions

Energy efficiency programs must have leadership and full management support. Some of the programs are expensive to implement but will lead to savings over time. Saving energy is a continuing project that does not end with the first report.



Source: Las Vegas Valley Water District.

Figure 4.6 Well pump decision matrix—operating cost vs. potential energy savings if rebuilt

Metro Vancouver/Greater Vancouver Water District, BC, Canada

	Plant Improvements and						
Management Tools	Management Changes	Water Treatment	Water Distribution	Water Conservation	Alternative/Renewable Energy Sources	Financial Assistance	Partnerships
	✓		✓			✓	✓

Background on the Water System and History of the “Issue”

The Greater Vancouver Water District (GVWD), which is part of the regional district of Metro Vancouver, supplies drinking water to 2 million people and associated businesses in 22 member municipalities in British Columbia (BC), Canada. Metro Vancouver’s water utility is one of the largest in North America. The three main reservoirs, Capilano, Seymour, and Coquitlam are protected by 585 square kilometers of mountainous land that is closed to public access. These large supply lakes collect water from snowmelt, creeks, and streams that are the water source for the Lower Mainland municipalities. All three reservoirs are dammed to impound water and provide releases to the drinking water system and to downstream rivers for fish and wildlife resources. Water is delivered through 550 kilometers of water mains, 22 peaking reservoirs, and 16 booster pump stations. Currently ozone and UV disinfection are used to treat the Coquitlam source water.

Chlorine is used as the primary disinfectant for the Seymour and Capilano reservoirs although a filtration plant is currently under construction. Once complete, this facility will treat 1.8 billion liters of water each day. Due to the low mineral content in the raw water sources, small amounts of soda ash (sodium carbonate) is added to the finished water for corrosion control in the distribution system.

Drivers for Improvement. Although Metro Vancouver's average annual water rate, at \$2.27/kgal, is one of the lowest in the industrialized world, Metro Vancouver is being driven by several key initiatives to improve its operations and enhance its water and energy efficiency efforts. The ultimate goal is for Metro Vancouver to be the greenest region in the world by 2020. To help meet this goal, in 2002, Metro Vancouver adopted the Sustainable Region Initiative (SRI) as its framework for decision-making as well as the mechanism by which sustainability principles are moved from ideas into action. The SRI has three sets of operating principles:

- Protect and enhance the natural environment
- Provide for on-going prosperity
- Build community capacity and social cohesion

From an energy perspective, the goals are to conserve energy and identify and use new renewable sources of energy. The SRI also includes goals for reducing GHGe. Initiatives to reduce energy use, recover energy from existing systems, and switch to cleaner energy sources all contribute to the GHGe goals.

To help define and implement the SRI, Metro Vancouver's Drinking Water Management Plan (DWMP) was adopted in 2005. The goals of the plan are to:

- Provide clean, safe drinking water
- Ensure the sustainable use of water
- Ensure the efficient supply of water
- Manage and protect the watersheds that provide the region's water as natural assets

The region is moving toward managing water by encompassing the full water cycle. This means considering the relationships among stormwater, drinking water, and liquid waste which have traditionally been treated as separate aspects of water management. Although the leakage rates in the water system are reasonably low, the plan takes further action to cost-effectively reduce leakage, thereby lowering energy used for pumping while simultaneously improving service levels. To further reduce resources and energy needed to operate the water treatment and distribution system, the DWMP also includes actions to match water quality usage requirements by assessing alternative sources of water (rainwater, grey water, and wastewater) for non-potable use. Additional actions such as eliminating once-through cooling water; requiring water efficient fixtures in new construction and renovations; implementing leak identification and repair programs; enforcement of the Water Shortage Response Plan; developing residential water metering programs; establishing municipal rebate programs for water efficient fixtures and appliances; and assessing the merits of standardized industrial, commercial, and institutional water audits for the largest 25 percent of business users to initiate water conservation improvements are all part of the DWMP.

Design elements of the new filtration plant include a unique geothermal heating/cooling system installed beneath a 200 million liter water reservoir, providing an alternative to electric resistance and natural gas heating. This application is planned to be featured as a demonstration

project through BC Hydro's Power Smart program, for consideration in other municipal projects. A life cycle cost comparison of different ultraviolet (UV) disinfection technologies was used to confirm the selection of energy efficient systems, which have higher capital costs, but longer term operational efficiencies. The project will also recover energy through an electrical turbine generator, which will be used to offset approximately 40 percent of the energy requirements of the new pumping system for moving water to the new filtration plant.

Type and Size of the Process or Technology Evaluated

Opportunity for Improvement Through Partnership. Metro Vancouver obtains its electricity from BC Hydro which provides electricity to 94 percent of BC. The BC Energy Plan, released in February 2007 highlights two actions directly influenced by demand-side management:

- Fifty percent of BC's incremental power needs will be through conservation by 2020
- BC will strive for electricity self-sufficiency by 2016

To help meet these goals and reduce energy consumption at Metro Vancouver's water system, the GVWD partnered with the Power Smart Division of BC Hydro. The Power Smart Partner Program provides eligible organizations with the opportunity to partner with BC Hydro and gain access to a variety of tools and resources to become more energy efficient. Two key tools available are energy studies and incentives. An energy study is usually performed by a consultant to identify and calculate energy savings at a particular site. Upon completion of the energy study, the customer can apply for incentives to cover partial cost of implementing the energy saving measures. Incentive money is calculated based on kilowatt hours per year (kWh/yr) savings, capital cost of projects, and effective measured life (EML) of the technology. These figures are run through a financial calculator, and a BC Hydro incentive amount is offered. The maximum funding that BC Hydro will offer is 75 percent of the total capital cost. The most favorable projects have a 5- to 10-year payback.

Metro Vancouver partnered with BC Hydro to study, fund, and implement pumping improvements at two of the pump stations within the drinking water distribution system, saving the region energy and saving residents money by reducing pumping costs. The energy savings during off-peak times at two pump stations—Central Park and Cape Horn were evaluated (see [Figures 4.7](#) and [4.8](#)).

These pump stations were built in the mid '70s and use fixed speed motors. Energy savings was not a consideration in their original design. Both pump stations operate in the winter to improve water quality in the reservoirs from which they pump. This winter pumping corresponds to BC Hydro's peak electrical demand season. Based on the initial analysis it was decided to use demands downstream of the Central Park pump station to cycle the reservoir—eliminating all pumping; and to use the low motor speed at the Cape Horn pumping station during the off-peak times to save electrical energy.

Change(s) Implemented and Results

In 2000, the annual energy costs for both sites were \$400,000. In 2007, the costs were \$930,000. Hydraulic modeling was used at both stations to validate operating strategies. At Central Park, the model was used to look at the downstream hydraulic grade line and its impact to municipal



Source: Photograph provided by BC Hydro.

Figure 4.7 Central Park pump station



Source: Photograph provided by BC Hydro.

Figure 4.8 Cape Horn pump station No. 1

members. At Cape Horn pump station No. 1, the model was used to look at valve operations to determine the proper resulting hydraulic grade line to use low speed pumping. After the equipment was tested and found to be operational, the two pump stations began operating under the new strategies in March/April 2009.

The results from the Cape Horn test showed a reduction in energy usage from 90,000 kWh using the motor high speed to 65,000 kWh using the motor low speed over 20 days of usage. Evaluation at the Central Park pump station reservoir level confirmed that there was no decrease in water quality with the switch from pumped to gravity feed. The projected energy savings is estimated to be 548,000 kWh per year. The cost savings for both pump stations over nine months is projected to be \$98,000, which includes both electrical demand and energy savings.

The next steps are to automate additional valves in the system to give the operators more flexibility in running energy savings scenarios, provide smart logic into the SCADA system to

assist in these operational strategies, and to continue to look for electrical energy cost savings at other Metro Vancouver sites.

Special Staff or IT needs or Other Considerations

While no specific system improvements such as new pumps or piping were needed to implement the strategy, it was definitely necessary to bring together key internal and external expert stakeholders to develop early “buy-in” to the changes. Internal staff “buy-in” and willingness to coordinate efforts and try new ideas was key to success. As Metro Vancouver moves to install additional automatic valves in the system and “smarts” into the SCADA system, some IT needs may be identified.

Lessons Learned

A number of important lessons were learned during this project. They include:

- It takes energy (time and resources) to save energy
- Willingness to try new ideas is important, despite the risks to system operation and to costs
- Perseverance is needed to keep projects moving
- It is important to engage partners that are willing and eager to approve, help fund, and provide data for such a project—in this case, the electricity utility, BC Hydro

Conclusion

The partnership between Metro Vancouver and BC Hydro was very important to implementing this project. Bringing in experts was important for developing “buy in” from Metro Vancouver staff. Willingness to devote staff resources to analyzing and making operational changes was much more important than committing funding to the project—other than staff time, the project had no costs.

Mohawk Valley Water Authority, NY

	Plant Improvements and Management Changes	Water Treatment	Water Distribution	Water Conservation	Alternative/Renewable Energy Sources	Financial Assistance	Partnerships
Management Tools					✓	✓	

Background on the Water System and History of the “Issue”

The Mohawk Valley Water Authority (MVWA) serves 130,000 people through 38,975 service connections. The water is treated via a 32 MGD water filtration plant and disinfected with chlorine. The water is also fluoridated and lime and soda ash are added to reduce the corrosiveness of the water.

In 2008 the MVWA produced approximately 6.5 billion gallons, with an average of 17.9 million gallons treated per day, with a single day high of 18.6 million gallons.

The MVWA receives its water from the New York State-owned Hinckley Reservoir, which is fed by streams and creeks in a remote 373 square mile Adirondack Mountain watershed, far from settled areas and farmland.

The MVWA spends approximately \$390,000 per year for electricity and \$54,000 per year for natural gas. Electric power, currently purchased from National Grid, is mostly consumed by pumping equipment, with additional usage for items such as lighting and control equipment. Natural gas is utilized mainly for space heating.

Type and Size of the Process or Technology Evaluated

The raw water is delivered to the treatment plant and from the plant to the distribution system almost entirely by gravity. In 1992, as part of a major upgrade to its water treatment facility, the MVWA identified an opportunity to utilize the excess head from its gravity system to generate electrical energy to help operate its facilities while saving energy costs. As part of the plant upgrade, two hydroturbines were installed upstream and downstream of the water treatment facility. The hydroturbines, which are primarily used to power three blowers at the treatment facility, are capable of generating 450 kilowatts (kW) of power. Excess energy is sold under a power sharing agreement with National Grid.

In 2009 the MVWA initiated an evaluation, conducted by Wendel Duchscherer and partially funded (50 percent) by NYSERDA, to assess the feasibility of adding additional hydroturbines to power the recirculation pump at the MVWA's new Deerfield storage tank by replacing existing pressure reducing valves (PRVs) used to reduce excessive pressures throughout the system. The hydroturbines are used to convert the excess pressure with turbine blades to power an electric generator. The electricity generated can be used to power onsite equipment or the excess sold to offset current electrical costs.

As part of its efforts to comply with the recently enacted federal and state Long Term 2 Surface Water Treatment Rule, MVWA recently constructed a new 10 MG enclosed water storage tank at its Deerfield Reservoir site. As part of the operation of the tank and to help with control of disinfection byproducts, MVWA included a recirculation pump (see [Figure 4.9](#)) to feed fresh water into the tank. This ensures that the water in the tank does not sit for extended periods of time, leading to undesirable water characteristics. As part of the project, a hydroturbine/generator was coupled directly to the recirculation pump to power continuous operation of the pump. The turbine was sized to provide approximately 25 kW of power or 202,000 kWh/yr, to meet the power requirements of the recirculation pump.

The study also recommended that hydroturbines/generators be installed at the Marcy Regulator House to take over the function of existing PRVs while generating electricity for sale. The energy of the flowing water is used to spin turbine impellers connected to an electric generator. At the same time, the capture of the energy of the water reduces pressures downstream of the turbine. The Marcy Regulator House contains two sets of 16-inch and 12-inch PRVs that serve two separate pressure zones (Intermediate and Low Zones). Each Zone would have a pair of turbines assigned, with one designed to run at the base design flow and the second when the high design flow is reached (see [Figure 4.10](#)). In the Intermediate Zone where flows typically range from 1 to 2 MGD, the first turbine would come online at 1 MGD and produce 21 kW of power, with the second turbine producing another 21 kW of power when flows reach 2 MGD for a total capacity of



Source: Picture taken by MVWA and included in NYSERDA's Technical Assistance Study, PON 963, prepared by Wendel Duchscherer.

Figure 4.9 Recirculation pump



Source: Picture taken by MVWA and included in NYSERDA's Technical Assistance Study, PON 963, prepared by Wendel Duchscherer.

Figure 4.10 Hydroturbines

Table 4.5
Deerfield Reservoir Control Building measure summary table

Mohawk Valley Water Authority Project No.: 4803-02
 16-Oct-09

Savings		
Average demand savings	0.0	kW/month
Electrical energy savings	202,138	kW/year
Fossil fuel savings	0	mmBtu/year
Operational & maintenance savings	(\$300)	Per year
Energy savings	\$40,094	Per year
Total energy & O&M savings	\$39,794	Per year
Project costs		
Total measure cost	\$75,000	
Payback		
Simple payback	1.9	Year(s)
Potential incentives	\$0	
Simple payback with incentives	1.9	Year(s)

Source: Table of savings prepared by Wendel Duchscherer for NYSERDA Technical Assistance Study PON 963.

42 kW. In the Low Zone, flows reach 3.65 to 7.3 MGD, with corresponding power outputs of 32 and 64 kW (96 kW total) possible. Based on the estimated annual operating hours of each PRV it was predicted that more than 812,000 kWh of electricity could be produced annually.

Change(s) Implemented and Results

Since 1992 the MVWA has benefitted from the hydroturbines at the water treatment facility which generate approximately 450 kW of power, and are primarily used to power three blowers at the treatment facility. This provides the MVWA with approximately 2 million kWh/yr, saving approximately \$120,000 per year in energy costs.

Based on the findings of the NYSERDA Technical Assistance Study, it was recommended that the Deerfield hydroturbine/generator be put into service. Simple payback calculations show that the measure would pay for itself within 1.9 years and thereafter, save the MVWA approximately \$40,000 per year at current utility rates (see [Table 4.5](#)). This system would be stand alone and no interconnection to the utility distribution system would be necessary.

Replacing existing PRVs, used to reduce excessive pressures at the Marcy Regulator House, with hydroturbines to convert the excess pressure with turbine blades could power an electric generator. The electricity generated could be sold to offset current electrical costs, potentially saving the MVWA more than \$28,000 a year in energy costs (see [Table 4.6](#)).

Special Staff or IT Needs or Other Considerations

The MVWA did not identify any specific additional skill sets needed to implement operation of the hydroturbines, however, annual preventative maintenance of the units is contracted out to an outside company.

Table 4.6
Marcy Regulator House measure summary table
 Mohawk Valley Water Authority Project No.: 4803-02
 20-May-09

Savings		
Average demand savings	0.0	kW/month
Electrical energy generated	812,490	kW/year
Fossil fuel savings	0	mmBtu/year
Operational & maintenance savings*	\$300	Per year
Energy savings/revenue	\$27,733	Per year
Total energy & O&M savings	\$28,033	Per year
Project costs		
Total measure cost	\$563,391	
Payback		
Simple payback	20.1	Year(s)
Potential incentives	\$1,141	
Simple payback with incentives	20.1	Year(s)

Source: Table of savings prepared by Wendel Dushscherer for NYSERDA Technical Assistance Study PON 963.

*Savings based on existing O&M cost of \$3,000; O&M costs after new equipment is installed will be only \$2,700.

Lessons Learned

It is critically important to understand how the hydraulics of the system are impacted by the operation of the hydroturbines, including the development of emergency procedures, such as bypass capabilities. With sufficient annual preventative maintenance, these units are virtually trouble free, providing “free revenue” to the utility.

Conclusion

The MVWA has effectively utilized the generation of electrical power from hydroturbines for over 16 years to reduce energy demand and costs. MVWA has used these renewable power sources to power three blowers at its water treatment facility, saving approximately \$120,000 a year.

By installing a hydroturbine/generator at its new storage tank at its Deerfield site and coupling the turbine/generator directly to the recirculation pump, MVWA will be able to provide electricity for continuous operation of the pump.

Additional energy savings are possible with the further replacement of PRVs with hydro-turbine/generators throughout the distribution system. The first of these to be considered is at the MVWA’s Marcy Regulator House, at which two sets of PRVs may be replaced with hydroturbines/generators, with the resulting electricity sold to generate revenue for the MVWA (see [Table 4.7](#)).

Table 4.7
Strategy of energy savings

Measure description	Measure status	Fuel type saved	Energy saved (kWh)	Energy saved (kW)	Annual dollars saved	Estimated costs for implementaion	Simple payback period (years)
Deerfield Reservoir control building hydro turbine	Implemented	Electric	202,138	—	\$40,000	\$75,000	1.9
Marcy Regulator House hydro turbine	Recommended	Electric	812,490	—	\$28,000	\$563,400	20.1
Total			1,014,628	—	\$68,000	\$638,400	9.4

Source: Table of energy savings prepared by Wendel Duchscherer for NYSERDA Technical Assistance Study PON 963.

Monroe County Water Authority, NY

Plant Improvements and Management Tools	Management Changes	Water Treatment	Water Distribution	Water Conservation	Alternative/Renewable Energy Sources	Financial Assistance	Partnerships
			✓			✓	✓

Background on the Water System and History of the “Issue”

Monroe County Water Authority (MCWA) is the third largest water provider in New York State, producing an average of approximately 59 MGD for homes and businesses in Monroe, Genesee, Ontario, Wayne, and Orleans Counties. The average summer demand is 69 MGD, and the average winter demand is 56 MGD. The primary water source is Lake Ontario, which is treated at the Shoremont Filtration Plant. In addition, MCWA purchases water from the Town of Ontario, the City of Batavia, the City of Rochester, and the Erie County Water Authority. The Shoremont Plant water and the purchased water is all treated by coagulation, filtration, and disinfection. Chlorine is used for primary and secondary disinfection. Fluoride is also added to help prevent tooth decay. An additional water treatment plant for a small well supply in the Village of Corfu consists of filtration, softening, and disinfection with chlorine.

MCWA’s water is pumped from the treatment plants to storage facilities and customers in the water system service area through approximately 200 miles of major transmission mains, ranging in diameter from 16" to 60", and approximately 2,350 miles of distribution mains, ranging in diameter from 2" to 12". The water system operates 34 booster pumping stations to provide adequate pressure to distribute water to storage facilities and customers. The system includes two finished water reservoirs and 45 other finished storage facilities with an aggregate capacity of 145 million gallons (MG). All customer service connections are equipped with meters owned by the Authority.

MCWA has long recognized the large impact of energy cost on the utility’s budget (about \$4 million per year, or 35 to 40 percent of the total O&M budget), and in the 90s took advantage of special negotiated rates with Rochester Gas and Electric Company (RG&E), and efficient

motor rebates with NORESCO. These efforts accelerated in 2000 with the formation of an Energy Committee to investigate additional ways MCWA could cut energy costs and improve efficiency. The utility more closely evaluated how water could be moved around the system more efficiently because the service area was expanding and another treatment plant had been added in 1998. A significant step came in 2003 when the utility discovered the load shedding program offered by New York State. The company that managed the utility's load shedding at the time coordinated the installation of power monitors at all of the pump stations, largely paid for through a grant from NYSERDA. Once the utility had access to real-time power monitoring, the ability to assess and track pumping efficiency greatly improved.

Soon after starting widespread pump efficiency testing, utility staff noticed how rough and tuberculated the insides of some pumps were, and how much this seemed to affect efficiency. Staff started experimenting with epoxy coatings to protect and smooth out the inside of pumps, and based on the promising results, secured a large grant from NYSERDA to conduct an expanded study involving 18 pumps of various sizes. Preliminary analyses indicated that the coatings appeared to increase efficiency by nearly 10 percent on average.

The utility also investigated ways that variable frequency drives (VFDs) on pumps could save energy, and applied for NYSERDA rebates toward the purchase of those new drives. In addition, the utility developed pumping strategies that tried to minimize pumping during high rate periods and avoid demand charges. This is becoming more important as the differential between peak and off-peak rates grows. These efforts are discussed in more detail in this case study.

Other ongoing efforts include:

- Reviewing electric bills (MCWA has identified nearly \$200,000 in erroneous charges);
- Evaluating more efficient ways to move water around the system;
- Detecting large leaks using system data then finding and fixing them; and
- Looking for new funding opportunities from NYSERDA or other organizations.

Type and Size of the Process or Technology Evaluated

The relatively large finished water storage capacity of the MCWA system gives the utility some flexibility to pump and store water before it is needed. MCWA worked with NYSERDA and others to take advantage of this flexibility to reduce energy usage and costs. MCWA participated in NYSERDA's New York Energy SmartSM Peak-Load Reduction Program, designed to reduce energy costs and improve electric system reliability by providing incentives that encourage summer-peak electricity demand reduction. Peak demand electricity pricing increases energy costs; as a result, water utilities look for more efficient technologies to run the large motors and pumps used in their systems. Peak demand costs can contribute significantly to the total operating cost of the facility.

MCWA plant managers knew that they were financially penalized when they started their large hp motors "across-the-line," which applies full line voltage to all of the motors. Starting the motors in this manner was especially costly during the peak times of the day when electrical rates increased. A more efficient approach is to use VFDs, a proven method of automatically controlling the speed of the pump motor. This enables the pump to start and stop at lower speeds, and reduces pump cycling by matching the appropriate pump speed to the demand.

MCWA depends on more than 100 centrifugal pumps with a total installed capacity of 35,000 hp (Verosky et al. 2008). The pumps range from 5 to 1750 hp and consume an average of

5 megawatts (MW) of power per day. Results of computer modeling of the MCWA distribution system showed that many of the pumps were not operating according to their manufacturers' pump curves. MCWA went into the field and measured each pump's performance (head, flow, kilowatt (kW), and RPM) and used the information gathered to develop field pump curves. When the field pump curves were compared with the original manufacturers' pump curves, it became apparent that most pumps were not operating at their most efficient point. Pump efficiencies measured in the field were lower than the manufacturers' stated efficiencies, often by 20 percent or more. Based on these findings, MCWA proceeded with a major effort to refurbish, sandblast, and coat the interiors of the pump casings.

Change(s) Implemented and Results

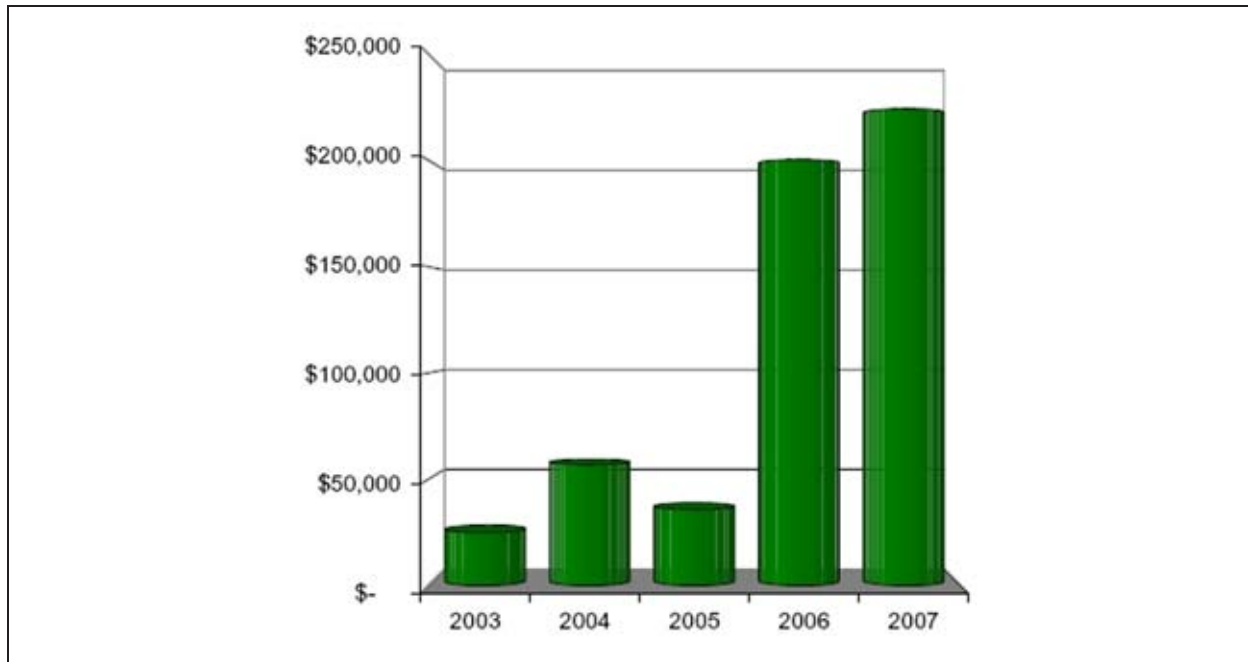
Load Shedding Program. An electrical load shedding program is run by the New York State Independent System Operator (NYISO). NYISO runs the power grid for the State, and is willing to pay customers to shed load during peak demand periods, rather than risk overloading the power grid. Load shedding is accomplished by shutting down as many pumps throughout the water distribution system and treatment plant as possible without undue risk to the system and relying on stored water during that time to meet demand.

MCWA has participated in the load shedding program since 2003 and earned \$568,288 in credit through 2007 on its monthly electric bills (see [Figure 4.11](#)). In 2008, MCWA earned \$255,372 in credit. Each season, there is a test event for participants to demonstrate that they are able to shed the amount of load pledged. To date, MCWA has been able to pass all tests.

MCWA contracted with an independent consultant to conduct a technical assessment of the utility's load shedding potential. The key recommendations resulting from the assessment were to:

- Install real-time electric meters at each pump location to determine energy usage and verify actual reduction during an energy curtailment.
- Integrate electric meters with pump scheduling and optimization software to analyze water demand and storage during a load shedding event to ensure adequate water supply.

Install Variable Frequency Drives. MCWA's Lee Road Pump Station pumps an average of 19 MGD of treated water to customers and storage tanks. The original system at the Lee Road Pump Station had five medium voltage motors, ranging from 400 to 700 hp, and all were started across-the-line (at full line voltage). MCWA uses a combination of pumps to achieve a flow rate of 10,000 to 20,000 gallons per minute to fill storage tanks for use during periods of high demand. Often, the combination of motors either pumped too much or too little, so the motors and pumps were cycling several times a day to produce the needed volume. Water consumption over the day can vary significantly and may peak at 24,000 gallons per minute during the early morning on some days. The challenge for MCWA was to try to manually calculate the proper combination of pumps and determine the best time of day to use them, based on the varying flow requirements. In trying to meet a high instantaneous demand, MCWA would frequently have to run the 700 hp motor at peak times of the day. This resulted in peak demand charges as well as stress on the motor and equipment. The need to reduce these energy costs, along with a NYSERDA incentive program, motivated the MCWA to upgrade its 700 hp centrifugal pump and motor with a VFD. The NYSERDA program gives rebates to companies applying energy efficient technologies. MCWA



Source: Monroe County Water Authority.

Figure 4.11 Revenue earned by MCWA from the NYISO electrical load shedding program through 2007

invested in a VFD for one of its centrifugal pumps and achieved annual energy savings of over \$23,000, plus the \$17,500 NYSERDA rebate.

A VFD provides energy savings and flow control capability. MCWA installed an Allen-Bradley® PowerFlex® 7000 750 hp 4160V medium voltage VFD with active front end (AFE) rectifier. The PowerFlex 7000s configuration, which included high reliability and efficiency, a simple design, low component count, compact size for minimal space requirements, and low harmonics generation were attractive features. Because of the small footprint, MCWA did not have to build any additional structures or expand to house the VFD. The general design and component layout also make it maintenance friendly and easy to work on. The integral isolation transformer saved space in the control room and was key to retrofitting the existing motor, which saved MCWA the cost of a new motor and installation.

MCWA now runs the 700 hp motor more consistently, but at a lower speed to achieve the needed volume that two pumps in combination used to provide. The VFD ramps up the motor more smoothly to prevent motor wear and allows the motor and pump to run only when necessary, saving thousands of dollars a year in energy costs.

Prior to the VFD installation, the system used 590 kW per month, with electrical costs of \$278,000 annually. After installation, the system used only 360 kW per month, at a cost of \$255,000 annually. As mentioned, NYSERDA also issued a rebate of \$17,500 to MCWA for their energy savings solution. The VFD pump has saved MCWA approximately \$23,000 annually through reduction in energy use and demand charges. The water authority expects payback in approximately three years. Due to the success of the first installation, MCWA has moved ahead



Source: Monroe County Water Authority.

Figure 4.12 MCWA pump interior before (left) and after (right) sandblasting and coating

with a second phase contract for a 1250 hp PowerFlex 7000 VFD on a centrifugal pump at the main treatment plant.

Pump Maintenance, Refurbishment, and Coating. Results of computer modeling of the MCWA distribution system showed that many of the pumps were not operating according to the manufacturers' pump curves. MCWA went into the field and measured each pump's performance (head, flow, kW and RPM) and used the information gathered to develop field pump curves. When the field pump curves were compared with the original manufacturers' pump curves, the field curve was below the manufacturer's curve for almost every pump tested. Pump efficiencies measured in the field were lower than the manufacturers' stated efficiencies; often by 20 percent or more.

In response to these findings, MCWA refurbished the pumps that were operating at the least efficient rates. Many of the internal components were replaced (e.g., rings, sleeves, seals, gaskets, bearings). This improved pump performance some, but not enough to return them to the manufacturers' specifications for head, flow, and efficiency. Some of the refurbished pumps were then sandblasted and coated with an NSF-approved brushable type ceramic-filled epoxy coating (see [Figure 4.12](#)). Pump efficiency increased by greater than 8 percent as a result of the sandblasting and coating efforts; overall performance of these pumps was returned to the original manufacturers' pump curve specifications. MCWA found that traditional mechanical refurbishment alone only recovered approximately half of a pump's total lost performance and efficiency. In order to fully restore a pump's performance, sandblasting and coating of the interior pump casings was required.

The MCWA estimates that if all of its 100 pumps were mechanically refurbished, sandblasted, and coated, MCWA could realize annual energy cost savings in excess of several hundred thousand dollars.

Special Staff or IT Needs or Other Considerations

As part of the contract for the VFD installation, MCWA specified utility staff training and start-up assistance. Four MCWA employees attended a one-week Global Manufacturing Solutions Drive maintenance and troubleshooting school in Ontario, Canada.

Lessons Learned

- **Take advantage of available funding programs.** MCWA aggressively pursues outside funding for energy projects. For example, NYSERDA is contributing 75 percent (\$121,000) of the project costs for rehabilitating and coating pumps in the MCWA system. NYSERDA has also contributed over \$120,000 for additional energy saving projects over the last five years.
- **Save energy through pump maintenance and conditioning.** Proper upkeep of all pumps will reduce energy costs. For MCWA, energy costs were reduced even more significantly by sandblasting and coating the interior pump casings.
- **Take advantage of the flexibility offered by a system's extra capacity.** If a water utility has sufficient finished water storage, the utility should review and optimize pumping operations to reduce pumping during hours of peak energy demand. This can provide significant cost savings.
- **Install VFDs to reduce energy usage during pump start and stops.** A VFD allows a pump to ramp up and down at a slower speed which requires less electricity. Installation of VFDs on multiple pumps can result in energy savings for the utility.
- **Identify energy and cost savings with real-time monitoring.** Real-time monitoring improves a water utility's understanding of pump usage patterns and pumping efficiencies. Monitoring can also help the water utility identify reduced water loss by identifying and addressing leaks in a timely manner. Direct measurement of pump performance and comparison to manufacturer pump curves provide key information for finding inefficient pumps.

Conclusion

MCWA has successfully reduced energy usage and achieved energy cost savings in its operation of the public water system. Despite generally increasing electricity costs, MCWA's unit pumping cost has decreased by over 15 percent over the last ten years. The utility's success was recognized with the presentation of the American Public Works Association's Management Innovation Award in January 2006. MCWA has taken an approach to improving energy efficiency that thoughtfully identifies ways energy is being wasted that can be addressed at reasonable costs; costs that pay for themselves in energy savings over a few years. MCWA has also successfully accessed available outside funding to defray the costs of these improvements.

New Jersey American Water, NJ

Management Tools	Plant Improvements and Management Changes	Water Treatment	Water Distribution	Water Conservation	Alternative/Renewable Energy Sources	Financial Assistance	Partnerships
					✓	✓	

Background on the Water System and History of the “Issue”

New Jersey American Water (NJAW) is a wholly-owned subsidiary of American Water (a private water utility) and is subject to regulation by the New Jersey Board of Public Utilities. NJAW is the largest investor-owned water utility in the State of New Jersey and serves over 2.5 million people in 35 public water systems and operates 173 treatment facilities. NJAW operates the Canal Road Water Treatment Plant (WTP) in Somerset, NJ. This plant was built in 1996 and was recently expanded to a capacity of 80 MGD. The Canal Road WTP treats surface water with conventional treatment and uses ozone for primary disinfection.

With increasingly stringent water quality standards and continually escalating electricity costs, American Water and NJAW began evaluating the potential for on-site, renewable power generation. In addition to concerns over rising electric power costs, American Water has a strong commitment to preserving the environment supported by its participation in a variety of environmental programs including:

- Maintaining Rodgers Refuge
- Enhancing biodiversity with the Audubon Society
- Improving water quality through River Friendly Programs
- Improving the riverbank in Delran
- Reducing air pollution with a “no idle” policy

These efforts further the attainment of NJAW’s Corporate Responsibility Goals.

Type and Size of the Process or Technology Evaluated

NJAW has an aggressive energy-reduction program to help reduce GHGe. This program includes regular energy audits of its facilities to identify cost-effective opportunities to decrease energy use and GHGe. These evaluations examine direct combustion (generators, boilers, furnaces, and fleet vehicles); pumps, motors, and lighting; and indirect emissions through purchased electricity. Through this program, NJAW evaluated the solar potential at a large, open site at the Canal Road WTP. This engineering and financial analysis resulted in what was at that time, the largest ground mounted solar photovoltaic (PV) array east of the Rocky Mountains. Two primary drivers for moving forward with the project were the rebates offered by the New Jersey Clean Energy Program and the sale of the renewable energy credits generated.

Change(s) Implemented and Results

In 2005, NJAW installed a 502 kilowatt hour (kW) direct current (dc) ground-mounted dual-array PV system at its Canal Road WTP. One array is located on the north side of the main building, and the other to the south. The installed system includes two 225 kW alternating current (ac) inverters, revenue-grade metering, and an internet-based data-acquisition system. The original solar array consisted of 2,871 solar PV modules, each rated at 175 watts for a total dc output of 502 kW. In 2007, the system was expanded by 87 kW (a 17 percent increase; see [Figure 4.13](#)) for an overall output of 590 kW. A third expansion of 109 kW dc was constructed on top of the filter basins in 2008 to increase the overall capacity of the site to 698 kW dc.



Source: New Jersey American.

Figure 4.13 Photovoltaic system at NJAW Canal Road WTP

The system provides power output to the WTP's 4,160-volt distribution network—all of the solar energy is used on-site. At the time of initial operation in October 2005, the solar array system was the largest ground-mounted system on the U.S. east coast.

The solar array currently supplements approximately 20 percent of the Canal Road WTP's peak usage; thereby, reducing the amount of electricity that NJAW must purchase from outside suppliers. The solar array has also produced a new revenue stream through the sale of tradable solar-specific renewable energy credits that electric marketers must acquire to meet the New Jersey Renewable Energy Portfolio Standard. The overall solar array facility provides an estimated annual savings of \$152,000. After a \$2.438 million rebate from the New Jersey Clean Energy Program, NJAW incurred approximately \$2.556 million in design and construction costs for the three systems. Additionally, they were able to take advantage of a 30 percent federal tax credit (10 percent of project cost). Based on the rebate and tax credit, NJAW projects a payback in less than 5 years.

NJAW installed a 99 kW solar PV system at the adjacent Raritan-Millstone Water Treatment Plant in 2008. There, the PV energy generated is used to power electric golf carts used for employee transportation around this large facility. This displaces the fossil fuels that would otherwise be used, saving the associated GHGe. The combined Canal Road and Raritan-Millstone PV systems have a generating capacity of about 800 kW. In 2008, these systems generated a total of 818,000 kWh of green, carbon-free electricity. This saved approximately 425 metric tons of carbon dioxide emissions (tCO₂e).

Special Staff or IT Needs or Other Considerations

To properly monitor and track the performance of the solar array system, an internet-based or other automatic data acquisition system is necessary. NJAW uses the internet-based data acquisition system to record PV output and compare it to the expected production. This comparison takes into account the solar irradiance, ambient temperature of the panels, and the local wind speed. Additionally, understanding of the O&M requirements is extremely important. The system

NJAW installed will require minimal maintenance except for the monitoring of the inverter to ensure proper control and operation.

Lessons Learned

NJAW learned three lessons during project planning, approval, and construction:

- It had to address the potential global shortage of solar panels to ensure the project remained on schedule.
- During the four-month planning approval process NJAW had to “educate” the County Planning Board on a new technology, and addressed review comments by local and state agencies.
- It had to address unexpected construction conditions as “shale” was encountered during installation of the array system that was unidentified in previous core-boring data. Through a quick response and decision making, no delays occurred to the project schedule and they were able to maintain the budget.

Conclusion

American Water has set an example to the community and has demonstrated its commitment to green energy. The solar array system supplements approximately 20 percent of the Canal Road WTP’s on-site peak usage, is operating better than expected, and has achieved higher than anticipated environmental benefits. The Raritan-Millstone PV system powers electric golf carts that provide carbon-free employee transportation around the plant. Additionally, through its aggressive energy-reduction program, NJAW has been able to control and impact its energy costs throughout all its facilities as electric power costs continue to increase. For example, American Water’s Energy Manager analyzes rate schedules and purchase options available for each of its systems. In some cases, significant savings have resulted from schemes that require active management of electrical consumption by water utility operators, something that is not common practice across the water industry. This trend is expected to increase with the adoption of more smart electric meters. Furthermore, NJAW recently completed a state-wide evaluation of 13 of its sites to determine the viability of solar and wind generators at those locations.

Queensbury Water District, NY

	Plant Improvements and						
Management Tools	Management Changes	Water Treatment	Water Distribution	Water Conservation	Alternative/Renewable Energy Sources	Financial Assistance	Partnerships
	✓		✓			✓	✓

Background on the Water System and History of the “Issue”

The Queensbury Water District (QWD) in New York provides drinking water directly to approximately 24,000 people through 180 miles of pipe, and five distribution storage tanks with a total capacity of 5 million gallons (MG). The QWD also wholesales water to consumers in the

Town of Moreau, the Village of Hudson Falls, and the Town of Kingsbury, for a total population served of approximately 35,000. QWD obtains its water from the Hudson River, a surface water supply that is located at the Sherman Island Dam. Water is pumped from the river to a conventional treatment facility consisting of the following: chemical pretreatment, coagulation, flocculation, sedimentation, pre-chlorination, filtration, post-chlorination, and corrosion control. The treatment plant is staffed 24 hours a day, 365 days per year under the supervision of two IA operators (the state's highest certification level).

Water demands at the QWD are substantially different between summer and winter conditions. Typical water usage during winter periods is 4.0 MGD, whereas summer usage increases to 7.5 MGD with maximum daily demands as high as 12 MGD. The average year-round usage is 5.7 MGD. QWD previously relied on two separate sets of high lift pumps to convey water from the plant's clearwell to the distribution system. Two 400 hp pumps were used in the winter time and two 700 hp pumps in the summer. The two 400 hp pumps were oversized for the lower winter demands, and were thus very inefficient in the use of energy, given the need to throttle back on delivery. Because of the higher summer demands; however, the existing larger 700 hp pumps can be efficiently used to convey water to the distribution system although problems occurred with overfilling the Luzerne Road Tank during off-peak pumping scenarios.

Type and Size of the Process or Technology Evaluated

An energy audit conducted in 2006 included on-site testing to determine the current performance characteristics of each pump; identification of hydraulic bottlenecks and potential operational improvements in the distribution system; and an assessment of energy conservation measures for raw and treated water pumping. In 2008, the QWD replaced the 400 hp high lift pumps with two 300 hp pumps and began to maximize the use of off-peak pumping. The new operations plan was implemented for the summer of 2009. Preliminary analyses indicated that the pump changes could result in an energy savings of approximately 473,500 kWh, while optimizing off-peak pumping could reduce peak demands by 363 kW. This could provide QWD with an energy cost savings of approximately \$42,000 annually.

In order to maximize off-peak pumping during the higher demand summer period, the QWD also installed an altitude valve (see [Figure 4.14](#)) on the Luzerne Road Tank that enabled the QWD to pump 11.5 MGD at night starting at 11PM. Without the altitude valve, such a pumping rate would have resulted in overflowing the Luzerne Road Tank by 3AM. Now, instead of overflowing the tank, it is closed before it over fills and the remainder of the water is diverted to tanks in another portion of the District. This pumping scheme enabled the system to optimize storage and maximize the use of off-peak pumping.

In addition to the change in pumps and the installation of an altitude valve at the Luzerne Road Tank, in 2009 the QWD began reducing energy consumption by transferring load to an on-site generator for a minimum of four hours, twice a year. The QWD expects to use its generator twice a year to generate approximately 500 kW in the summer and 250 kW in the winter. This will provide an annual revenue source to QWD of approximately \$4,500.

With these projects, QWD qualified for two different NYSERDA funding programs: the Enhanced Commercial and Industrial Performance Program and the Peak Load Reduction Program.

Enhanced Commercial and Industrial Performance Program. NYSERDA's Enhanced Commercial and Industrial Performance Program provides financial incentives for purchasing energy efficient equipment. The program offers three tiers of incentives for projects. Projects like



Source: Queensbury Water District.

Figure 4.14 Altitude valve at Luzerne Road Tank

pump replacement fall under Tier III—“Performance-based Incentives for Energy Efficiency.” Under this tier, the incentive rate is \$0.10 per kWh saved as a result of implementing cost-effective electrical energy efficiency measures. The reduction is the total load reduced over a twelve-month time period.

By replacing the existing 400 hp pumps with two new 300 hp pumps, all the non-summer pumping can be completed using these new pumps. Because there are now two 300 hp high lift pumps, the 700 hp pumps will be used as standby in the winter and only used intermittently to exercise the pumps. This will result in a reduction of approximately 473,500 kWh. At a \$0.10/kWh for every kWh reduced, NYSERDA has estimated that QWD may be eligible for up to \$47,350. NYSERDA has indicated that it will disburse the monies as follows: approximately \$24,000 will be issued up front and the remainder will be disbursed upon verification of actual kWh saved.

Peak Load Reduction Program. NYSERDA’s Peak Load Reduction Program provides financial incentives to reduce electrical usage during periods of peak electrical demand. The primary focus of this program is to improve the reliability of New York’s electric grid while helping businesses and industries reduce operating costs. This program offers incentives of \$50/kW of reduced demand to offset the costs of improvements. The incentives are offered to cover up to 65 percent of the project costs. Since the installation of the altitude valve at the Luzerne Tank will allow the Town to permanently reduce pumping operations during periods of peak electrical demand and increase pumping during low demand hours, QWD qualifies for the incentive under the Load Curtailment and Shifting portion of the Peak Load Reduction Program. Under this program the incentive is based upon the reduction in the peak demand from noon to 6:00 PM Monday through Friday during the six-month period from May to October. The installation of the new altitude valve will have its greatest impact during the summer months when the Town experiences its greatest water demand. Since the peak summer demand was reduced from approximately 681 kW to 318 kW resulting in a reduction in peak demand of approximately 363 kW, NYSERDA provided \$18,000 in reimbursements to the Town.

Change(s) Implemented and Results

Based on the variety of changes implemented, QWD has successfully reduced its energy demand and costs. These savings include:

1. Pump replacement: Estimated savings of \$35,000 annually, with a 4-year simple payback.
2. Altitude Valve: Estimated savings of \$12,500 annually, with a simple payback of approximately 2 years.
3. Contracted with Energy Curtailment Specialists, Inc. to reduce energy demand by utilizing emergency generator capacity twice a year to generate revenue for the QWD. Approximately \$4,500 in annual revenue is anticipated.
4. Applied for and received NYSERDA funding under the Enhanced Commercial and Industrial Performance and Peak Load Reduction Programs.

Six months after the installation of the new pumps, trending data indicates that a savings of approximately 473,000 kWh will be achieved for the entire year (6/09 to 5/10).

Special Staff or IT Needs or Other Considerations

The QWD did not require any additional staff or expertise to implement the recommended changes. However, the operational changes require much closer oversight and involvement by the utility's management team. The operators were very comfortable with their existing procedures and past success, accepting the necessary changes only reluctantly. The more involved role of management in daily decisions may require a long-term change in operator culture and roles as the program evolves.

Lessons Learned

QWD has found that the successful implementation of water system improvement projects and operational changes requires input from multiple individuals at different levels of management and operation, and a variety of stakeholders. The needs of both internal and external constituencies need to be considered in the decision process.

Barriers to implementing energy management projects include the need for authorization of adequate planning funding, operator acceptance, and the need to balance water quality goals with efficient operations. For example, maximizing storage enables greater off-peak pumping, but can also result in increased disinfection by-products by increasing detention times in the storage tanks. Generally, the more finished water storage in the system, the older the water age. However, the new altitude valve has allowed QWD to redistribute water storage more equitably and increase the daily tank turnover rate from about 15 percent in prior summers to 35 percent. QWD's hydraulic model shows a 10–15 percent improvement in water age now as compared to a few years ago. As a result, recent water quality monitoring results showed decreased levels of disinfection by-products in the distribution system.

The QWD management's commitment to efficient operations, utilization of engineering consultants for hydraulic modeling and cost estimating, and effective partnering contributed

significantly to the success of these projects. The resources and effective cooperation and leadership provided by NYSERDA were also critical to the QWD’s success.

Conclusion

The QWD, with the assistance of NYSERDA and its consulting engineers, has implemented significant energy cost reductions by improving pump efficiencies and maximizing the use of storage to increase off-peak pumping. Through a contract with Energy Curtailment Specialists, Inc., QWD now also sells excess generator capacity to generate additional revenue.

An effective partnership among the water utility management and operators, owners (Town Board), its consultants, and the state financing and regulatory bodies was essential. Effective partnerships and affordable financing are needed to enable small water systems to implement similar projects.

Suffolk County Water Authority, NY

	Plant Improvements and						
Management Tools	Management Changes	Water Treatment	Water Distribution	Water Conservation	Alternative/Renewable Energy Sources	Financial Assistance	Partnerships

✓

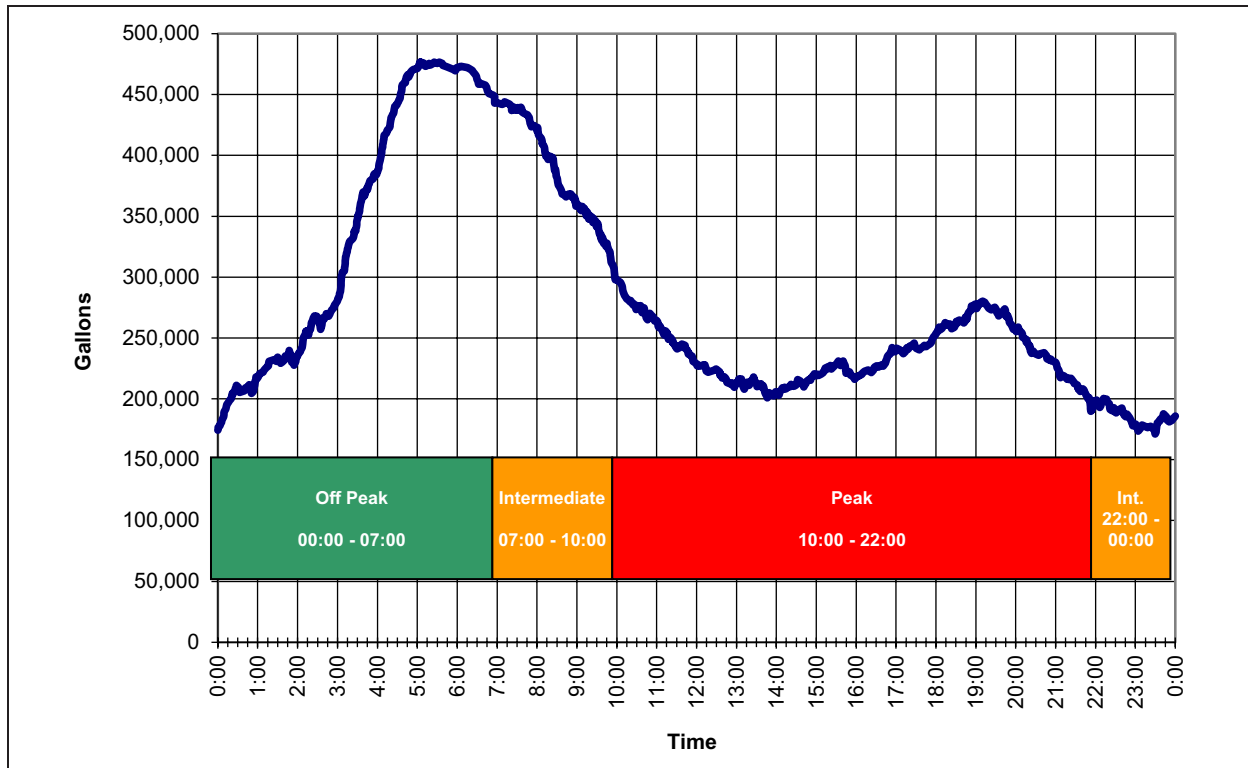
Background on the Water System and History of the “Issue”

Suffolk County Water Authority (SCWA) serves approximately 1.2 million people, providing 182 MGD. The water is obtained from nearly 600 wells located throughout the SCWA service area. Water is taken from three primary formations which lie, one on top of the other, and make up the Long Island Aquifer System.

From the shallowest to the deepest, these formations are:

- *Glacial*—contains the youngest or newest water to the groundwater system. The SCWA has 259 wells drawing from this portion of the aquifer. Virtually all private wells draw from the Glacial Aquifer.
- *Magothy*—is the largest of the three formations and holds the most water, much of which is hundreds of years old. There are 323 SCWA wells drawing from this portion of the aquifer.
- *Lloyd*—is a largely-untapped layer that contains the oldest water, some of which has been held in the aquifer system for more than 5,000 years. The SCWA has four Lloyd wells.

All of the water is chlorinated and the SCWA operates 115 granular activated carbon (GAC) treatment facilities, 26 iron removal facilities, and 3 nitrate removal systems. The energy costs related to pumping approximately 182 MGD from nearly 600 wells throughout its distribution system is a significant percentage (24 percent of O&M) of the cost of delivering safe drinking water in Suffolk County. Reductions in the cost of energy can have a significant impact on user rates.



Source: Suffolk County Water Authority.

Figure 4.15 Typical summer flow vs. LIPA demand periods

Type and Size of the Process or Technology Evaluated

In 2007, SCWA initiated a Pilot Study to examine the potential cost savings that could be realized by shifting pump operating hours to off-peak periods, taking advantage of lower electric rates at these times. The Pilot Study involved 20 wells in a specific pumping zone and included an analysis of how off-peak pumping could be implemented system-wide, recognizing that the trade-off could be reduced water system reliability. Storage tank levels are allowed to drop lower than what previously would have been considered “acceptable.” Less of a buffer means an increased risk of a loss of system pressure. Operational issues needed to be identified and the scope of the changes in pump control determined to see if the SCWA could realize substantial savings while still supplying water with adequate pressure to its customers without compromising fire protection or water quality. A pilot test was conducted in Zone 11, a small zone of 10 pump stations in the Commack-Kings Park area during August and September of 2007.

After carefully compiling and analyzing the data, the SCWA determined that significant savings could be achieved through both lowered electrical demand charges and reduced pumping. Numerous operational challenges were also identified and insight was gained as to what was required to expand the program, system-wide.

Based on the trial, which indicated that savings as much as 10 percent could be achieved, in 2009, the SCWA implemented a system-wide process of shifting the hours of pumping to off-peak times to take advantage of lower electrical rates during these periods. This is particularly relevant in the summer months when water system usage peaks between the hours of midnight and 7:00

am, coinciding with Long Island Power Authority's (LIPA's) off-peak period (see [Figure 4.15](#)). For many sites, the cost to operate pumps varies at different times of the day. By taking advantage of this and shifting pump operation to the off-peak period while relying on storage capacity and minimizing pump operation during the peak period, energy costs are reduced.

To achieve proper optimization, SCWA personnel needed to be more proactive concerning energy conservation. Previously, water quality (high iron) or high treatment costs (GAC) were the primary factors considered in restricting pump operation. Otherwise pumps were operated strictly whenever the system demanded water. Operations staff never hesitated to manually start a well for samples or to check chemical settings. Historically, during summer time use, wells would run on time clocks and locally on hand control ensuring that the demand could be met. Keeping the wells running and the tanks full were the principal concerns.

The introduction of SCWA's SCADA system in the late 1990s provided SCWA with a "virtual" window into its pump stations. While the system was built with resiliency and redundancy in mind, energy conservation was not a consideration. As it turned out, the vast improvement in controlling the wells provided by the SCADA system created an opportunity for energy savings as well. A system that totally relies on pumped water, such as the SCWA with its nearly 600 wells, is particularly sensitive to rising energy costs. Energy optimization, or more commonly called "off-peak pumping," required a cultural change and a balancing act. The operators needed to accept the trade-off of decreased system reliability and the assumed increased risk of loss of water system pressure. Storage capacity is more heavily relied on to meet demands (i.e., tank levels are allowed to drop lower than would have previously been considered acceptable) in order to save on power costs and demand charges.

SCWA pump stations fall under different rate structures and the time of day is crucial. LIPA utilizes three periods in its time-of-day billing. In the summer from June 1st–September 30th there are 3 periods, "Off Peak," "Intermediate Peak (Int Peak)," and "Peak." These are outlined in [Table 4.8](#). Avoiding pumping during the "Peak" period will produce the largest savings. For the remainder of the year there is only "Off Peak" and "Int Peak" options.

[Figure 4.16](#) shows an example of how shifting the pump operation can provide savings. A 1200 gallon per minute well with a 150 hp motor, started for more than 15 minutes during the Peak demand period would cost the SCWA approximately \$2,358 vs. the same scenario during Int demand at approximately \$562. This is the initial startup charge that is applied for each well for each monthly billing period. The graph represents Peak and Int demand charges based on the motor horsepower.

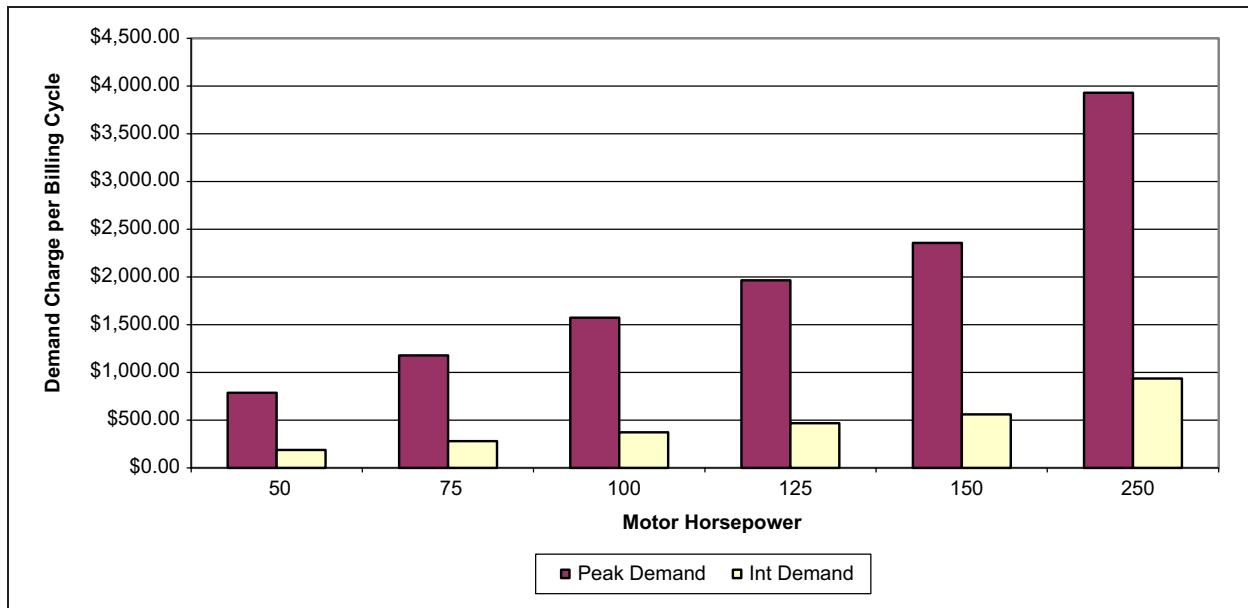
Change(s) Implemented and Results

In 2009, SCWA implemented a system-wide shifting of the hours of pumping to off-peak times to take advantage of lower electrical rates. In the pilot study of 20 wells over a two-month period, the results showed a savings of \$0.0662 per thousand gallons of water and/or \$0.0392 per kWh during the trial. This equates to a total savings of \$37,451 for the period. Of this amount \$27,023 was in electrical demand charges and \$10,428 related to pumping water at a reduced usage rate. This indicates a potential cost savings of up to 10 percent. While cost savings are not yet available for the 2009 implementation year, the total system-wide savings are estimated to have been \$1.8 million for the four summer months.

Table 4.8
Billing rates based on time of day

Time	Midnight– 7:00 AM	7:00 AM– 10:00 AM	10:00 AM– 10:00 PM	10:00 PM– Midnight
Demand period	Off peak	Int peak	Peak	Int peak
Demand charges	No charge	\$4.68 kW	\$19.65 kW	\$4.68 kW
kWh Rates	\$0.0237	\$0.0378	\$0.0485	\$0.0378

Source: Suffolk County Water Authority.



Source: Suffolk County Water Authority.

Figure 4.16 Demand charges based on demand period and motor horsepower

Special Staff or IT Needs or Other Considerations

To implement the enhanced operations mode required to optimize off-peak pumping in the summer months, a new Control Center supervisor was added about six months prior to the optimization. The optimization requires daily administration, which in the summer requires about 20 to 40 percent of the new supervisor's time. Operations and maintenance activities were also adjusted to accommodate pump operating schedules. Mechanics and electricians have been brought in on overtime to troubleshoot and repair pumps and treatment equipment to avoid demand charges. The Authority is considering work shift changes in order to optimize savings.

Lessons Learned

An effective SCADA system and knowledgeable personnel are critical in managing the increased risks associated with off-peak pumping. Operator acceptance must also be taken into

consideration when making such significant departures from “normal” practices. It may be necessary to change the operating “culture.”

Operators need to accept and recognize the trade-offs in adopting this mode of operation, since water system reliability is sacrificed and an increased risk of loss of water system pressure is assumed. Storage capacity is more heavily relied on to meet demands (i.e., tank levels are allowed to drop lower than would have previously been considered acceptable) in order to save money. Reducing the safety buffer of reserve storage capacity increases water system vulnerability in the event of a pump failure or other type of supply emergency.

A fully operational and effective SCADA system is critical to the successful optimization of off- peak pumping. SCADA expertise, and diligent operator attention and commitment were key ingredients in the successful implementation.

Conclusion

In 2009, the SCWA implemented a system-wide process of shifting the hours of pumping to off-peak times to take advantage of lower electrical rates during these periods. A preliminary assessment of the savings from the full-scale implementation appears to indicate a 9 percent savings or approximately \$1.8 million for the four summer months in 2009. The installation of an effective system-wide SCADA system was critical to implementation.

Village of Waterloo, NY

	Plant Improvements and						
Management Tools	Management Changes	Water Treatment	Water Distribution	Water Conservation	Alternative/Renewable Energy Sources	Financial Assistance	Partnerships
	✓						

Background on the Water System and History of the “Issue”

The Village of Waterloo water system draws surface water from Seneca Lake, located west of the Village in the heart of the Finger Lakes in upstate New York. The system serves 9,500 people in and around the Village. An average of 1.2 MGD are pumped from the lake and treated with diatomaceous earth filtration, chlorine dioxide, and chloramines to maintain a disinfectant residual throughout the distribution system.

Waterloo’s distribution system is extensive. Treated water moves over an area of 100 square miles. The relatively small water system has seven storage tanks, two booster pumping stations, and 5 pressure zones. In addition, there continues to be pressure on the Village from neighboring communities to extend mains and sell more water to adjacent service areas.

Until recently, operators managed the distribution system manually. For example, they would drive to a remote storage tank to open a valve to fill the tank, and then return to the tank a few hours later to close the valve. Chlorine residuals were measured by travelling to distribution system locations and testing the water collected. Security surveillance was conducted by frequently driving to key distribution system locations. The Village’s operators travelled a significant number of miles each week while carrying out the regular operation of the water system.

In 1998, when the system switched to chloramines for secondary disinfection, there was additional concern about biofilm management and the risk of nitrification in the system. On two occasions, the Village observed an increase in heterotrophic plate count (HPC) bacteria numbers and traced the cause of these events to stagnation in a remote storage tank.

The Waterloo system needed a way to manage its treatment plant and distribution system that was more efficient in terms of operator time as well as energy spent. The burden of making operational changes in the distribution system manually was wasting gas and limiting the amount of time available to efficiently operate the system. In addition, concerns about water quality prompted the need to evaluate more holistic management approaches. More intensive, active management was needed to reduce water age and minimize stagnation in finished water storage tanks.

Type and Size of the Process or Technology Evaluated

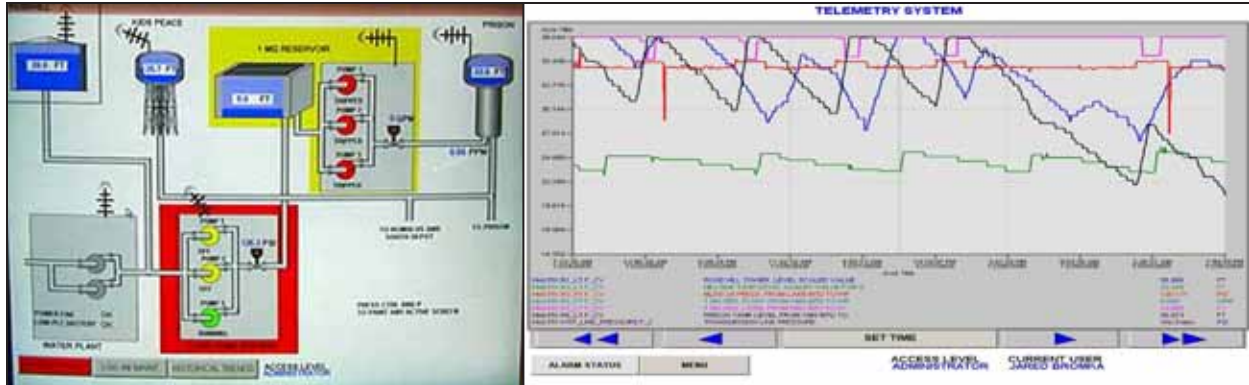
It was decided that the Village needed a more automated approach where operational decisions could be executed from a central location. They wanted to replace their existing master control panel with a new, state-of-the-art Programmable Logic Controller or PLC. Also, the main computer, operating system software, and SCADA system needed to be brought up-to-date. An integrated radio telemetry system would allow the pump stations and valve controllers to monitor remote tank levels and automatically turn on and off pumps, as needed, to maintain optimal levels in the tanks.

Change(s) Implemented and Results

In 2007, the SCADA system was upgraded and new automatic controls were installed at the water treatment plant, replacing the manual controls. A new filter control console that controls and monitors the entire plant was installed, and communicates with the same computer used for the remote sites using an Allen-Bradley PLC and a 10-inch touch screen operator interface unit. In addition, the treatment plant's operation and sequences are now automated and the touch screen walks operators through filter backwash sequences. Pilot lights and manual switches are provided to allow operators to run the plant manually if needed in an emergency. Tank water levels and distribution system meters can now be read from a centralized location. Real-time results of Hach CL17 continuous chlorine analyzers that test the water before and after storage tanks are in the process of being put onto the SCADA system as well. Valves can be opened and closed without operators driving out to remote storage tanks. The Village is installing video cameras and microphones at remote locations and the data will feed back into the system. Microphones are helpful in terms of providing additional notification when alarms sound or pumps or valves malfunction.

The radio telemetry and SCADA have enabled operators to monitor tank levels, meters, chlorine analyzers, security cameras and pump status for real-time daily operations, increasing system efficiency and security. Operators can also remotely control pumps and system valves as needed. [Figure 4.17](#) provides an example of a computer screen showing real-time monitoring of storage tank water levels. Priority is given to filling tanks at night so pumps normally run during off peak times. If a tank is drained too far down due to a break or high demand (e.g., the result of a fire), the pumps automatically start during the day if needed.

The SCADA system has user-based security so only water plant operators can see water plant related information and no one can reset or change anything without logging in. Alarms are continuously monitored and logged. All of the plant and remote site operational data (i.e., water



Source: Village of Waterloo.

Figure 4.17 Computer screen showing real-time monitoring of storage tank water levels

quality, flow, pressure, and tank level) are logged to the computer hard drive and displayed on trend screens for analysis. Operators can dial into the computer using remote access software to remotely control and monitor the system. Secure remote access can be provided in the future with high speed internet if needed.

The improvements made to Waterloo's telemetry and SCADA system and the creation of a reliably centralized way to operate the extensive distribution system have allowed operators to respond more quickly to episodes of water loss. In the past, several hours could pass before a leak or break was detected. Now, tank water level and pressure readings and pump operational data alert operators of a problem much more quickly.

For example, in December 2008 a 750,000-gallon elevated storage tank began to leak at its base. Wooden shoring was holding the tank's standpipe in position. The wood had rotted, resulting in the standpipe shifting at the base of the tower and a large leak forming at the base of the tank. The storage tank serves the Five Points Maximum Security Prison; water loss to the prison could have been disastrous for many reasons. The Village water operators noticed on the SCADA that water levels were dropping faster than normal, prompting them to visit the tank and find the leak. Before the SCADA system was in place, the leak may not have been detected until the prison did not have adequate water pressure. The manager of the Village's water system estimates that up to 500,000 gallons of water could have been lost; the prison pays \$5.64 per 1,000 gallons. The wooden shoring has since been replaced with concrete and the tank is back in operation.

As another example, in early February 2010 water operators noticed from the SCADA that the same 750,000-gallon tank was not filling as fast as usual. The tank is routinely filled at night; for two nights in a row operators noticed the tank's water level was not changing. The 1,000 gal/min pumps were also being run for longer hours and pumping less flow. Operators visited the tank and found that a bypass valve had been left open, diverting water elsewhere in the distribution system and preventing the tank from filling. Before the SCADA was installed, operators would probably not have noticed the problem until the tank's water level was so low an audible alarm would have sounded at the prison. In the meantime, energy would have been wasted running the pumps as they sent water through the bypass instead of into the tank.

Special Staff or IT needs or Other Considerations

Operators did not require special training in order to use the new system. One operator taught himself about ladder logic and how to make necessary changes to the management system. Telephone and on-site assistance is available from the SCADA system supplier.

Lessons Learned

The Village considers the investment in a SCADA system to be a success. System operation has improved because operators now have access to more information in a timely manner. This allows them to solve water quality problems before the water reaches the customers' taps, and to maintain finished water tanks and system pressure at desired service levels. Water is pumped more efficiently, and leaks or inappropriate valve settings are identified quickly. Energy is saved by reducing travel to distribution system locations to manually operate and observe the system. While the Village does not think they have actually saved money on gasoline and truck costs, because the distribution system is growing and there is more to manage, they do feel that the SCADA system has enabled them to operate the water system much more efficiently in terms of their travel.

Conclusion

The Village of Waterloo improved system operation and reduced energy consumption by updating its SCADA system and installing a PLC. The new control system reduced manual inspection and monitoring practices, improved use of operators' time, and made time and energy spent travelling throughout the distribution system more efficient. It allows a quicker response to system water quality and pressure issues which effectively conserves water, reduces water age, saves energy costs, and improves service reliability. Substantial volumes of treated water have been conserved because Village personnel are notified of water loss sooner and can diagnose and locate problems more promptly and effectively.

West Basin Water District, CA

Management Tools	Plant Improvements and Management Changes	Water Treatment	Water Distribution	Water Conservation	Alternative/Renewable Energy Sources	Financial Assistance	Partnerships
		✓			✓	✓	✓

Background on the Water System and History of the "Issue"

The West Basin Municipal Water District (West Basin) was established in 1947 with voter approval and is a member agency of The Metropolitan Water District of Southern California (MWD). West Basin purchases treated imported water (65 percent) from the MWD and then distributes this water to cities, investor-owned utilities, and private companies in southwest Los Angeles County. West Basin's service area includes 17 cities with an average demand of 205,000 acre-feet of water annually. In addition to wholesaling potable water, West Basin operates a world class water recycling facility that supplies recycled water for irrigation, commercial, and industrial

uses as well as for injection into South Bay’s groundwater basin to protect the basin from seawater intrusion. West Basin is committed to being an innovative leader through exploration of new methods and technologies to enhance the water supply. To further secure “new” water, West Basin has been evaluating the desalination of ocean water on a pilot scale from 2002 to 2008 and is now embarking on a full-scale demonstration facility. West Basin has set a goal that desalinated ocean-water will comprise 9 percent (20 MGD) of its drinking water supply by 2020.

West Basin serves water to a semi-arid region that is subject to recurring droughts. MWD’s raw and finished storage reservoirs have a potential storage capacity of 5.3 million acre-feet. The recent reservoir levels have decreased from 3.11 million acre-feet in 2006 to approximately 1.77 million acre-feet in February 2009. The dry summer of 2009 has further strained the water supplies. Even as the drought continues and water supply is reduced, the population growth of southern California is expected to continue to grow by approximately 220,000 persons per year. These drought conditions as well as concerns over the reliability of its imported supplies and impact on GHGe prompted West Basin to take a holistic approach to water management and become a leader in water conservation, water recycling, and energy management.

Type and Size of the Process or Technology Evaluated

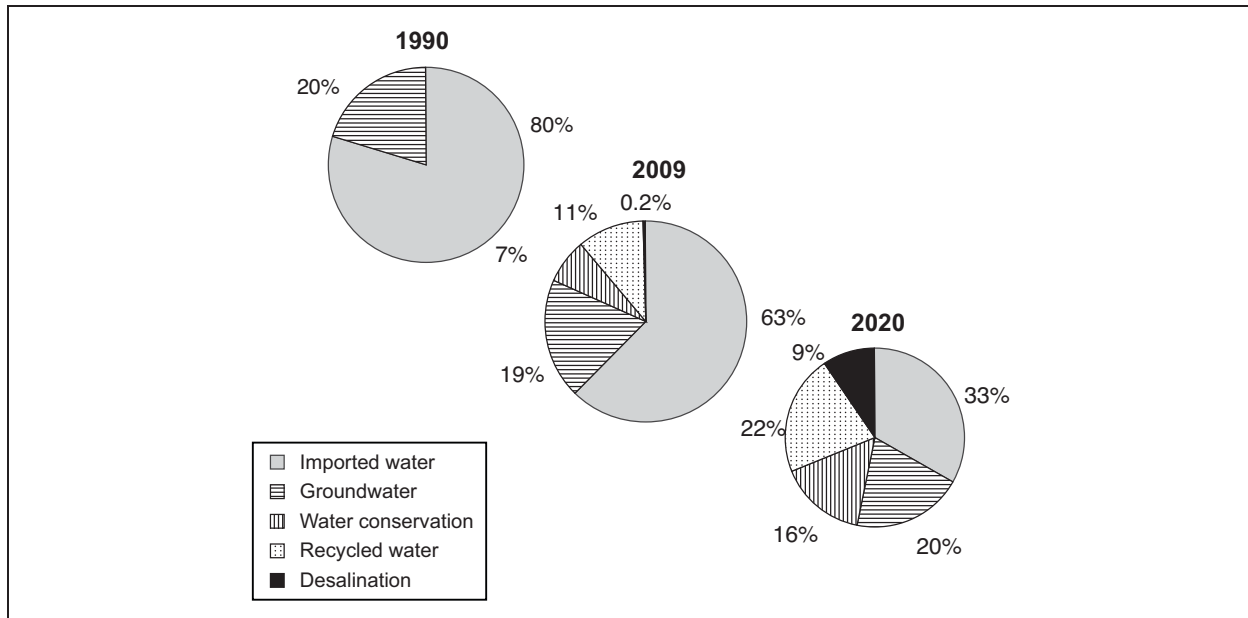
In 2008, West Basin launched its *Water Reliability 2020 Initiative* with the objective of decreasing its dependency on imported water and increasing its dependency on local supplies. The *Initiative* will double West Basin’s water recycling production, double water conservation efforts, expand education programs, and deliver potable water from a full-scale ocean water desalination facility. [Figure 4.18](#) illustrates how West Basin’s water supply portfolio will evolve from 1990 to 2020.

Energy management is very important to West Basin and is guided by two main energy management objectives—to optimize energy use and reduce its carbon footprint. As a result, West Basin is in the process of developing an *Energy Management Plan* to provide a road map in which to responsibly manage its resources while providing cost-effective service to its customers. The *Water Reliability 2020 Initiative* and the *Energy Management Plan*, will help West Basin meet the California Global Warming Solutions Act of 2006 (AB 32) that seeks to reduce GHGe to 1990 levels by 2020. West Basin is also seeking renewable energy opportunities at its facilities to further reduce its carbon footprint.

Change(s) Implemented and Results

West Basin has been forward thinking in finding ways to improve energy efficiency, reduce GHGe, reduce operating costs, and promote conservation of the drinking water supply. West Basin has implemented a variety of energy efficiency and water conservation measures and technologies into its facilities. These initiatives include:

- Building a world-class, state-of-the-art water recycling treatment facility that is the largest water recycling facility of its kind in the U.S., resulting in developing a reliable local supply to its service area that offsets West Basin’s need for imported water.
- Partnering with the South Bay Environmental Services Center (SBESC) in 2006 to leverage energy efficiency programs.



Source: West Basin Water District.

Figure 4.18 West Basin's water supply portfolio mix

- Installing a 35,156 square foot solar power generating system at the recycling facility that takes 10 percent off the peak power demands from the traditional energy grid during the most expensive hours.
- Evaluating the feasibility of ocean-water desalination to enhance the water supply through a testing pilot facility.
- Ensuring full compliance with existing and future regulations.

Recycled Water Program. To supplement the potable water supply and protect the groundwater basin from seawater intrusion, West Basin built the Edward C. Little Water Recycling Facility in 1995. The facility's treatment capacity was increased from 20 MGD to 35 MGD in 2005/2006 to meet the region's water demand. The recycled water distribution system includes over 100 miles of reuse pipeline. Since the plant began operation in 1995, West Basin has distributed over 100 billion gallons of recycled water. For every gallon of recycled water produced the dependence on imported water decreases and local water supply reliability increases. The facility was recognized in 2002 by the National Water Research Institute as one of the six National Centers for Water Treatment Technologies in the country.

West Basin is planning to expand the recycling facility's treatment capacity to 40 MGD primarily to provide additional water to recharge the local groundwater basin—to replenish the regional aquifers and prevent saltwater intrusion. Working with the Water Replenishment District (WRD) of Southern California, West Basin currently supplies both potable and recycled water (up to 75 percent recycled water) into the West Coast Groundwater Barrier, preventing seawater intrusion into this groundwater basin. The remaining 25 percent of water injected into the barrier is from imported potable drinking water. The goal is to use 100 percent recycled water from West Basin's facility by 2012 for injection into the seawater barrier, further reducing dependence on imported potable drinking water.

Energy Partnership. Through a partnership with the SBESC, West Basin implements programs that have water saving and energy efficiency benefits. Since the early 1990s, West Basin has been providing water conservation programs and education to the public as a way to reduce water demands through demand-side water conservation. Between 1990 and 2008, the West Basin service area has successfully conserved over 17,000 acre-feet of imported water through the conservation programs and the partnership with SBESC. This translates to over 72 Gigawatt-hours (GWh) of embedded energy savings as a result of not having to deliver this imported water to the end user.

Specific programs include:

- *Cash for Kitchens Program* has provided water and energy audits, water-efficiency devices, and “train the trainer” training sessions to over 25 commercial kitchens in West Basin’s service area. West Basin offers devices that save hot water—pre-rinse spray valves, connectionless food steamers, faucet aerators, and waterbrooms.
- *Green Living Program* is a direct install program targeting multi-family complexes constructed prior to 1992 to replace inefficient toilets, light bulbs, showerheads, and faucet aerators. The program is administered by West Basin in partnership with Southern California Edison (SCE) and Southern California Gas Company (SCG). West Basin provides high-efficiency toilets, SCE provides compact florescent light bulbs, and SCG provides low-flow showerheads and faucet aerators.
- *Waterbroom Distribution Program* has provided over 450 high-efficiency waterbrooms to City facilities, school districts, and restaurants throughout the South Bay area.
- *Southern California Edison’s Rebate Programs* are available, on a region-wide level, to both commercial and residential customers for water-saving devices. Many of these devices typically use hot water and have the benefit of direct energy savings as well as water conservation. West Basin promotes these “combined” incentives. Looking into the future, the partnership plans to further merge auditing activities, expand funding opportunities to offer more combined rebates, and to ultimately quantify the “embedded” energy savings from using water.

West Basin also began the *It’s Time to Get Serious* campaign in 2007 that highlighted the need to take water-use efficiency very seriously and to heighten awareness at the City Council level. Fourteen of its cities passed the *It’s Time to Get Serious* Resolution in which they resolved to review and update ordinances and city policies as they pertained to water-use efficiency. West Basin was also recognized by the State Legislature for its resolution and its commitment to efficient water use. To date, five cities have passed new water efficiency resolutions and two more are in the process of passing ordinances.

Renewable Energy—Solar Panels

Renewable resources are essential for reducing GHGe and reaching West Basin’s AB32 goals. In late 2006, West Basin installed 36,156 square feet of fixed-tilt photovoltaic panels at the Edward C. Little Water Recycling Facility at a cost of \$4.2 million (see [Figure 4.19](#)). West Basin received incentives from SCE in the amount of \$1.9 million to offset the cost. In the first year of operation (calendar year 2007), the system produced 11 percent more electricity than expected



Source: West Basin Water District.

Figure 4.19 Solar panels at Edward C. Little Water Recycling Facility

(903,800 kW produced compared to the estimated 814,199 kW). This resulted in a cost savings of \$90,000 (~\$0.0995/kWh).

The photovoltaic system has been in continuous operation since it was installed and through July 2009, has produced approximately 2.21 GWh of energy; enough power to supply over 200 homes in one year. This has resulted in approximately \$220,000 in energy cost savings, based on a rate of \$0.0995/kWh. West Basin's current renewable energy component of its entire power consumption portfolio is 1 percent of its total consumption. West Basin's use of solar power in its recycled water operations has kept 1,173 tons of carbon dioxide from being released into the environment that would otherwise have been released through the use of traditional energy sources.

This solar powered system takes 10 percent off the peak power demands from the traditional energy grid during the most expensive hours. The solar panels are expected to last for more than 25 years.

Desalination Pilot Study. West Basin is evaluating desalination of ocean water which can provide a safe and reliable water source that is not dependent on weather conditions or water rights limitations. From 2002 to 2008, West Basin conducted a pilot scale study with promising results. West Basin has identified optimal operating parameters. The desalination pilot study process uses micro-filtration as a pre-treatment to reverse osmosis to process 40 gallons per minute of ocean water. The treated water was only used for water quality testing and released back into the ocean.

West Basin is now in the planning process for a full-scale demonstration facility to evaluate equipment that will minimize energy consumption and offset the plant's carbon footprint including evaluating the following applications:

- an isobaric energy recovery system*,
- high-efficiency pumps,
- energy efficient reverse osmosis membranes, and
- solar power

*"Pressure-equalizing" energy recovery devices transfer energy from membrane reject stream directly to the membrane feed stream. These devices employ positive displacement mechanisms.

Regulations. Since 2008, West Basin has been a member of the California Climate Action Registry and a founding member of The Climate Registry. Both organizations are voluntary organizations that protect and promote early actions to reduce GHGe by ensuring that its members receive appropriate consideration for early actions in light of future State, Federal, or international GHG regulatory programs. In addition, these organizations provide support for members by setting consistent and transparent standards to calculate, verify, and publicly report GHGe into a single registry. These memberships will help West Basin be better prepared when regulations are in place (currently scheduled for January 2011). West Basin has submitted data such as its electricity, natural gas, and sludge hauling usage to The Climate Registry (the California Climate Registry dissolved and merged with The Climate Registry) and is currently going through a third party data verification process. Once the data is verified, and reconciled, it will be submitted by March 1, 2010. This is an annual reporting requirement as a result of becoming a member of The Climate Registry.

Special Staff or IT Needs or Other Considerations

To ensure optimum operations of the water recycling facility, solar generating station, and desalination pilot plant, highly technical and highly trained operations staff and engineers are a necessity. In addition, implementing energy efficiency optimization and water conservation measures requires dedicated staff and constant communication among management, staff, and energy partners, as well as strategic and policy direction from the West Basin Board of Directors.

Lessons Learned

For an organization to be effective in energy management, it is essential that there be a champion at the top of the organization. Additionally, it is important to focus on the obvious issues/improvements and the low-hanging fruit to demonstrate early successes and help sell each successive step. In managing energy usage, strategies must be integrated into the daily operations and responsibilities of management and employees. In order to achieve significant results, certain management principles must be in place such as:

- Leadership at the very top should have a clear commitment to results.
- Goals should be clearly stated and objectives should be measurable at appropriate levels.
- The utility should assign accountability for results.
- The utility should provide sufficient resources to enable achievement of the objectives and goals.
- The utility should periodically review and update goals, objectives, and resource commitments.
- The utility should recognize progress and reward achievements.

Conclusion

West Basin's overall objectives are to reduce dependency on imported water, optimize energy use, and meet or exceed its regulatory obligations. West Basin's overall regulatory goal is to comply with AB32 targets at a minimum. Until these regulatory requirements are in place,

West Basin will focus on reducing its overall energy consumption and carbon footprint. Through its *Water Reliability 2020 Initiative*, West Basin has developed a preferred water resource mix for 2020 that will reduce the energy requirement by approximately 14 percent as compared to 1990 usage of 440.7 million kWh/y, resulting in a projected savings of over 22,000 tons of carbon dioxide emissions per year.

LESSONS LEARNED

Although the type and size of energy efficiency best practices implemented varied widely, there were some common elements and themes of lessons learned that resonated through many of the case studies. They can be attributed to a number of areas including:

Management

- Preventing pollution, enhancing the environment, and promoting sustainability through energy efficiency practices can help utilities deal with changing water quality standards (standards), variations and changes in source water quality, and changes in distribution systems.
- Optimizing energy use is a way to save money, promote environmental stewardship, and improve sustainability.
- Corporate officers and senior managers must be the drivers to establish energy goals and promote “green” as good for business.
- Operator and staff buy-in and training on energy efficiency practices, SOPs, and managing data tracking systems is critical. It is a challenge for water system staff to make a personal commitment to carry out energy conservation goals and use the available technology to meet these goals.
- Improving energy efficiency is a constantly evolving process.

Databases and Tracking Systems

- Investment in adequate monitoring and tracking systems, databases, and SCADA are critical for managing energy usage, measuring success, and formulating new energy efficiency strategies.
- Energy efficiency efforts should be tied to asset management plans and systems to ensure assets are properly maintained.
- A water system can never have too many meters or submeters. The collection of accurate electric data is an important component of a program.

Partnerships

- It is critical to work closely with the local energy provider to optimize energy usage as well as maximize energy conservation rebates.
- Internal (staff) and external partnerships (energy provider, customers, etc.) are necessary.

Financial

- Take advantage of available funding programs.
- It takes energy (time and resources) to save energy; it is vital to allocate adequate resources for staff training and equipment maintenance.
- Include high efficiency pumps, motors, lighting in bid specifications.
- Improving energy efficiency can decrease costs and control water rates for customers. Staying competitive with utility rates can help retain existing (particularly industrial) customers and entice new customers to locate to the service area.
- Evaluate programs and monitor actual savings.

Public Health Protection and Compliance

- Changes may require more closely monitoring system operations and water quality.
- What works for one system may not work well for another.

CHAPTER 5

DEVELOPING A ROADMAP TO ENERGY EFFICIENCY

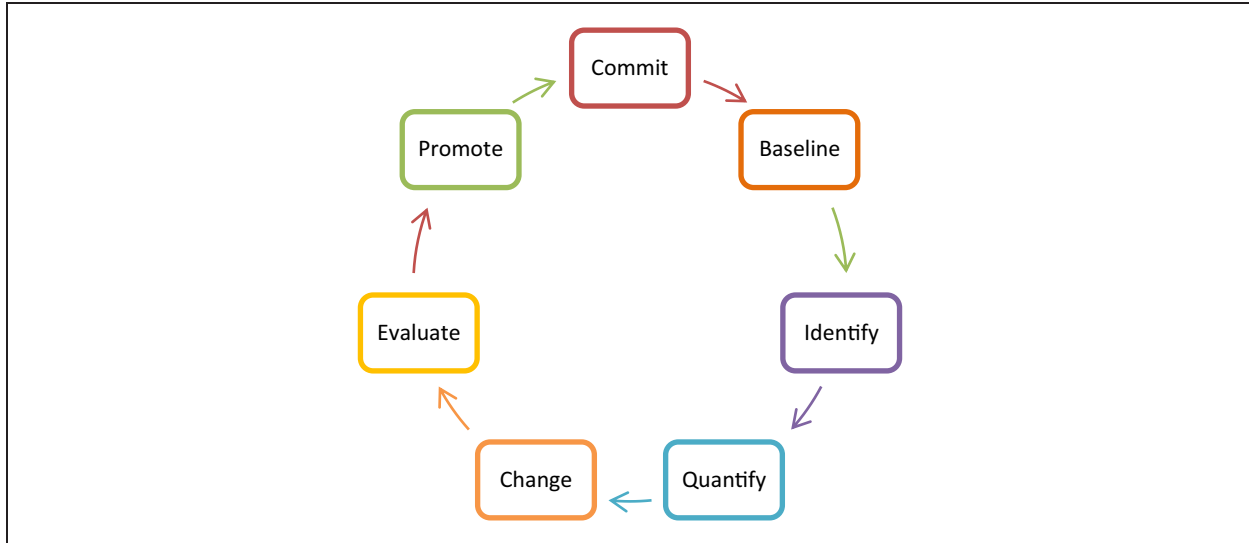
INTRODUCTION

Drinking water utilities, regardless of size, can and should take steps to reduce energy costs and consumption. Estimates indicate that between 10 and 30 percent savings are readily achievable by almost all systems. These efforts can result in a number of benefits including:

- Cost savings that can be reinvested in infrastructure or additional energy reduction measures
- Less strain on the current energy grid
- Meeting new state energy reduction targets
- Reduced GHG emissions
- Improved environmental stewardship
- Improved customer relations

Utilities have found that identifying approaches to integrate energy efficiency practices in the daily management and long-term planning also contributes to long-term sustainability by reducing operating costs and improving efficiency and process control. There are substantial opportunities and potential to reduce energy costs, some of which can be implemented easily with a limited investment cost, such as taking advantage of systems upgrades or expansion to incorporate efficient processes and technologies. These savings can be realized through a range of actions including:

- utilizing new, energy-efficient technologies
- incorporating energy efficient practices into daily operations
- taking advantage of incentives and rebates from energy providers
- installing premium efficiency motors and variable speed drives
- resizing pumping systems
- developing alternative pumping schemes and pump system upgrades
- installing controls and SCADA systems
- optimizing operations
- implementing building upgrades (e.g., lighting and HVAC)
- benchmarking and energy audits
- evaluating demand side management opportunities to reduce energy consumption by shifting power consumption from on-peak to off-peak hours
- adding storage
- promoting water conservation and use of energy efficient products
- reducing system leaks
- evaluating system life cycle energy costs associated with proposed projects, and
- evaluating the use of alternative energy sources



Source: Adapted from USEPA 2008.

Figure 5.1 Steps for an energy program

This chapter will discuss various approaches that systems can take from a full-blown comprehensive energy management approach, to an intermediate approach, to a targeted approach. To some degree, the approach selected by a utility will vary based on cost, staff expertise, and ability to quantify results. The goal, however, is for all utilities to take some steps to improve energy efficiency.

GETTING STARTED ON AN ENERGY EFFICIENCY PROGRAM

Utilities of all sizes can and should take steps to save energy and reduce costs. Seven steps that utilities should take to establish a successful energy program are shown in [Figure 5.1](#) and discussed below.

Step 1. Establish a Utility Commitment

Based on the review of a number of references and the case studies developed for this project, it is clear that design, adoption, and implementation of a comprehensive energy management plan requires the full support and buy-in from upper management, as well as utility operators and staff. A successful energy management program begins with a strong commitment. This commitment may be initiated at the municipality level and carry down to the utility Board, the utility management and operators, and utility customers. The utility power provider and various state energy and funding agencies also play a vital role in energy management decision implementation and funding. At a minimum, it is critical that utility managers and operators buy into the process since they ultimately will be responsible for successful implementation of the energy program.

Typically, a utility should identify an *Energy Program Manager* (USEPA 2008) who has the responsibility and management authority for implementing the energy improvement program. This individual will be aided by the assistance of an *Energy Program Team* typically comprised of staff from various levels and functions within the utility that will help design and implement

the energy program. Depending on the size of the utility, team members may come from several departments including operations, engineering, water quality, public relations, and financing. Utility operators are a critical element of the team since they have on-the-ground experience in running the facility and will likely be responsible for day-to-day implementation of many of the recommendations. Operator understanding and buy-in is critical to success. The *Energy Program Team* will be responsible for developing the energy management plan; establishing and evaluating performance goals, metrics, and results; identifying resources needed to implement the recommended changes; and communicating information about the energy program both internally and externally. An important external partner in this process is the utility energy provider. Many of these providers have incentive and rebate programs and may provide free services such as energy audits and metering of equipment. They may also have experience with other utilities in the area and can work with the utility to identify potential energy saving measures.

Step 2. Establish a Baseline

One of the first and most important actions a utility can take is to develop an understanding of energy use and flow within the utility. Key to this is gathering baseline information. A strategy for data collection is to focus on key facilities, assets, and processes; capture information related to the top 80 percent of energy use; and don't attempt to detail energy use below the lowest interval of metering data available. Typically at least one year's worth of monthly data is needed to evaluate seasonal variability but three or more years of data is preferred. Information sources can include power utility billing records, operations information from SCADA or other data sources, hydraulic data, meter readings, equipment asset inventory information, and current conservation (demand-side) practices. The types of detail to collect for energy use include consumption data separated into daily or hourly intervals, kWh total consumption, peak demand usage, load profiles if available, and operating schedules of system processes. Climate data such as temperature and precipitation is also useful. This information is gathered to establish a baseline or benchmark. This benchmark can be used to compare the total energy consumption of the utility with other similar utilities, and to compare the results of changes implemented through the energy management plan.

While larger utilities or those with more staff and sophisticated data systems can use this information to develop a variety of models or purchase proprietary software, even smaller systems can use the information to create a generic spreadsheet to track energy usage and flow. Two primary benchmarking tools that are available at no cost include an AwwaRF research report published in 2007 titled *Energy Index Development for Benchmarking Water and Wastewater Utilities* and USEPA's ENERGY STAR® *Portfolio Manager*.

Step 3. Identify Opportunities for Improvements

Once a baseline is established, it is important to gather actual field data, typically through the conduct of an energy audit. The goal of an energy audit is for management to assess the energy use or energy flows of the water system and to identify the most energy-intensive areas of the system, outline possible actions and energy conservation measures, and set a plan of action in motion. Energy audits can be performed by a variety of individuals including electric utility experts, drinking water utility staff, and outside energy specialists and contractors. Staff can perform either a "high-level" or a comprehensive "detailed process" energy audit. Typically, a high-level or walk-through energy audit is initially performed to identify the major problem areas or most energy-use

intensive processes. The walk-through energy audit involves the collection of facility energy data, the reviews of energy bills, compares the facility's unit energy consumption with facilities using similar processes, and identifies processes and equipment where energy improvements can be made. Equipment audits, such as lighting, HVAC, and pumping audits, can be performed as part of the walk-through audit or can be a component of a more detailed process audit. A walk-through audit can help direct management where to concentrate a more detailed process energy audit or audits. Detailed process audits focus on the assessment of a specific process or operation identified as being energy intensive and provides for an understanding of where improvements can be made. These audits include evaluating individual components and end uses as well as how the processes and systems work together as a whole. Process audits involve field tests of equipment and systems, discussion of the impacts of specific energy conservation ideas, identification of the energy profiles of individual system components, and development of an equipment inventory and corresponding energy consumption data. During this process, it is important to talk with system operators to verify operational procedures, understand system limitations, and obtain suggestions for energy saving opportunities.

Pumps are often the largest consumers of energy at water utilities. The U.S. Department of Energy's publication *Energy Tips—Pumping Systems* (U.S. Department of Energy, 2005) is a useful guide for what pumping information should be collected and evaluated during the energy audit. Information to collect for pumps includes:

- Pump and drive motor nameplate information
- Operating schedules for each pump to develop load profiles
- Head/capacity curves (if available) from the pump manufacturers to document the pumping system design and operating points
- System flow rate and pressure requirements, pump style, operating speed, number of stages, and specific gravity of the fluid being pumped
- Flow rate, suction, and discharge pressures and any related conditions that are associated with inefficient pump operation, including indicators such as:
 - Pumps with high maintenance requirements
 - Oversized pumps that operate in a throttled condition
 - Cavitating or badly worn pumps
 - Mis-applied pumps
 - Pumping systems with large flow rate or pressure variations
 - Pumping systems with bypass flow
 - Throttled control valves to provide fixed or variable flow rates
 - Noisy pumps or valves
 - Clogged pipelines or pumps
 - Wear on pump impellers and casings that increase clearances between fixed and moving parts
 - Excessive wear on wear rings and bearings
 - Improper packing adjustment that causes binding on the pump shaft
 - Multiple pump systems where excess capacity is bypassed or excess pressure is provided
 - Changes from initial design conditions. Distribution system cross-connections, parallel main lines, or changes in pipe diameter or material may change the original system curve.

- Low-flow rate, high-pressure end-use applications. An entire pumping system may be operated at high pressure to meet the requirements of a single end use. A booster or dedicated pump may allow system operating pressure to be reduced.

The energy audit will typically provide a long list of energy savings opportunities that are specific to the facility, with some preliminary capital costs and potential energy savings. This information will be used to establish priorities for energy improvement changes.

Step 4. Evaluate and Quantify Changes

The next step is to evaluate and quantify potential changes in order to develop a prioritized approach. This may include quantifying savings, calculating payback periods for capital investment, and investigating the availability of resources. Grouping energy efficiency opportunities may make it easier to sort through all the data and identify options. These categories may include energy use modifications (i.e., working with your energy provider to change the time of peak pumping, load shedding, interruptible load programs); capital equipment purchases or replacement needs; optimization of equipment and processes (with a special focus on pumps and motors); installation of controls, meters, and SCADA systems; building lighting and HVAC improvements; fleet management changes; potential for renewable energy; leak detection and water loss programs; and demand-side water conservation approaches. At this point, it is often useful to investigate what other utilities have done in these areas. A number of case studies are documented in chapter 4 of this report and others can be found through Web searches. It is important to work closely with your energy provider, your state drinking water and SRF programs, and state energy offices or authorities that may have additional expertise and resources. Based on this input and that of the *Energy Program Team*, a short list of energy efficiency changes should be identified. In many cases, particularly for small systems, it may be easiest to identify the “low-hanging fruit” that can be most easily implemented even if this does not result in making the largest energy efficiency improvements. Sometimes starting small and building on initial success can help promote and “sell” future efforts to upper management, boards, and customers. Information on quantifying changes and savings may be presented in kWh energy reductions, reduction in GHG emissions, and projected cost savings. While each of these measures of savings is useful, it is often best to present the potential results in monetary terms. This is useful in comparing across various options and is more easily understood by boards and other stakeholders. [Note: The Water Research Foundation recently sponsored a project (#4090) to develop an energy management decision support system to help utilities evaluate various options. The Excel-based tool, which should be available in 2011, will help decision-makers select one or many options to create an energy management strategy and present that strategy to policy makers.]

Step 5. Implement Changes

The *Energy Program Team* then develops an implementation plan. This plan should clearly spell out the changes that will be made, the timeframe for making the changes, who is responsible for making the changes, and the costs associated with the changes. This plan should be communicated to upper management, Boards, and other stakeholders as appropriate. It is particularly important to ensure staff and operator buy-in to the changes. It may be necessary to provide specific operator training, modify standard operating procedures, or establish new monitoring procedures.

Those changes that may have a direct or indirect impact on water quality and hence regulatory compliance are particularly important. For example, operators and staff need to understand how potential changes such as off-peak pumping and increased storage may impact water age and therefore chemical and microbiological quality.

Step 6. Evaluate and Track Progress

The next step is to monitor and measure progress in implementing the changes. This evaluation can include review of schedules, impacts on operations and maintenance, and performance metrics. In some cases, such as making changes to lighting, the results will be almost instantaneous. Some operational changes may take time to realize the full benefits as staff become familiar with new procedures and processes. Other changes such as special billing rates and various energy programs implemented by the energy utility will vary over time as different procedures are implemented. Changes such as implementing customer water conservation practices may take longer and require special education and outreach initiatives.

Changes in energy use should be tracked and compared with the baseline data over time to document successful implementation. One useful tool for utility use is USEPA's ENERGY STAR® *Portfolio Manager*. Once the baseline has been established, the utility can input new data and quickly see how energy use has changed over time. While this program does not allow for benchmarking drinking water utilities against other utilities at this time, it can be used for internal purposes to track changes over time. The *Energy Program Team* should periodically review the data and confirm that energy reduction goals have been met. The list of priorities should be reviewed on a regular basis to identify the next series of changes that the utility may want to undertake. It may be necessary to conduct periodic energy audits to determine if energy use has changed at the utility and to cross reference this information with the list of priorities to determine if modifications to the list are needed.

Step 7. Communicate and Promote Success

Communicating success internally and externally is a critical aspect of an energy management program. Boards and directors need to know that investments and changes have had a positive effect and have reduced energy use and costs. Operators and staff who have ownership of many of the changes implemented will feel proud that they have been part of a process to save money and improve the environment. This will enhance support for future changes. Customers and other stakeholders will see that your utility is concerned about environmental stewardship and you are doing your part to reduce energy use. Success can be shared at Board meetings, on Web sites, through bill stuffers, in Consumer Confidence Reports (CCRs), and through newsletters or other outreach mechanisms.

DISCUSSION OF THREE APPROACHES TO ENERGY EFFICIENCY CHANGES

This section describes three different approaches that might be considered by a utility in developing and implementing an energy program plan. These approaches are drawn from project observations and findings of this research project. The approaches range from a Targeted Approach to an Intermediate Approach to a Comprehensive Approach and generally correlate to small, medium, and large system sizes, respectively. Each can be modified to meet an individual utility's

needs, however. The approaches vary in complexity and cost and are designed to encourage all utilities to take some steps to reduce energy consumption. The actions identified for each of the three approaches correlate to the seven steps identified in [Table 5.1](#) and discussed in this chapter, and the energy efficiency best practices identified in [Table 3.1](#) and discussed in that chapter. In some cases, utilities may select options from different approaches to meet their system's particular needs.

Targeted Approach

The Targeted Approach is well-suited for smaller-sized utilities that may have limited staff and resource capacity. While it acknowledges the potential limitations for these utilities, it also provides some specific direction to help these systems target “low hanging fruit” and enable them to move toward greater energy efficiency. In the case of many small utilities, the staff consists of one operator who may have multiple responsibilities. Typically, this operator is not well versed in energy efficient practices. This is where collaboration and partnership with the utility energy provider can reap significant benefits. Many energy providers will provide free energy audits. Some will assign a project manager to work with the utility to review and evaluate possible energy saving options. It is in the best interest of both the water and energy provider to develop this relationship.

The next step is to collect baseline information. Typically one to three years of monthly energy bills are evaluated to assess seasonal and temporal changes. The energy bill will also indicate the type of billing rate and any demand charges related to pumping at high-peak times. From this analysis, a utility can calculate its annual energy costs and develop a baseline to track changes over time as ECMs are implemented. A key piece of this effort is gathering asset inventory information. For purposes of the Targeted Approach, this should focus on critical pumps and motors and other high energy use components. For pumps and motors, the utility should gather as much information as possible about these assets including:

- Location
- Original pump curve and data sheet (including installed impeller size)
- Suction and discharge levels (relative to Mean Sea Level or common datum)
- Suction and discharge operating pressures
- All pump and drive motor nameplate information, including (but not limited to):
- Motor horsepower and speed
- Motor service factor rating
- Gallons per minute at rated RPM
- Head (in feet) at nameplate flow
- Pump run times
- Maintenance history

Information should also be collected from various meters. Operating schedules and processes should be reviewed such as the timing of treatment backwash and understanding how pumps are operated (i.e., manual on/off, controls with VFDs, throttling, etc.). For a small system, the information can be entered into ENERGY STAR® *Portfolio Manager* to establish a baseline.

The third step is to conduct an audit. Assistance may be available from your power provider or even the state drinking water or energy agency. It is also possible to hire a firm to conduct the audit but that will require resources that may not be available to the utility. A high-level

Table 5.1
Three energy efficiency approaches

Steps	Targeted approach	Intermediate approach	Comprehensive approach
1	Buy-in at the utility level: <ul style="list-style-type: none"> Utility operator/ manager directs program Coordinate with energy provider 	Buy-in at the utility and Board level: <ul style="list-style-type: none"> Identification of an <i>Energy Program Manager</i> Coordinate with energy provider 	Buy-in at the utility, Board, municipal government level: <ul style="list-style-type: none"> Identification of an <i>Energy Program Manager</i> and <i>Energy Program Team</i> Coordinate with energy provider
2	Collect baseline data: <ul style="list-style-type: none"> 1 to 3 years of power utility billing records Asset inventory information Meter readings Operating schedules Develop baseline: <ul style="list-style-type: none"> ENERGY STAR® <i>Portfolio Manager</i> 	Collect baseline data: <ul style="list-style-type: none"> 1 to 3 years of power utility billing records Asset inventory information Meter readings Operating schedules SCADA information Peak demand usage Develop baseline: <ul style="list-style-type: none"> ENERGY STAR® <i>Portfolio Manager</i> <i>AwwaRF Energy Index</i> Proprietary software 	Collect baseline data: <ul style="list-style-type: none"> 1 to 3 years of power utility billing records Asset inventory information Meter readings Operating schedules SCADA information Peak demand usage Hydraulic data Climate data Conservation information Develop baseline: <ul style="list-style-type: none"> ENERGY STAR® <i>Portfolio Manager</i> <i>AwwaRF Energy Index</i> Proprietary software Develop models
3	Conduct audit: <ul style="list-style-type: none"> High level/walk through Equipment audit <ul style="list-style-type: none"> Pumps/motors Lighting 	Conduct audit: <ul style="list-style-type: none"> High level/walk through Equipment audit <ul style="list-style-type: none"> Pumps/motors Lighting HVAC Fleet vehicles Detailed process audit 	Conduct audit: <ul style="list-style-type: none"> High level/walk through Equipment audit <ul style="list-style-type: none"> Pumps/motors Lighting HVAC Fleet vehicles Detailed process audit
4	Energy use modifications: <ul style="list-style-type: none"> Time-of-use Optimization of equipment (pumps and motors) and processes (treatment) Installation of meters Building lighting Leak detection	Energy use modifications: <ul style="list-style-type: none"> Time-of-use Load demand profiles Optimization of equipment (pumps and motors) and processes (treatment) Capital equipment purchase or replacement Installation of controls, meters, SCADA Building lighting and HVAC In-line turbines	Energy use modifications: <ul style="list-style-type: none"> Time-of-use Load demand profiles Interruptible load programs Demand bidding Optimization of equipment (pumps and motors) and processes (treatment) Capital equipment purchase or replacement Installation of controls, meters, SCADA

(continued)

Table 5.1 (Continued)

Steps	Targeted approach	Intermediate approach	Comprehensive approach
		Potential for renewable alternatives (purchasing green energy) Leak detection and water audits	Building lighting and HVAC Fleet management changes In-line turbines Potential for renewable alternatives (solar, wind) Leak detection, water audits, and conservation programs
5	Select easiest/least cost options first	Develop implementation plan—systematically implement changes	Develop implementation plan- identify changes to be made, timeframe, cost, and responsibility
6	Track progress using ENERGY STAR® <i>Portfolio Manager</i>	Develop performance metrics and review schedules, implementation status, and evaluate list of priorities. Track progress with more sophisticated tools.	Develop comprehensive tracking and accountability system to evaluate changes and impacts on energy consumption
7	Communicate success internally (staff meetings), externally (CCR, bill stuffers)	Communicate success internally (staff meetings and Board meetings), externally (CCR, Web sites, bill stuffers)	Communicate success internally (staff meetings and Board meetings), externally (CCR, Web sites, bill stuffers, newsletters, fact sheets, marketing campaign)

or walk-through audit should be conducted with an equipment audit that focuses on pumps and motors and lighting. These areas represent the most obvious opportunity for energy savings and may be the least costly to implement with relatively short pay-back periods.

Step 4 entails evaluating and quantifying changes in order to develop a prioritized approach. Typically, small utilities should target pumps and motors first with lighting options second. In many cases, simple modifications such as changing the time that pumps are operated from high-peak to low- or off-peak hours can realize significant cost savings. In this case, it's unlikely that *less* energy is being used, rather, the energy that is being used is *less expensive*. This cost savings can add significantly to a utility's bottom line and provide additional operating revenue or resources to invest back into capital or other energy saving programs.

In many cases, pumps are oversized for their task, or have become inefficient over time due to age and general deterioration. Each pump should be evaluated to determine if it is operating at the BEP. The BEP is the point at which effects of head (pressure) and flow converge to produce the greatest amount of output for the least amount of energy.

Where appropriate, utilities should consider pump modifications such as refurbishing, trimming impellers, and the use of VFDs. This can improve efficiencies, particularly in cases where pumps are oversized or pumps are controlled by throttling. Easton Consultants (1995) estimated that correcting oversized pumps could save 15 to 25 percent of energy costs from pumping. Comparing the manufacturer specifications and performance curves with actual operational data is an integral part of optimizing pumps and evaluating pump efficiency. There are a variety of factors that can lead to pumps operating at less than optimal settings. These factors include:

- Improper design resulting in installed components being inherently inefficient during normal operating conditions as a result of pumps being oversized for the normal job, or changes in operating conditions
- Degradation or deterioration of components
- Improper or inefficient operation because too much flow or more head (pressure) is provided than the system requires or equipment is being operated when it is not required. Operators need to understand the effect of operating equipment at “higher-than-necessary” flows and pressures
- Generation of excess pressure by use of multiple pump systems
- Using high system pressure instead of a booster pump
- Inefficient motors (see section on Motors)

Based on the pump evaluation and efficiency/life cycle analysis, a water utility can make necessary equipment adjustments, determine if a pump needs to be re-sized or replaced with multiple pumps (which can be turned on as needed), develop pump optimization procedures, and change the pumping schedule to maximize efficiency along with other approaches. Many pump optimization options have a relatively short payback when incorporating savings from maintenance and energy costs (DOE 2006).

Additionally, with any pump optimization or improvement, evaluation should be given to the pump motor (see Motor section). The motors powering pumps should also be high efficiency. High efficiency AC motors can be in the range of 10 percent more efficient than normal AC motors (efficiency also depends on rated output) (DOE 2006). While the savings may seem modest, it adds up quickly for pump motors that are used frequently or constantly.

If a system is unmetered, one of the most important steps to take is installing meters. As resources may be limited, the utility should focus first on commercial and industrial customers so that they can monitor water consumption of various processes to find ways to reduce consumption and costs. This can save the utility energy costs by reducing the amount of water that must be treated and delivered. The drinking water and clean water SRFs now have a requirement to direct 20 percent of their capitalization funds to “green projects.” Under ARRA, many utilities chose to use this funding to install meters. In some cases, states provided this funding as a no interest or negative interest loan (i.e., grant). While this may not be the case going forward under the base SRF programs, a utility should still contact the state to find out what programs and incentives they may have in place to support metering projects under GPR.

Lighting is another area that should be evaluated by a small utility. Typically, the greatest potential exists as part of designing a new facility, although a system can take some initial steps in this area. This involves modifying current operating procedures to require any replacements to adhere to new energy efficiency standards. Bulbs should be maintained and cleaned on a regular basis since dirt and materials accumulating on lighting can reduce the lighting output by as much as 30 percent (CEC 2000b).

Leak detection and repair is an important part of any energy savings program. Identifying and fixing leaks can reduce a water system’s “real” water losses that can then be available to generate revenue. Loss of water through leaks costs the utility in the form of wasted money on chemical addition and treatment, and wasted energy on treating and pumping water that is “lost” to the system. The average water loss in a system is approximately 16 percent but that can be up to 50 percent for poorly maintained and failing systems (Thornton 2002). For small utilities, the best approach is to fix leaks as soon as they are discovered. The purchase of leak detection equipment

may also be fundable through state SRF programs under GPR. Metering can help a utility account for all water and can speed the identification of and response to leaks.

Once a utility has identified the changes to be made it should develop an implementation plan (Step 5). This involves identifying priorities and timeframes for making the changes. For a small utility, this could be as simple as a document listing action items with a tentative timeframe. The utility should keep it simple and start with the least cost, easiest options first. This may be contacting the power provider and sitting down with them to discuss the utility's energy bills and options to evaluate alternative rate structures or changing time-of-use patterns. The utility should also inquire about the availability of free energy audits. The audit will provide more information about pump and motor efficiencies and changes may need to be made.

To evaluate and track progress (Step 6) a small utility should use baseline established in the ENERGY STAR® *Portfolio Manager* to compare changes in energy use as various actions are implemented. Finally, small utilities should communicate their energy efficiency efforts to their customers. This information could be included in a utility's annual CCR or as a bill stuffer in monthly or quarterly water bills. Once a utility takes the initial step to identify and implement energy efficiency options, it may find that resources saved can be put back into expanding the program.

Intermediate Approach

The Intermediate Approach is suited for medium-sized utilities that have several staff, active management such as a Board and utility managers, more sophisticated monitoring and metering systems, and perhaps a more steady, defined revenue stream. The concepts described in the Targeted Approach are still applicable to these systems but they can be addressed in more detail and more holistically. A utility of this size may identify an *Energy Program Manager* to take an active lead in evaluating energy efficiency options and lead implementation efforts. This utility may have a more developed asset management inventory that can be expanded to include details related to energy efficiency for pumps, motors, and treatment processes. It may have operating SOPs and SCADA systems that can be used to evaluate and track implementation efforts. SCADA systems are versatile and include multiple applications and can be set up to automatically monitor and control a single component of the water facility or all aspects of the water facility such as wells, pump stations, valves, treatment plants, storage facilities, etc. The system can track energy use, and improve overall water system efficiencies by automatically controlling equipment operations, flow rates, and pressure based on real-time data. SCADA can also monitor equipment efficiency, leak detection, and meter reading and can sound necessary alarms when operations are out of "normal" range. Automatic control by a SCADA system can achieve 10 to 20 percent energy savings (EPRI 1997). Water utilities can install SCADA systems in a step-by-step manner over time which allows the water system to use the automatic control in areas that will provide the most benefit. A SCADA system is an important management tool with regard to data storage as it provides the water utility with useful operation information for analysis of the facility's processes, energy use, and benchmarking comparisons.

Coordination with the power provider is still a first step in developing an energy efficiency program as is the use of the ENERGY STAR® *Portfolio Manager*, *AwwaRF Energy Index*, SCADA, or a proprietary software system that can be purchased off-the-shelf to develop a baseline of energy use. In addition to a high level/walk through audit, the equipment audit should include an evaluation of HVAC and fleet vehicles. Detailed process audits should be conducted that focus

on the assessment of a specific process or operation identified as being energy intensive. Raw water pumping, distribution system pumping, and filtration and treatment processes are good focal points for performing a detailed process energy audit. Data gathered during the energy audit can be used to create an energy inventory and help in developing an energy map. The “Lean and Energy Toolkit” from USEPA (<http://www.epa.gov/lean>) outlines the process of developing an energy map.

As with the Targeted Approach, utilities in this group should evaluate their energy bills to reduce the energy consumed during peak demand periods. Many rate structures correlate to a demand response option or program that encourages customers to reduce on-peak demand usage. The rate options available vary by electric provider and many providers are open to negotiating special rates; therefore, water utilities should open the lines of communication and work with their energy provider in order to select the best available rate structure. The various available rate structures that might apply to this size utility include:

- Fixed pricing
- Demand pricing
- Time of Use (TOU) pricing
- Real-Time Pricing (RTP)

Implementing TOU rate structures encourages water utilities to shift load demand from on-peak to off-peak periods by changing operation schedules. However, shifting pumping operations to off-peak or partial-peak hours requires the water utility to have adequate water storage or on-site electric generation as well as adequate staffing. Utilities should use water consumption forecasting to help operators to take advantage of various electric rates and off-peak periods.

Calculating and evaluating electric consumption data is vital for water utility managers to understand energy use and to determine how to best make improvements. From load demand profiles, managers can determine how much energy is used, when it is used, and by what equipment it is used. Since energy usage can vary from minute-to-minute, hour-to-hour, and month-to-month, a water utility manager should develop various load demand profiles.

The load demand profiles should compare water demand usage to energy usage, electric usage (load) as a function of time as related to water demand, and electric usage as related to electric rate schedules (on- and off-peak periods). Collection of the necessary data can occur during an energy audit or benchmarking process. It may be necessary to request assistance from the electric provider or hire an outside expert to help collect the appropriate data and develop the load profiles. Additionally, software programs are available to assist water systems with load demand profiles. Based on the load demand profiles generated, water utility managers can develop energy forecasting models for the short- and long-term to assist in energy conservation strategies.

Understanding electric billing can help the water utility to adjust its operational schedules based on the load demand profiles. The most common electric billing includes two components: demand charges which vary with time of day and with highest rates during periods of peak utility use, and energy consumption charges which are based on kilowatt hours consumed. The demand charges typically are the most significant to a water utility’s monthly energy bill since peak water demand normally correlates to peak energy demand. This billing structure may not be applicable once a water utility uses/accepts special rate or incentive structures, such as real-time pricing, interruptible load, or demand bidding.

Water utilities can reduce load demand by optimizing existing equipment, installing variable frequency drive (VFD) motors for equipment that must operate during peak demand, or adding smaller motors that can operate during low demand periods.

If primary meter and submeters are not already installed at various processes and equipment throughout the water system, it would be a very beneficial improvement to consider, especially if the water system plans to implement or utilize energy forecasting and create demand load profiles to reduce electrical demand and costs. Retrofits to existing equipment are possible; however, installation of meters and submeters during installation of new equipment is less expensive and provides a start to collection of real-time data. An integral component to the installation of electric meters is having an available SCADA system to collect, store, and relay the data.

These utilities should also consider conducting a water audit to determine the volume of water loss. Water audits entail gathering details on the facility; evaluating design plans and pipeline infrastructure; listing all equipment that use water, such as conveyance and distribution lines; performing a walkthrough of the facility to look for individual processes and their water use; performing a leak detection survey on pipelines; identifying zones of low pressure; and defining areas for further investigation and improvement.

As part of water loss management, a water utility should define short-term and long-term goals to reduce water loss. These goals could include implementing active leakage control to locate unreported breaks, identifying ways to reduce the number of leaks and breaks such as pressure management, pipeline replacement programs, asset management, and implementing an automatic control system. Automatic control systems, such as SCADA, can automatically detect leaks and monitor and control pressure along the distribution system. The instantaneous knowledge of a potential leak allows for quick fixes and limits the volume of water loss.

Water utilities find comprehensive water auditing procedures outlined in AWWA's third edition M36 publication, *Water Loss Control*. AWWA and International Water Association developed a free water audit software program available for water systems that can be downloaded at: <http://www.awwa.org/Resources/WaterLossControl.cfm?ItemNumber=48511&navItemNumber=48158>.

The AWWA water audit program details a variety of consumption and losses that exist in a water system and applies a water balance approach in the analysis of a water system's data. The water balance approach provides accountability, as the quantity of water drawn into the distribution system should, in theory, equal the quantity of water taken out of the distribution system. The water audit program standardizes the approach to allow for comparisons and benchmarking of best practices which allows the systems to make meaningful assessments of water loss and to set goals.

Under the Intermediate Approach, a utility may also want to evaluate energy generating options or purchasing green power. Unlike wastewater systems, drinking water systems do not have significant opportunities to generate energy. The most common approach is to use of in-line (micro) turbines in place of PRVs. The energy generated can be used to run affiliated pumps or other equipment.

Under Step 5, these utilities should be able to develop implementation plans to systematically evaluate and implement energy efficiency improvements. This may include the conduct of life-cycle analyses and evaluation of costs and pay-back periods. Payback is defined as 'the time it takes the cash inflows from a capital investment project to equal the cash outflows, usually expressed in years.' The payback period analysis is often used as a "first screening method," meaning that when a capital investment project is being considered, the first question to ask is: "How

long will it take to pay back its cost?” This analysis can also be used when comparing two or more project options, where the decision is often to accept the project with the shortest payback period.

In the case of energy efficiency, the payback analysis quantifies the number of years of energy savings that it would take to account for the costs of the energy efficiency improvement. The energy savings (or financial benefits) will accrue annually over the life of the project. In general, the shorter the payback the more attractive the project is, particularly for utilities where there is limited funding for capital investment.

Plans should be communicated to Boards and other stakeholders. Of particular importance is ensuring staff and operator buy-in to the changes. It may be necessary to revise SOPs, conduct operator training, or establish new monitoring procedures to successfully implement the proposed changes.

Developing performance metrics, reviewing schedules and implementation status, and tracking progress can be accomplished with more sophisticated tools such as proprietary software or SCADA systems under Step 6. Results of some changes may be realized almost immediately whereas other changes may take awhile to see results, and others may vary over time.

Utilities using this approach will likely have broader communication and outreach tools available to them such as Web sites, newsletters, and other outreach mechanisms to communicate and share success.

Comprehensive Approach

The Comprehensive Approach provides the broadest and most detailed step-by-step analysis and decision-making involved in making energy efficiency changes. While primarily designed for larger utilities with adequate staff and resources, some of the elements can be structured on a lesser scale for medium and small utilities.

Under Step 1, larger utilities will likely have the resources to create an *Energy Management Team* to assist the *Energy Program Manager*. Members of the *Team* are comprised of staff from various levels and functions within the utility. Members will represent various departments including operations, engineering, water quality, finance, and public relations. Utility operators are a critical part of the team. Collectively, this team can bring together all critical functions of the utility to holistically identify and evaluate energy efficiency options. In addition to the activities described under Step 2 for the previous two approaches, utilities using this approach may also consider the use of hydraulic data, climate data, and information about conservation practices as they develop their energy baseline. In addition to using ENERGY STAR® *Portfolio Manager*, the *AwwaRF Energy Index*, SCADA, or a proprietary software system, these systems may also choose to develop their own models. These systems may already have Energy Management Systems and/or Energy and Water Quality Management Systems, and Computerized Maintenance Management Systems in place to track and manage energy consumption and asset inventory information.

The process to complete Step 3 is similar to the Intermediate Approach but the detailed process audit may also address more sophisticated and energy-intensive treatment processes such as RO, UV, membranes, and desalination. Energy use modifications under Step 4 may also include:

- *Interruptible Load* programs that provide the customer with a 1-hour notice to reduce load in exchange for a lower rate.
- *Demand Bidding* programs have customers bid on the time-of-day and number of hours to curtail load for financial incentives.

These larger utilities will likely have short- and long-term capital improvement plans that incorporate equipment purchase or replacement to address priorities in their energy efficiency plans. This may include the purchase of renewable technologies such as solar and wind and use of in-line turbines. They may also have more substantive conservation programs with rebates and customer incentives to reduce water and energy use. A comprehensive tracking and accounting system is needed to evaluate changes and the impact on energy consumption for these systems. In addition to the communication vehicles identified for the other two approaches, these utilities may also engage in marketing and educational campaigns designed to change consumer behavior.

As demonstrated by these three approaches, regardless of utility size, complexity, or financial means, all water systems can and should take steps to understand, evaluate, and implement energy efficiency practices and procedures. Strategies in each approach can be used by utilities of any size. Working with your energy provider is a key first step to start down the path of improved energy efficiency and cost savings.

POTENTIAL BARRIERS AND HURDLES

Developing and implementing energy efficiency programs can be daunting for water utilities new to this arena. A number of potential barriers and hurdles exist as described by NYSERDA (2008). These barriers include:

- *Operational barriers:* commonly the result of staff having limited or no education or experience in the identification or implementation of energy efficiency measures.
- *Institutional barriers:* results from staff and management not changing the “status-quo” and difficulties implementing new policies and the absence of a holistic approach across multiple departments.
- *Political barriers:* associated with the lack of understanding of the technical or economic aspects of the improvement and the subsequent unwillingness to invest in energy efficiency projects, and the desire to avoid rate increases and rate shock.
- *Regulatory barriers:* results from management not wanting to risk any decrease in public safety in an attempt to improve energy efficiency; therefore, equipment is typically oversized.
- *Financial barriers:* results from the inability to obtain funding without implementing rate increases, the concern that the potential savings will promote smaller operating budgets, and the dependence on the relatively low costs of energy. In many cases, utilities are unaware of financing incentives and rebates that could help pay for energy efficiency improvements such as energy provider rebate and incentive programs and state SRF programs.

The AwwaRF report *Risk and Benefits of Energy Management for Drinking Water Utilities* (Raucher et al. 2008) identified a number of energy management challenges facing water utilities. These include public health and safety, system reliability, and prudent cost management which are all dependent on how well a water utility manages its energy demands and power supply options. The report addresses a water utility’s need to recognize the wide range of energy management options—including energy demands and generating energy supply, as well as the risks and benefits of these options. For example, optimizing the electrical demand profile in transmission and distribution (i.e., filling tanks at night and using stored water during the day) may lead to water supply

and quality reliability issues. Optimizing pump cycling has benefits in terms of energy management but it needs to be balanced with other system needs such as maintaining adequate system pressure. Advanced treatment technologies such as ozone, UV, and membranes are significantly more energy intensive and may require a high degree of power quality for treatment and automatic control systems. The authors conclude that the solutions will be many, varied, and unique to specific utilities and will likely entail a combination of modified operational practices and new or retrofitted capital equipment.

CHAPTER 6

SUMMARY AND RECOMMENDATIONS

SUMMARY OF KEY FINDINGS

Through the conduct of an extensive literature search and case studies, the authors of the report identified a multitude of energy efficiency best practices currently in use at drinking water systems in North America. These practices were organized and consolidated into eight major areas including management tools, plant improvements and management changes, water treatment, water distribution, water conservation, alternative/renewable energy sources, financial assistance, and partnerships. These areas cover the full breadth and scope of utility services as well as identify resources and partnerships that can aid utilities in implementing energy efficiency improvements. In many cases, such improvements will not require expensive or extensive capital investments—simply optimizing a utility’s current equipment and operations practices can lead to significant reductions in energy consumption. Key findings include:

- Some level or type of energy efficiency improvement can be realized by utilities of all sizes and management structure. However, it requires leadership commitment at the executive level and operator buy-in to be successful. Corporate officers and senior managers must be the drivers to establish energy goals and promote energy efficiency as good for business.
- Optimizing energy use is a way to save money, promote environmental stewardship, and improve sustainability.
- Improving energy efficiency is a constantly evolving process.
- It takes energy (time and resources) to save energy; it is vital to allocate adequate resources for staff training and equipment maintenance.
- Operator and staff buy-in and training on energy efficiency practices, SOPs, and managing data tracking systems is critical. It is a challenge for water utility staff to make a personal commitment to carry out energy conservation goals and use the available technology to meet these goals.
- Partnerships with the energy providers may be particularly useful in identifying energy conserving options. While simple approaches like working with energy providers to evaluate the schedule and timing of pump usage can lead to significant cost reductions (although perhaps not energy use reductions), such cost savings can inspire a utility to look for other opportunities to enhance energy efficiency.
- For drinking water utilities, the primary area to target improvements is pumps and motors since pumping accounts for 80 to 90 percent of the energy used at most water utilities. This may include pump rehabilitation, pump optimization, correctly sizing pumps, and use of VFDs.
- Benchmarking and conducting energy audits can help a utility define its current energy usage and establish a baseline from which to measure and track changes and reductions over time as energy improvements are implemented.

- Investment in adequate monitoring and tracking systems, databases, and SCADA are critical for managing energy usage, measuring success, and formulating new energy efficiency strategies.
- Energy efficiency efforts should be tied to asset management plans and systems to ensure assets are properly maintained. Include high efficiency pumps, motors, lighting in bid specifications.
- Unlike wastewater facilities, options to “generate” energy are somewhat limited for drinking water utilities. The most common approach is the use of in-line turbines that generate energy to run ancillary equipment such as pumps at the site location. Some larger utilities have incorporated alternative energy sources such as solar and wind but this may not be cost effective for smaller utilities.
- Water efficiency can lead to energy efficiency since less water is treated and moved through the distribution system. Leak identification and repair in the distribution system, water audits, and conservation programs for commercial and residential users can reduce water use. Key to success is adequate metering and a rate structure that does not penalize a water utility by reducing revenue because it has successfully encouraged its customers to conserve water.
- A water utility can never have too many meters or submeters. The collection of accurate electric data is an important component of a program.
- Funding is available to water utilities to implement energy efficiency options. Drinking water SRFs now include a requirement for the states to allocate 20 percent of the capitalization grant to “green projects.” For drinking water, this includes funding for on-site production of power, energy audits, equipment upgrades, leak detection equipment, meter installation, and installation of water efficient devices. State energy offices, other state authorities, and individual energy providers may have funding for studies and pilot projects as well as financial incentive and rebate programs that can help pay for project implementation costs. In some cases, energy providers will “pay” utilities to improve energy efficiency.
- Utilities need to understand that efforts to increase energy efficiency are not without risks and tradeoffs that may impact water quality and public health protection. Changes may require more closely monitoring system operations and water quality

SIGNIFICANCE OF RESULTS TO UTILITY PRACTICE

Reducing greenhouse gas emissions, enhancing the environment, and promoting sustainability through energy efficiency practices is good for drinking water utilities, good for customers, and good for the planet. Energy efficiency improvements can help utilities deal with changing water quality standards, variations and changes in source water quality, changes in distribution systems, and can save a utility a significant amount of money.

All utilities, regardless of size, complexity, and management structure can undertake energy conserving measures to reduce energy use. In many cases, such improvements may not require expensive or extensive capital investments—simply optimizing a utility’s current equipment and operations practices can lead to significant reductions in energy consumption. To be successful, however, leadership commitment at the utility level and operator buy-in is critical. Corporate officers and senior managers must be the drivers to establish energy goals and promote energy efficiency as good for business. They must be willing, if necessary, to invest in operating

and tracking systems, staff training, and an on-going and evolving energy efficiency plan. In addition, a partnership with the utility's energy provider is a critical first step in heading down the road to improved energy efficiency.

This report documents numerous opportunities in eight major areas—management tools, plant improvements and management changes, water treatment, water distribution, water conservation, alternative/renewable energy sources, financial assistance, and partnerships. These areas cover the full breadth and scope of utility services as well as identify resources and partnerships that can aid utilities in implementing energy efficiency improvements. There is something in this report for every utility—no matter how small or how large.

This is not a case of one-size-fits-all. Each utility is unique and needs to evaluate its own goals, financial conditions, and commitment to improved energy efficiency. Regardless of where a utility is on the path to energy efficiency, they can always take additional steps. That's not to say that the utility won't encounter hurdles or barriers along the way. Efforts to increase energy efficiency are not without risks and tradeoffs that may impact water quality and public health protection. While these changes may require more closely monitoring system operations and water quality, that can actually be good for, and reap additional benefits to the utility.

Energy efficiency is in and opportunities, partnerships, and resources have never been more available to utilities than they are today. This is expected to be the case well into the future. Now is the time for utilities to step up to the plate and embrace energy efficiency. Begin learning about energy efficiency options, expand current energy efficiency programs, and promote energy efficiency programs to peers and customers. The tools and knowledge are within your grasp—all you have to do is reach out and grab them.

RELEVANCY TO UTILITIES IN NEW YORK STATE

In November 2008, NYSERDA published a report titled *Statewide Assessment of Energy Use by the Municipal Water and Wastewater Sector* (NYSERDA 2008). The report established a baseline electricity use by the water and wastewater sector in New York State estimated between 2.5 and 3 billion kWh/year; about two-thirds being consumed by wastewater treatment facilities. Nearly 95 percent of all New York State's residents are served by a public water supply and/or municipal wastewater treatment plant according to the report. This includes 702 wastewater treatment plants with a combined design treatment capacity of 3.7 billion gallons per day and nearly 2,900 community water supply systems that produce an estimated 3.1 billion gallons of drinking water per day. Additionally, there are approximately 7,000 non-community water supply systems. With respect to smaller utilities, the electric energy consumed by surface water source utilities serving less than 3,300 people is approximately 50 percent greater than electric energy consumed by groundwater source systems serving the same number of people. For utilities serving between 3,300 and 100,000 people, electric energy use is comparable between surface water and groundwater source systems. Although the state-wide electric energy use average of 705 kWh/MG is about one half the national average of 1,400 to 1,500 kWh/MG for drinking water utilities due to a number of variables detailed in the report; there is still opportunity for water utilities to reduce energy consumption. Additionally, economic incentives to do so exist because the average retail price for electricity is 40 to 60 percent higher in New York State than the national average.

According to the NYSERDA report, the smallest community water utilities are generally the least energy efficient on a per unit basis (kWh/MG); however, as with wastewater systems, these facilities account for only a small percentage of the State's overall energy use. Based on the

analysis, it appears that small surface water systems and large groundwater systems may offer reasonable opportunity for energy efficiency improvements. Large groundwater systems, serving greater than 100,000 people appear to provide the greatest opportunity. Small to mid-sized facilities are also prime candidates for energy efficiency improvements, as they represent a substantial portion of the State's overall population served by public water systems but do not appear to have fully benefited from the economies of scale associated with the largest utilities. For drinking water utilities, peak electric demand on a seasonal basis typically occurs in the summer months.

In addition to NYSERDA (see chapter 3 for a discussion of NYSERDA programs), the New York Independent System Operator (NYISO), the New York Power Authority, the Long Island Power Authority, the New York State Environmental Facilities Corporation, and others offer programs aimed at promoting energy efficiency practices in New York State. The NYISO is responsible for the reliable operation of New York's nearly 11,000 miles of high-voltage transmission and the dispatch of over 500 electric power generators (<http://www.nyiso.com/public/index.jsp>). In addition, the NYISO administers bulk power markets that trade over \$11 billion in electricity and related products annually. NYISO operates a number of peak demand reduction programs to improve the reliability of New York's electric grid. Specific programs include:

- **Emergency Demand Response Program (EDRP)**—A short-notice program that provides payments to electric customers who reduce load during specific times in response to NYISO concerns over the availability or reliability of the grid.
- **Day-Ahead Demand Reduction Program (DADRP)**—A program that allows large energy users to bid their load-reduction capability into New York's wholesale electricity market on a day-to-day basis. These load reduction bids compete with generators' offers to meet the State's electricity demands.
- **Installed Capacity Special Case Resources**—A reserve capacity program that contracts resources to meet supply requirements over a specified contract period.

In addition to programs administered by the NYISO, water utilities may choose to use backup generators to offload peak demand in an effort to reduce demand charges associated with operation of their facility. However, in many cases the backup generating equipment is aging and may not meet current environmental standards, particularly those related to air emissions. Additionally, water utilities may be able to stagger or delay the operation of large equipment or specific treatment processes to flatten electrical demands during peak periods.

The New York Power Authority (NYPA) is the country's largest state public power organization and one of the nation's largest hydropower producers (<http://www.nypa.gov/>). It offers a number of energy efficiency programs across the state, a number of which can be utilized by drinking water utilities. These include the following.

Energy Efficiency and Renewable Energy Programs—Programs for publicly-owned facilities that include upgraded lighting and sensors in buildings, installation of boilers and chillers, installation of mounted solar panels, replacement of windows, and development of energy management systems. The program provides energy-efficiency improvements, with no up-front costs, to public schools and other government facilities. NYPA has undertaken more than 1,500 energy-efficiency projects at some 2,300 public buildings across the state. These measures have reduced demand by more than 190,000 kilowatts—equivalent to the output of a medium-sized power plant—and lowered the electric bills of state and municipal governments by more than \$93 million a year. Over the past decade, NYPA has completed energy efficiency projects at over two

dozen wastewater facilities statewide, resulting in over \$35 million in energy savings. In March 2009, NYPA announced a campaign to reduce by approximately 20 percent the energy demand of water supply and wastewater treatment plants in New York State by 2015 and help to lower greenhouse gas emissions. To achieve energy savings at these facilities, NYPA will promote a combination of on-site solar electric power systems, biogas recovery to supply on-site power, and energy efficiency measures.

Peak Load Management Program—A NYPA load reduction program designed to provide system reliability and help manage the electric demand of customers during system peak load times. In addition to NYPA demand response programs, the Peak Load Management portfolio incorporates NYISO-sponsored programs including Special Case Resources, and Emergency Demand Response, as well as the Consolidated Edison Company of New York (Con Ed) voluntary and mandatory offerings of the Distribution Load Relief Program.

The Long Island Power Authority (LIPA), a non-profit municipal electric provider, owns the retail electric Transmission and Distribution System on Long Island and provides electric service to more than 1.1 million customers in Nassau and Suffolk counties and the Rockaway Peninsula in Queens (<http://www.lipower.org/>). LIPA is the 2nd largest municipal electric utility in the nation in terms of electric revenues, 3rd largest in terms of customers served and the 7th largest in terms of electricity delivered. LIPA offers a variety of energy efficiency programs for homes including rebates and incentives for appliances and access to home efficiency audits. LIPA also has renewable energy programs that include backyard and off-shore wind, geothermal systems, and solar energy.

The New York State Environmental Facilities Corporation (EFC) provides low-cost capital and expert technical assistance to municipalities, businesses, and state agencies for environmental projects in the state of New York (<http://www.nysefc.org/home/>). The EFC administers a number of programs that can help drinking water and wastewater utilities. These include:

Drinking Water and Clean Water State Revolving Loan Funds (SRFs)—Since 1970, EFC has provided almost \$15.5 billion in low-cost financing and grants for over 2,100 water and sewer infrastructure projects in the state. As part of a larger consortium of state agencies, EFC is working to incorporate Smart Growth and energy efficiency into the administration of these funds.

Water Conservation Programs—It takes a considerable amount of energy to treat and deliver water. By reducing water use, the energy required to supply and treat public water supplies also is reduced, thereby saving on operating costs for facilities. These savings often translate into capital and operating savings, which allow utilities to defer or avoid significant expenses for water supply facilities and wastewater facilities. Using water more efficiently also helps maintain water supplies at safe levels. Many water systems do not generate enough revenue to cover their operating costs. That means for every gallon sold, more money flows out than flows in. For these utilities, selling less water actually improves the bottom line. For systems on a firmer financial footing, selling less water may decrease profits but sales losses can be offset when treatment, disposal, and energy costs come down because less water is processed. On average, these savings can offset about 30 percent of the losses associated with selling less water. The EFC has a number of programs that support water conservation. These include water saving tips and a residential water survey, information on high efficiency appliances that use water, water conservation seminars for building managers, and a water reuse program.

Chapter 4 of this report provides five real-world case studies of drinking water utilities in the State of New York and the steps they have taken to improve energy efficiency. The sizes of these utilities range from 9,500 to 1.2 million persons served. The technologies discussed include

in-line turbines (hydroturbines), use of SCADA systems, pump optimization and refurbishment, use of VFDs, load shedding, and peak load reduction programs. These actions have saved millions of kWh/year and have resulted in savings up to several hundred thousand dollars per year.

These five case studies, along with the discussion of other case studies and the comprehensive description of energy efficiency best practices found in this report, should provide the tools and support to guide New York state water utilities toward improving energy efficiency, reducing GHG emissions, and ultimately saving money. One of the best first steps is developing a comprehensive asset inventory of water utility equipment, components, and processes that use energy. Next, explore how operations practices can be optimized to reduce energy consumption. These efforts, while they take staff time, can be accomplished with little or no capital cost. Finally, review Chapter 5, *Developing a Roadmap to Energy Efficiency*, which provides a framework that can be used to actively develop and implement an energy efficiency program. Remember to take small, incremental steps that can lead to success and start the utility down the right path toward improved energy efficiency. Learn about the resources available in your state that are described in this section. These resources can provide the technical and financial support to help bring your plan to fruition. The information, tools, strategies, and support are available, the time has never been better to take up the challenge.

ADDITIONAL RESEARCH NEEDS AND RECOMMENDATIONS

One of the challenges experienced in preparing this report was reading through and distilling so much information on energy efficiency for drinking water utilities, ranging from fact sheets, to journal articles, to Web sites, to lengthy research-oriented reports. In this report, the authors have attempted to identify and provide information and links to some of the more useful tools and resources in each of the eight categories discussed in Chapter 3. It might be beneficial for the Water Research Foundation to review these materials and develop a Web page with links to each of these tools and resources under specific headings such as pumps, motors, energy audits, funding programs, etc. This one-stop-shop of tools and “how to” guides might be very useful to utilities that are interested in learning more about these programs but do not have the time or staff resources to spend sifting through all the information. In addition, the information in this report has been summarized in an easy-to-use searchable database that is provided as a companion CD-ROM to this report. The Water Research Foundation should consider uploading the database to its Web site and provide access to it by drinking water utilities and others. Thought should also be given to how the database might be maintained and updated over time to reflect the new tools and resources that are published on a frequent basis.

While a number of fact sheets, guides, and manuals have been published related to energy efficiency, there seems to be a lack of good tools for small and medium-sized utilities with regard to conducting an energy audit. While these guides provide a list of steps and explain what information should be evaluated, they don’t really say “how” they should be evaluated. For example, a guide might say “collect and analyze one to three years of energy use data” but it never really explains what exactly a system should look for during the analysis. Copies of sample monthly electric bills with critical information highlighted and an explanation as to how to interpret and analyze the information might be particularly useful for small systems.

Since drinking water and wastewater utilities are relatively large energy consumers, starting a dialogue between water utility organizations and power provider organizations to discuss how power companies and water utilities might better work together could be very beneficial. This might include developing a list of power providers that offer incentives and assistance to water utilities.

APPENDIX A

CASE STUDY INFORMATION TABLES

American Water, NJ

Ref. Enquiry Item	Response information, description, and remarks
1 Location: Country, urban or rural and small, medium or large system:	USA and Canada Various sizes in both urban and rural locations
2 Sector: drinking water [clean], wastewater [waste] or sludge:	Drinking Water and Wastewater
3 [Utility] Works Owner or Operator: with financial set-up, regulatory or not.	Own or Operate 870 water facilities and 270 wastewater facilities in 32 states and Canada
4 Size: flows and loads or population equivalent:	Varies at each facility
5 Energy Provider: with costs, incentives, taxes and conditions:	Varies at each facility
6 Process: physical, chemical, or biological description:	Varies at each facility
7 Component: all or part of the works:	Not applicable
8 Specific energy problem: including quality or consent details:	Pumping (raw water and well pumps, high service pumps, filter backwash pumps, and booster pumps) consumes 85 to 99% of the electricity at water treatment plants. American Water is focused on improving energy efficiency, reducing non-revenue water (NRW) from water “lost” before reaching the customer, and reducing its environmental impact, especially as applied to climate change.
9 Process/Plant changes: mechanical, electrical or controls:	<p>Increasing pumping efficiency by trimming or replacing impellers and bowls, sand blasting and recoating pump wetted parts, installing VFDs or soft starters, and installing new high efficiency pumps and motors. To ensure that pump efficiency is maintained, American Water performs routine pump efficiency, vibration, noise, and thermal tests to identify early signs of degradation of pump and motor efficiency. American Water will improve pumping efficiency through implementation of a <i>Pump Efficiency Testing Plan</i>. American Water will conduct pump tests at the 48 facilities that are responsible for 50% of its annual electricity use. The pump testing will take 24 months using in-house staff.</p> <p>Pump testing is currently underway and is expected to be completed by December of 2010. These results will be used by corporate engineering planning and design staff to identify those pump improvements that will yield the highest energy/carbon savings. The improvements will be designed and constructed over a six-year period. The pump performance and energy use will be monitored annually to quantify the net energy and carbon savings resulting from the pumping improvements.</p> <p>Additional changes include:</p> <ul style="list-style-type: none"> • In process of retrofitting two water treatment facilities with energy-efficient lighting (replace T-12 fixtures with T-8 fluorescent fixtures). American Water has plans to implement the program company-wide.

(continued)

American Water, NJ (Continued)

Ref.	Enquiry Item	Response information, description, and remarks
		<ul style="list-style-type: none"> Improved fleet management through incorporation of “hybrid” vehicles when possible, implementing a “no-idle” policy, and continuing to evaluate vehicle options. “Green” power generation or purchase through installing renewable energy at facilities when possible. Two solar PV installations of 698 kW and 100 kW.
10	Civil/Physical Changes: to water/effluent quality, civil works, or process:	Not applicable
11	Operational Changes: skill levels, procedures and maintenance routines:	<p>Training of staff on new pump optimization procedures.</p> <p>American Water joined USEPA’s Climate Leader program in 2006. Through the program, American Water has committed to significantly reducing its impact on the global environment by setting and achieving a long-term GHG reduction goal. Through the program, the partners commit to the following:</p> <ul style="list-style-type: none"> Setting corporate-wide GHGe reduction goals, to be achieved in 5–10 years; Developing a corporate-wide inventory of the six major GHGs; Developing a corporate GHG inventory management plan; and Reporting inventory data annually and documenting progress toward the reduction goal.
12	Risks and Dependencies: risk assessment of project and changes.	Not applicable
13	Implementation: design, build, procurement, installation and commissioning:	Pumping improvements will be accomplished via a Design, Bid, Build process. Lighting improvements will use a negotiated procurement.
14	Energy Efficiency gains: kWh & kWh/m ³ before and after implementation	Not applicable. Most I mprovements are just starting. Solar PV installations produced 818,000 kWh of electricity in 2008.
15	Cost/Benefit analysis: financial appraisal or payback time.	Energy efficiency improvements require a simple payback of less than two years. Energy efficiency improvements with significant environmental benefits are allowed a longer payback; in some cases up to eight to ten years.
16	Project review: could it be improved or developed?	Not applicable
17	Confidence grade: on data provided.	High

Ann Arbor Water Treatment Services, MI

Ref.	Enquiry Item	Response information, description, and remarks
1	Location: Country, urban or rural and small, medium or large system:	USA, Midwest, urban, large system
2	Sector: drinking water [clean], wastewater [waste] or sludge:	Drinking Water
3	[Utility] Works Owner or Operator: with financial set-up, regulatory or not.	City of Ann Arbor Ann Arbor Water Treatment Services

(continued)

Ann Arbor Water Treatment Services, MI (Continued)

Ref.	Enquiry Item	Response information, description, and remarks
4	Size: flows and loads or population equivalent:	The combined capacity of both water filtration treatment plants is 50 MGD (22 MGD for the original WTP, and 28 MGD for the second WTP)
5	Energy Provider: with costs, incentives, taxes and conditions:	DTE Energy Company (http://www.dteenergy.com/businessCustomers/municipalities/)
6	Process: physical, chemical, or biological description:	<p>Ozone generation system used for primary disinfection of treated water.</p> <p>Implementation of a Demand Management System of standard operating procedures and the ability for operators to view real time energy use at a facility.</p> <p>Physical replacement of single speed motors and pumps with more efficient variable frequency drive motors.</p> <p>Installation of a central computer system to operate the heating and cooling of the facilities at the most efficient level.</p>
7	Component: all or part of the works:	Part of the infrastructure works
8	Specific energy problem: including quality or consent details:	<p>Ozone generation is an effective disinfectant, but requires a significant amount of power to produce the ozone gas. The City believed that by changing water conditions, it could use a lower ozone dose and thereby use less power to generate the disinfectant.</p> <p>Until the Demand Management System was in place, operators were running pumps and processes at peak power demand time and using “top tier” energy pricing without regard to “big picture” operation management.</p> <p>Motors installed in pump stations built prior to the 1980s often had single speeds, which are not energy efficient at low pumping volumes. The City needed to look at a more efficient way of operating its pump stations as well as the pumps at the water treatment facilities.</p> <p>The heating/cooling bills for the City’s buildings and facilities are a large part of the general fund operating budget. It made sense to the City to try and regulate the entire system rather than having workers in one area of a building operate the system completely different than workers in another area.</p>
9	Process/Plant changes: mechanical, electrical or controls:	<p>The City conducted a pilot study prior to full-scale construction to investigate water chemistry impact on energy for ozonation; an optimal system was installed to depress pH by adding carbon dioxide in the water stream, apply the ozone dose, then raise the pH with caustic soda for disinfectant maintenance in the distribution system.</p> <p>AAWTS has worked to gather input from the power company, operators, and energy system monitors to create a Demand Management System that can interface with operations and the SCADA network system.</p> <p>Energy consumption savings have been achieved by replacing single speed motors with variable speed drives.</p> <p>AAWTS has purchased proprietary software from Siemens to operate all heating and cooling functions.</p>

(continued)

Ann Arbor Water Treatment Services, MI (Continued)

Ref.	Enquiry Item	Response information, description, and remarks
10	Civil/Physical Changes: to water/effluent quality, civil works, or process:	<p>Primary ozone disinfection can be performed at optimum conditions so less ozone is needed. There is no change in the quality of the finished water.</p> <p>Operators now follow a “script” for routine operations based on energy demand and daily pricing of energy.</p> <p>Variable frequency drive motors employ a slower “soft” start as compared to a standard motor. The slower start has less of a water hammer effect on the pipe network and valves, the slower start reduces the amount of electricity needed at start up.</p> <p>No physical change other than added software and interfacing equipment.</p>
11	Operational Changes: skill levels, procedures and maintenance routines:	<p>AAWTS needs to examine the cost savings of less energy needed for ozone generation against the cost of the carbon dioxide and caustic soda feed systems including safety measures associated with each chemical.</p> <p>Operators must be trained in using the Demand Management System as well as review the SOPs behind the system on an on-going basis.</p> <p>Electrical changes must be made to accommodate the new motors including a new interface with the SCADA system.</p> <p>The upgrade to the computer system that controls the HVAC has not resulted in significant changes to the heating quality of the facilities</p>
12	Risks and Dependencies: risk assessment of project and changes.	No significant risk from the implementation of any of these projects.
13	Implementation: design, build, procurement, installation and commissioning:	<p>The ozone system was originally designed to incorporate modifying the water chemistry during the ozone gas application in order to be efficient in the design of the treatment facility.</p> <p>All the work for the Demand Management System, the high efficiency pump and motor replacement, and the heating system for the utility have been accomplished in-house.</p>
14	Energy Efficiency gains: kWh & kWh/m ³ before and after implementation	AAWTS has not developed any metrics to be able to quantify actual energy savings. Operating the ozone plant by depressing the pH of the water as the ozone gas is applied is the only manner in which that treatment process has been operated. So no data exists in the “before” state. Replacing existing pumps and motors with high efficiency equipment will reduce energy consumption, but the proof of the savings is buried in complex power bills for multiple facilities—too cumbersome to extract power data to individual pumps and motors. The Demand Management System only directly impacts the price paid for energy. It is reasonable to assume that there is an energy conservation gain as a result of the system, but that savings would be realized by the power company, not the water utility.
15	Cost/Benefit analysis: financial appraisal or payback time.	AAWTS estimates a 5-year payback period on all motor replacement projects.
16	Project review: could it be improved or developed?	As the utility gains more experience with energy savings, better metrics can be developed to document the magnitude of the savings benefit.
17	Confidence grade: on data provided.	High

Austin Water Utility (1), TX

Ref.	Enquiry Item	Response information, description, and remarks
1	Location: Country, urban or rural and small, medium or large system:	USA, south central, urban, large system
2	Sector: drinking water [clean], wastewater [waste] or sludge:	Drinking Water and Wastewater
3	[Utility] Works Owner or Operator: with financial set-up, regulatory or not.	Owner/Operator: City of Austin Municipality
4	Size: flows and loads or population equivalent:	285 MGD maximum capacity (two water treatment plants combined). Maximum peak demand (Aug 2009) of 226 MGD. Pump/Treat average of 50 billion gallons of water per year.
5	Energy Provider: with costs, incentives, taxes and conditions:	Austin Energy Community-owned (Department of City of Austin) Serves over 388,000 customers Total energy usage for AWU in 2008 (both water and wastewater) was 210 million kWh. AWU estimates it takes 2600 kWh per million gallons for system-wide treatment and distribution of drinking water. Electric costs are approximately \$.08 per kWh
6	Process: physical, chemical, or biological description:	Physical: optimize raw water pumping, utilize gravity feed, improvements in fleet vehicles, and use of renewable energy.
7	Component: all or part of the works:	Raw water intake pumps
8	Specific energy problem: including quality or consent details:	In 2007 AWU staff determined that inefficient pumping operations were resulting in large energy demands for pumping water at the Ullrich Water Treatment Plant. Operators were “throttling” the raw water intake pumps in an effort to save energy by avoiding switching pumps. But leaving the valves throttled for extended periods turned out to be more inefficient.
9	Process/Plant changes: mechanical, electrical or controls:	Mechanical
10	Civil/Physical Changes: to water/effluent quality, civil works, or process:	Not applicable
11	Operational Changes: skill levels, procedures and maintenance routines:	Developed clear guidance and procedures on when to switch pumps and when to throttle. Procedures provide guidance to minimize the use of “throttling” to control flow.
12	Risks and Dependencies: risk assessment of project and changes.	Not applicable
13	Implementation: design, build, procurement, installation and commissioning:	Not applicable
14	Energy Efficiency gains: kWh & kWh/m ³ before and after implementation	Reduction from 2048 kWh/MG to 1866 kWh/MG plant average which is an 8% reduction in energy consumption for the Ullrich WTP For 1st year, process reduced use by 5,000 MWh/yr.
15	Cost/Benefit analysis: financial appraisal or payback time.	Approximately \$400,000 annual savings at the Ullrich WTP at minimal costs since no new equipment was purchased.
16	Project review: could it be improved or developed?	Not applicable
17	Confidence grade: on data provided.	High confidence in energy savings calculations.

Austin Water Utility (2), TX

Ref.	Enquiry Item	Response information, description, and remarks
1	Location: Country, urban or rural and small, medium or large system:	USA, south central, urban, large system
2	Sector: drinking water [clean], wastewater [waste] or sludge:	Drinking Water and Wastewater
3	[Utility] Works Owner or Operator: with financial set-up, regulatory or not.	Owner/Operator: City of Austin Municipality
4	Size: flows and loads or population equivalent:	285 MGD maximum capacity (two water treatment plants combined). Maximum peak demand (Aug 2009) of 226 MGD. Pump/Treat average of 50 billion gallons of drinking water per year.
5	Energy Provider: with costs, incentives, taxes and conditions:	Austin Energy Community-owned (Department of City of Austin) Serves over 388,000 customers. Total energy costs for AWU in 2008 (both water and wastewater) was 210 million kWh. AWU estimates it takes 2400 kWh/MG gallons for treatment and distribution of drinking water; and electric costs are approximately \$.08 per kWh.
6	Process: physical, chemical, or biological description:	Not applicable
7	Component: all or part of the works:	Not applicable—Water conservation programs
8	Specific energy problem: including quality or consent details:	In 2006, Austin’s City Council approved a conservation goal of reducing peak-day water use by 25 MGD within 10 years. This should result in energy savings as well.
9	Process/Plant changes: mechanical, electrical or controls:	Not applicable
10	Civil/Physical Changes: to water/effluent quality, civil works, or process:	Not applicable
11	Operational Changes: skill levels, procedures and maintenance routines:	Established Water Conservation Task Force (WCTF) responsible for setting policy and to promote accountability of the water conservation program. Additionally, the utility has a strong program for water loss management including leak detection monitoring, water meter accuracy testing, improved response times to fix main leaks and breaks, annual water loss analysis, and increased funding for main replacement. Current and new staff need to be trained on water resource management.
12	Risks and Dependencies: risk assessment of project and changes.	Continued monitoring of programs to ensure they are providing the conservation results expected.
13	Implementation: design, build, procurement, installation and commissioning:	Not applicable
14	Energy Efficiency gains: kWh & kWh/m ³ before and after implementation	The low-end estimate of 5 MGD savings of water over 5 summer months translates to an estimated savings of 1800 MWh each year (360 MWh/MGD). AWU estimates it takes 2400 kWh/MG for treatment and distribution of drinking water and electric costs are approximately \$.08 per kWh.

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Austin Water Utility (2), TX (Continued)

Ref.	Enquiry Item	Response information, description, and remarks
15	Cost/Benefit analysis: financial appraisal or payback time.	Current goal of saving 25 MGD peak-day by 2017, which may result in 15 MGD average reduction; the associated energy cost savings is estimated to be over \$1,000,000 per year.
16	Project review: could it be improved or developed?	Conservation program has continued to evolve in response to changing customer needs, emerging technologies, political concerns, and available resources.
17	Confidence grade: on data provided.	High

Cedar Rapids Water Department, IA

Ref.	Enquiry Item	Response information, description, and remarks
1	Location: Country, urban or rural and small, medium or large system:	USA, Midwest, urban, large system
2	Sector: drinking water [clean], wastewater [waste] or sludge:	Drinking Water
3	[Utility] Works Owner or Operator: with financial set-up, regulatory or not.	Owner/Operator: City of Cedar Rapids Municipality
4	Size: flows and loads or population equivalent:	Average flow: 38.1 MGD Peak Flow: 51.1 MGD Design Capacity: 65 MGD 75% of water consumption for industrial use (food processing) Population: 125,000
5	Energy Provider: with costs, incentives, taxes and conditions:	Electric Provider: Alliant Energy (Private) Billing is demand charged based with monthly energy cost adjustments. Rates vary for summer vs. winter periods. Rates vary for peak and off-peak periods of the day. Additional monthly credits received for Power Factor (PF) correction and participation in the Power Interruptible Rate Program, as well as one-time incentive rebates for implementing energy conservation measures during new construction. No taxes are charged to municipal entities. No power is sold back to the utility.
6	Process: physical, chemical, or biological description:	Physical: Metering, VFDs, SCADA, Energy Management System.
7	Component: all or part of the works:	Energy management program is effective for all of the water system. Includes: <ul style="list-style-type: none"> • Industrial water use monitoring • Peak demand, real-time, and Power Factor monitoring • Tracking and analysis of electric usage • Installation of variable frequency drives on pumps
8	Specific energy problem: including quality or consent details:	Energy costs are the second largest cost of the water department's budget behind payroll/benefits. 75% of the water production is used for wet milling operations and it is incumbent upon the City to hold costs at a reasonable level to keep those customers competitive. Overall objectives are to control costs and be good stewards of the environment.

(continued)

Cedar Rapids Water Department, IA (Continued)

Ref.	Enquiry Item	Response information, description, and remarks
9	Process/Plant changes: mechanical, electrical or controls:	<p>Many components are utilized to achieve the ultimate goal of energy management.</p> <ul style="list-style-type: none"> • Real-time monitoring of incoming power usage is displayed on the SCADA system and closely watched by trained operators and plant management. • VFDs have been installed on well pumps and finished water high service pumps to maximize pumpage without over pressurizing the supply lines, and to fine-tune plant operations. • Submeters are installed to monitor PF, component electrical usage, operation efficiency, and optimization. PF correction capacitors have been installed to provide good quality power to large pumps as well as take advantage of the cost savings available. Over 20 submeters are located throughout the system. • New construction projects are evaluated on a life-cycle cost basis to make sure equipment selected will provide the best fit while optimizing energy input.
10	Civil/Physical Changes: to water/effluent quality, civil works, or process:	Not applicable
11	Operational Changes: skill levels, procedures and maintenance routines:	Operators trained with SCADA, peak demand management to take advantage of interruptible rates, flow/hp pump selection chart to determine optimum production while minimizing hp, monitoring SCADA to determine if there is a failure—i.e., capacitor bank that has dropped off and needs to be reset, outlining programs such as the process to implement the interruptible program curtailment and optimize use of off-peak operation, education on electrical costs and billing data.
12	Risks and Dependencies: risk assessment of project and changes.	All CIP projects evaluated on life-cycle costs, functionality, and ease of operation to determine best options. Energy management program has been in place for 15 years and has shown significant cost savings during that time.
13	Implementation: design, build, procurement, installation and commissioning:	A rolling 10-year CIP plan is the basis for ongoing improvements. Design of structure is evaluated for energy costs such as potential headloss or pumping costs. CIP project major equipment is evaluated using life-cycle costs, functionality, and ease of operation. Selection of equipment takes all these factors into account. During the bidding and construction phase, contractor input is solicited for project improvements, including energy cost savings. Many times the City will pre-purchase equipment for CIP projects to ensure the best fit item is installed. All other times, only pre-selected major component make and model is called out in bidding documents to assure a minimum level of quality. Factory performance tests are required on all major components, followed by field performance tests witnessed by the City.
14	Energy Efficiency gains: kWh & kWh/m ³ before and after implementation	<p>1994 = 21.4 kWh</p> <p>2008 = 23.3 kWh</p> <p>8% gain in kWh use for 27% increase in gallons produced.</p>

(continued)

Cedar Rapids Water Department, IA (Continued)

Ref. Enquiry Item	Response information, description, and remarks
	<p>Since the CRWD began monitoring power usage and initiating energy conservation measures in 1993, a new water treatment plant was constructed and brought on line, nearly 100 miles of raw and finished water line added, average daily demand increased by 27%, four horizontal collector wells and seven vertical wells, and two new high service pumps have been added to the system. In addition, treatment rules and regulations have become more stringent and seasonal water quality issues have reduced flexibility in operating the well field. Given all the challenges listed above, CRWD has demonstrated a minimal increase in power required to pump, treat, and distribute every million gallons produced.</p>
15 Cost/Benefit analysis: financial appraisal or payback time.	<p>Measureable savings since program started.</p> <ul style="list-style-type: none"> • Approximately \$150,000 per year by taking part in electric utility's Power Factor correction and interruptible program. • Peak demand cap is estimated to save \$15,000 per year. • VFD's on new pumping station pumps is estimated to offset the increased energy costs due to new UV reactors, an off-set cost of \$30,000 per year. <p>Since 1994, water utility has been able to maintain annual cost per kWh between \$0.04 and \$0.05.</p> <p>Overall components of CRWD energy management program do not include purchasing of specific high cost equipment. As noted above, life-cycle cost analysis is performed. Regarding recent improvements to the system, the SCADA upgrade was a necessity due to advances in the system and obsolescence of prior system. No actual payback period calculated. In regards to the installation of VFDs, analysis is performed to determine which pumps would realize the most benefit. No data available on payback period of recently installed equipment.</p>
16 Project review: could it be improved or developed?	<p>As with all monitoring programs, there is room for improvements. Such improvements might include closer tracking of submeters, implementation of automated selection of pump operation, and increased storage to take more advantage of off-peak pumping.</p>
17 Confidence grade: on data provided.	<p>Very confident in energy conservation/management measures and the ability to monitor, track, and provide documentation.</p>

Cleveland Water Division, OH

Ref. Enquiry Item	Response information, description, and remarks
1 Location: Country, urban or rural and small, medium or large system:	USA, Midwest, urban, large system
2 Sector: drinking water [clean], wastewater [waste] or sludge:	Drinking Water
3 [Utility] Works Owner or Operator: with financial set-up, regulatory or not.	City of Cleveland, OH Cleveland Water Division (CWD)
4 Size: flows and loads or population equivalent:	The four treatment plants combined can produce over 540 MGD of treated water.
5 Energy Provider: with costs, incentives, taxes and conditions:	Cleveland Public Power; Cleveland Electric Illuminating; Ohio Edison

(continued)

Cleveland Water Division, OH (Continued)

Ref. Enquiry Item	Response information, description, and remarks
6 Process: physical, chemical, or biological description:	All projects involve physical processes.
7 Component: all or part of the works:	<p>Optimizing the water system's operations involve all the works from raw water intake to the distribution system pumping facilities.</p> <p>Constructing wind turbines to create a new energy source involves part of the works—pertaining to the raw water intake structure.</p> <p>Running the treatment plant backwash pumps and air scour blowers at off-peak energy demand times involves part of the works.</p> <p>The impacts are on the pumping capabilities of the CWD system only.</p>
8 Specific energy problem: including quality or consent details:	<p>CWD realized that not all operations were carried out in a consistent fashion. The lack of consistent optimization in operations led CWD to believe that training in optimization would lead to the full utilization of CWD's infrastructure to its most efficient state.</p> <p>CWD needed power at the end of the intake crib that stretches out into Lake Erie to supply the raw water intake pumps. Running an electrical line for several miles out into the lake would be an expensive project.</p> <p>CWD teamed with Cleveland Public Power to create an operational schedule where the WTP could perform the treatment plant functions with a lower energy rate than CWD previously had used. The cost of peak demand time power was high compared to the cost of electricity in off-peak periods.</p> <p>CWD believed that it could trim the electrical costs of operating pumps and pumping stations by switching to high efficiency pumps and motors and carefully selecting specific pumps for specific hydraulic conditions.</p>
9 Process/Plant changes: mechanical, electrical or controls:	<p>Operations optimization creates process related changes as CWD has embarked on a multiple-year training process that will teach all operators to understand and adhere to the SOPs for facility operation.</p> <p>Installing a wind turbine to generate power for intake pumping facilities has process, mechanical, and electrical control changes.</p> <p>Operational changes were made to switch the routine backwash sequences from the day shift to the night shift when the cost per kW/hr of power is less expensive.</p> <p>CWD amended its construction standards and specifications to include language that requires all new pumps and pumping stations to be energy efficient. Where possible, multiple small pumps are specified to take the place of one large pump, or single speed motors are replaced with variable frequency drive motors given the appropriate operating conditions.</p>
10 Civil/Physical Changes: to water/effluent quality, civil works, or process:	<p>No significant physical changes are anticipated as a result of energy operation optimization.</p> <p>No changes are anticipated to the water or the downstream infrastructure as a result of switching power sources from the electrical grid supplied electricity to the wind power.</p> <p>Switching the timing of the routine operational practices has had no adverse impacts on the water quality.</p> <p>No significant physical or chemical changes are associated with the construction standard changes.</p>

(continued)

Cleveland Water Division, OH (Continued)

Ref. Enquiry Item	Response information, description, and remarks
11 Operational Changes: skill levels, procedures and maintenance routines:	<p>Operators will need to learn how the facility operations fit into the large, overall energy management scheme. That is, forethought and planning must be placed into the timing of routine tasks such as backwashing a filter so that its energy use fits into the overall management plan.</p> <p>Operators will need to learn how to operate the wind turbine system and make it compatible with the CWD SCADA system.</p> <p>Additional reliance is placed on the night shift operators to perform tasks that have been traditionally viewed as day shift operations, though night staff have always performed these tasks to some degree.</p> <p>Operators need to learn how to operate and perform routine maintenance on the VFD motors.</p>
12 Risks and Dependencies: risk assessment of project and changes.	<p>CWD is cautious that the significant amount of training implemented may not have the desired results of changed “thinking” or “operational behaviour.” All operators must “buy into” these new standard operation procedures (SOPs) compiled into the overlay program for optimizing performance in order to save power.</p> <p>CWD will need to incorporate certain safety SOP features once the wind turbine is constructed.</p> <p>No significant risk factors are created by switching to off-peak power consumption as all the WTP operators are trained in all facets of the plant operational processes. Filters can still be backwashed if needed during the day shift.</p> <p>No significant risk factors involved with switching to high efficiency pumps and motors.</p>
13 Implementation: design, build, procurement, installation and commissioning:	<p>The software manufacturer was selected by a bid process. In-house time and labor were used for developing the SOPs that fed into the proprietary software platform.</p> <p>The 60-meter tower was constructed with a weather monitoring station only. Construction of additional towers with wind turbines could be 5–10 additional years out due to capital financing.</p> <p>CWD may revise the utility’s SOP’s to create a unified approach to routine maintenance practices.</p> <p>The new construction standards apply to all traditional bid, design-build, and CWD procurement forms of construction contracts.</p>
14 Energy Efficiency gains: kWh & kWh/m ³ before and after implementation	<p>Developing an alternate source of power in itself does not achieve any kW/hr savings as much as it allows the utility to use less expensive, more renewable and reliable sources of power.</p> <p>The purchasing of off-peak power from the power utility saves the utility money spent on energy directly, not the amount of energy consumed.</p>

(continued)

Cleveland Water Division, OH (Continued)

Ref. Enquiry Item	Response information, description, and remarks
15 Cost / Benefit analysis: financial appraisal or payback time.	<p>Preliminary estimates by CWD project utility savings between 10–15% of its current energy expenses when the training has been completed with all the operations staff and the proprietary software program is fully implemented.</p> <p>The cost to construct one 5-Megawatt capacity wind turbine is \$80 million (2009 dollars). Neither the potential energy savings from not buying power from Cleveland Public Power nor the payback schedule on the investment have been determined.</p> <p>CWD estimates that the payback time for replacing the inefficient pumps and motors could be over 20 years. The energy cost savings could be as much as \$10 million over 5 years.</p>
16 Project review: could it be improved or developed?	<p>Operations staff refine and improve the SOPs based on new operational and financial energy rate information. CWD would like to improve on the amount of time it has taken to get operations staff up to speed with the training.</p> <p>Possibly too early in the process to determine any areas of improvement.</p> <p>Operations staff continue to provide input to the SOPs for treatment process improvements.</p>
17 Confidence grade: on data provided.	High

Columbus Water Works, GA

Ref. Enquiry Item	Response information, description, and remarks
1 Location: Country, urban or rural and small, medium or large system:	USA, southeast, urban, large system
2 Sector: drinking water [clean], wastewater [waste] or sludge:	Drinking Water
3 [Utility] Works Owner or Operator: with financial set-up, regulatory or not.	Columbus Water Works City of Columbus, Georgia
4 Size: flows and loads or population equivalent:	North Columbus Water Resources Treatment Facility has a 90 MGD capacity. Average daily production is 27.5 MGD, and peak day production is 54.5 MGD. The utility also operates the Fort Benning Water Treatment Plant which has a capacity of 12 MGD.
5 Energy Provider: with costs, incentives, taxes and conditions:	Georgia Power Company
6 Process: physical, chemical, or biological description:	<p>Establishing alternative rate structures is mostly an operational process between finance and the operations division.</p> <p>Developing on-site power generation is a physical process involving the operation of electric generators.</p> <p>Working with the power company for new electrical meters is a physical process involving paying for electric meter and routine reading.</p>
7 Component: all or part of the works:	Alternate rate structures encompass all areas of the utility organization whereas developing on-site power generation and establishing new electric metering involve components of the system only.

(continued)

Columbus Water Works, GA (Continued)

Ref. Enquiry Item	Response information, description, and remarks
8 Specific energy problem: including quality or consent details:	<p>Columbus Water Works sought a way to trim the energy costs of buying power “on-demand” any time of the day at costs/rates the utility believed it had no effective way to control. Thus, establishing alternate rate structures surfaced as a means to achieve that goal.</p> <p>CWW wanted a way to have reliable power as a backup source at the WTP while at the same time have a partner in the project that could benefit the power supplier.</p> <p>CWW discovered that the utility paid a large sum of money to the power utility to maintain two separate electric meters for the water treatment plant pumps and for the river pumps.</p>
9 Process/Plant changes: mechanical, electrical or controls:	<p>To take advantage of the alternate rate structures, the changes implemented were mostly operational changes of the mechanical systems (such as running pump stations at alternate time sequences to realize the savings of purchasing power at lesser rates).</p> <p>Mechanical and electrical changes are needed to install the on-site power generators.</p> <p>Switching from two meters to one meter involved both physical and mechanical changes to the method CWW is billed for electricity.</p>
10 Civil/Physical Changes: to water/effluent quality, civil works, or process:	<p>For any of the these measures, there was no physical changes to the water supply as a result of rate structure changes, sources of power, or electrical metering.</p>
11 Operational Changes: skill levels, procedures and maintenance routines:	<p>Once trained in the alternate rate structures, no special skills are needed to understand the power efficiency scenarios.</p> <p>Once operators know how the electrical buy-back plan works under the contract with the power company, no special skills are required to manage the on-site generators.</p> <p>No special skills are needed now that the meters have been reduced to one single meter.</p>
12 Risks and Dependencies: risk assessment of project and changes.	<p>No significant risks, though there is significant importance for the operators to follow the guidance of the negotiated rates and SOPs.</p>
13 Implementation: design, build, procurement, installation and commissioning:	<p>Creating a partnership with the local power company was the key to developing this strategy of optimizing electrical rate savings.</p> <p>CWW solicited for bids for the construction and maintenance operations of the on-site generators.</p> <p>This project was initiated by CWW to engage the power company. The work of installing a new electric metering format was performed as a joint project between the power company and CWW.</p>
14 Energy Efficiency gains: kWh & kWh/m ³ before and after implementation	<p>Not available for drinking water. Primary savings have been related to “cost avoidance” from utilizing the various programs and efforts outlined in the <i>Energy Management Program</i>.</p>

(continued)

Columbus Water Works, GA (Continued)

Ref. Enquiry Item	Response information, description, and remarks
15 Cost/Benefit analysis: financial appraisal or payback time.	<p>The cost savings of an alternate rate structure vary from day-to-day. Rate savings can range from 10 to 20% of the peak hour demand costs on average. No real payback time period is appropriate since no capital was invested in the project.</p> <p>The initial investment in the on-site generators was \$4 million. Average annual savings of \$450,000. Payback time even with \$250,000 annual payment to Cummins is less than 10 years.</p> <p>The cost/benefit comparison of combining the electrical meters at water facilities varies from year-to-year and is impacted by the amount of power purchased, which is directly related to the amount of water produced.</p>
16 Project review: could it be improved or developed?	CWW believes that there is always a way to improve what has been done. However, the utility is moving forward with a number of different projects that it believes places them on the leading front of utilities managing energy usage and energy costs efficiently.
17 Confidence grade: on data provided.	High

Las Vegas Valley Water District, NV

Ref. Enquiry Item	Response information, description, and remarks
1 Location: Country, urban or rural and small, medium or large system:	USA, southwest, urban, large system
2 Sector: drinking water [clean], wastewater [waste] or sludge:	Drinking Water
3 [Utility] Works Owner or Operator: with financial set-up, regulatory or not.	Las Vegas Valley Water District (District)
4 Size: flows and loads or population equivalent:	The District serves 1.3 million people. In 2009, the maximum day consumption was 429 MG.
5 Energy Provider: with costs, incentives, taxes and conditions:	Not available.
6 Process: physical, chemical, or biological description:	The District has implemented a variety of programs to improve energy efficiency, all physical in nature. They cover a wide spectrum of practices including an EWQMS, HVAC, renewable energy, pump performance and optimization, leak detection, and efficient use of reservoir storage.
7 Component: all or part of the works:	The EWQMS and leak detection program cover all of the system. HVAC, renewable energy, pump performance and optimization, and efficient use of reservoir storage cover various parts of the system.
8 Specific energy problem: including quality or consent details:	The District is divided into 19 pressure zones that range from elevations 1,845 feet to 3,665 feet. The various zone reservoirs are filled at night using water delivered by SNWS to nine receiving points. Lifting water to these elevations results in electricity being a large portion of the District's annual budget. Energy costs for fiscal year 2009 were \$14.7 million, about 30 percent of the Operations Department's budget. The District implemented a variety of energy conserving programs to help reduce energy costs.

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Las Vegas Valley Water District, NV (Continued)

Ref. Enquiry Item	Response information, description, and remarks
9 Process/Plant changes: mechanical, electrical or controls:	Most of the zone reservoirs have mixers to reduce stratification and improve water quality. The old style mixer was very high maintenance and used 10 HP motors. These have been replaced with SolarBee® mixers that draw only 1/20 HP.
10 Civil/Physical Changes: to water/effluent quality, civil works, or process:	<p>The District has installed 3.1 MW of solar panels at seven of its reservoir sites to supplement peak electrical loads.</p> <p>Almost all District pump station buildings are not staffed. Building temperatures are monitored by the SCADA system, and alarms have been set to monitor temperatures when maintenance work is finished, such that summer-time building temperatures are kept at the highest temperature possible without damaging equipment but not for human comfort.</p>
11 Operational Changes: skill levels, procedures and maintenance routines:	<p>The District has built its own EWQMS system based on concepts developed by EPRI and Water Research Foundation. The EWQMS program is used to optimize water quality, storage levels, and available pump efficiencies to achieve the lowest energy cost per MG of water delivered, while maintaining water quality.</p> <p>Monthly reservoir storage tables have been produced using minimum storage required for fire safety, demand, and water quality. These tables are used to minimize the pumping required per day. For example the reservoirs might be nearly full in the summer and only half full in the winter.</p> <p>Pump performance data such as flow, pressures, and energy are monitored by the SCADA system and stored in a process-information history database for future analysis. The District uses the pump performance data to evaluate pump performance which greatly reduces the need for expensive on-site pump testing. The District then compares the net present value (NPV) of pump performance degradation to the NPV of pump repair cost to determine which pumps are economically justified to repair.</p> <p>Because of varying pumping water levels throughout the Las Vegas Valley service area, there can be significant differences in energy cost to deliver water. Not only does the water level vary by location, but also through the well pumping season. To determine the most cost effective wells, the District monitors production and energy consumption for each well. The data is then used to determine which combination of wells will deliver the lowest energy cost per MG.</p> <p>The District has a comprehensive leak detection program using the Permalog™ Logger System and traditional acoustic leak correlators. The Permalog™ units listen at night for leaks and then radio alarms to a monthly patrol vehicle. Acoustic geo-phones and/or leak correlators are then used to verify and locate the actual leak.</p> <p>Some additional training has been necessary to learn new systems or equipment. SCADA and process-information historian data have been essential tools for monitoring and analyzing process data.</p>

(continued)

Las Vegas Valley Water District, NV (Continued)

Ref. Enquiry Item	Response information, description, and remarks
12 Risks and Dependencies: risk assessment of project and changes.	No significant risks.
13 Implementation: design, build, procurement, installation and commissioning:	The District built its own EWQMS based on concepts developed by EPRI and Water Research Foundation.
14 Energy Efficiency gains: kWh & kWh/m ³ before and after implementation	Since 2007, the energy cost per acre-ft has decreased from \$132/ac-ft (1,574 kWh/ac-ft) to \$111/ac-ft (1,318 kWh/ac-ft).
15 Cost/Benefit analysis: financial appraisal or payback time.	<p>The District uses at least 50 percent of the 3.1 MW solar power generated onsite while the remaining energy is returned to the grid. For the 12 month period ending June 20, 2010, the District received over \$1.2 million in solar return credits.</p> <p>The 34 installed SolarBee[®] mixers have resulted in saving \$65K per year in maintenance, and \$115K per year in energy cost.</p> <p>By maintaining un-manned pump-station buildings at temperatures suitable for equipment (90 degrees F in the summer) instead of human comfort levels, the District estimates its 2009 savings to be nearly \$125K.</p> <p>In 2009, booster pump performance was analyzed for all pumps over 5 years old. For each pump, the potential annual energy savings was calculated based on measured efficiency compared to as new efficiency. The potential annual efficiency savings were then compared to the estimated rebuild cost. Pumps were prioritized for repair based on simple payback. Rebuilding 7 top priority pumps resulted in over \$30K/year in energy savings. The 10 year net savings (including repair cost) are projected to be \$103K.</p> <p>Choosing to operate the lowest energy cost per MG wells has saved the District nearly \$115K (12 percent) compared to the same period in 2008.</p> <p>The cost of the water leak detection program has been \$2.7M. This includes the data loggers, vehicles, and staffing. The program is expected to have a 15-year payback based on reduced water and associated energy.</p>
16 Project review: could it be improved or developed?	LVVWD believes that there is always a way to improve what has been done. However, the utility is moving forward with a number of different projects that it believes places them on the leading front of utilities managing energy usage and energy costs efficiently.
17 Confidence grade: on data provided.	High

Metro Vancouver/Greater Vancouver Water District (BC, Canada)

Ref. Enquiry Item	Response information, description, and remarks
1 Location: Country, urban or rural and small, medium or large system:	Canada, urban, large system
2 Sector: drinking water [clean], wastewater [waste] or sludge:	Drinking Water
3 [Utility] Works Owner or Operator: with financial set-up, regulatory or not.	Metro Vancouver
4 Size: flows and loads or population equivalent:	Entire system services 2.1 million people, and delivers 700 MGD.
5 Energy Provider: with costs, incentives, taxes and conditions:	BC Hydro (regulated utility; electricity provider)

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Metro Vancouver/Greater Vancouver Water District (BC, Canada) (Continued)

Ref. Enquiry Item	Response information, description, and remarks
6 Process: physical, chemical, or biological description:	Not applicable
7 Component: all or part of the works:	Part
8 Specific energy problem: including quality or consent details:	System optimization: changing operations of pumping
9 Process/Plant changes: mechanical, electrical or controls:	Mechanical/social
10 Civil/Physical Changes: to water/effluent quality, civil works, or process:	Not applicable
11 Operational Changes: skill levels, procedures and maintenance routines:	Procedures and maintenance routines
12 Risks and Dependencies: risk assessment of project and changes.	Low to none
13 Implementation: design, build, procurement, installation and commissioning:	Not applicable
14 Energy Efficiency gains: kWh & kWh/m ³ before and after implementation	Estimated savings of 548,000 kWh per year.
15 Cost/Benefit analysis: financial appraisal or payback time.	No operational or capital funds required: only staff time committed for analysis. High benefit-to-cost ratio likely, but estimate of value of staff time not undertaken.
16 Project review: could it be improved or developed?	Some possible improvements to SCADA.
17 Confidence grade: on data provided.	Moderately high

Mohawk Valley Water Authority, NY

Ref. Enquiry Item	Response information, description, and remarks
1 Location: Country, urban or rural and small, medium or large system:	USA, northeastern, suburban, large system
2 Sector: drinking water [clean], wastewater [waste] or sludge:	Drinking Water
3 [Utility] Works Owner or Operator: with financial set-up, regulatory or not.	Mohawk Valley Water Authority—State created special regional authority
4 Size: flows and loads or population equivalent:	130,000 population—17.9 MGD average
5 Energy Provider: with costs, incentives, taxes and conditions:	National Grid
6 Process: physical, chemical, or biological description:	Conventional filtration, chlorination, fluoridation, and pH control (lime and soda ash)
7 Component: all or part of the works:	Hydroturbines—treatment plant and distribution system
8 Specific energy problem: including quality or consent details:	Opportunity to utilize excess head from gravity system to generate power
9 Process/Plant changes: mechanical, electrical or controls:	Install and operate hydroturbines
10 Civil/Physical Changes: to water/effluent quality, civil works, or process:	Replacing PRVs with hydroturbines

(continued)

Mohawk Valley Water Authority, NY (Continued)

Ref.	Enquiry Item	Response information, description, and remarks
11	Operational Changes: skill levels, procedures and maintenance routines:	Minimal, contract out maintenance of hydroturbines
12	Risks and Dependencies: risk assessment of project and changes.	Minimal
13	Implementation: design, build, procurement, installation and commissioning:	First two hydroturbines installed as part of a major plant upgrade in 1992, a second as part of new tank construction. Additional turbines will include separate contracts/projects.
14	Energy Efficiency gains: kWh & kWh/m ³ before and after implementation	Plant turbines—2,000,000 kWh/yr Deerfield Turbine—202,000 kWh/yr Marcy Turbines—812,000 kWh/yr
15	Cost/Benefit analysis: financial appraisal or payback time.	Plant turbines—payback (completed)—unavailable Deerfield Turbine—1.9 years Marcy Turbines—20.1 years
16	Project review: could it be improved or developed?	No comment
17	Confidence grade: on data provided.	High, given extensive study

Monroe County Water Authority, NY

Ref.	Enquiry Item	Response information, description, and remarks
1	Location: Country, urban or rural and small, medium or large system:	USA, northeastern, urban, large system
2	Sector: drinking water [clean], wastewater [waste] or sludge:	Drinking Water
3	[Utility] Works Owner or Operator: with financial set-up, regulatory or not.	Monroe County Water Authority Public benefit corporation organized in 1950 under the New York State Public Authorities Law.
4	Size: flows and loads or population equivalent:	650,000 people served; average production of 59 MGD
5	Energy Provider: with costs, incentives, taxes and conditions:	Electricity is provided by RG&E (70 accounts), National Grid (35 accounts), Fairport Electric (9 accounts) and Churchville Electric (1 account). The largest facilities are on RG&E, so over 90% of electricity is provided by RG&E. Fairport and Churchville are small villages in Monroe County that provide electricity at special low rates granted to them through old agreements involving hydroelectric power in New York State.
6	Process: physical, chemical, or biological description:	Physical processes: installed variable frequency drive (VFD); undertook pump maintenance, refurbishment, sandblasting, and interior coating
7	Component: all or part of the works:	Part of works—pumps and motors
8	Specific energy problem: including quality or consent details:	High energy costs for pumping water throughout a large distribution system (approx. 2,100 miles of pipe)
9	Process/Plant changes: mechanical, electrical or controls:	Pump maintenance, sandblasting, lining; improved monitoring of pump activities; installation of a variable frequency drive (VFD) to allow for lower electricity use.
10	Civil/Physical Changes: to water/effluent quality, civil works, or process:	Refurbished, sandblasted, and lined pumps; variable frequency drive

(continued)

Monroe County Water Authority, NY (Continued)

Ref.	Enquiry Item	Response information, description, and remarks
11	Operational Changes: skill levels, procedures and maintenance routines:	Training of staff for maintenance and troubleshooting of VFDs
12	Risks and Dependencies: risk assessment of project and changes.	None
13	Implementation: design, build, procurement, installation and commissioning:	Consulting engineers and pump vendors
14	Energy Efficiency gains: kWh & kWh/m ³ before and after implementation	VFD reduced monthly energy use from 590 kW to 360 kW; or 0.021 kWh/m ³ .
15	Cost/Benefit analysis: financial appraisal or payback time.	\$23,000 annual savings due to installation of VFD; several hundred thousand dollars will be saved if all 100 system pumps were to be refurbished, sandblasted, and lined.
16	Project review: could it be improved or developed?	Additional improvements will be realized when all inefficient pumps are refurbished.
17	Confidence grade: on data provided.	High

New Jersey American Water, NJ

Ref	Enquiry Item	Response information, description, and remarks
1	Location: Country, urban or rural and small, medium or large system:	USA, northeastern, urban, large system
2	Sector: drinking water [clean], wastewater [waste] or sludge:	Drinking Water
3	[Utility] Works Owner or Operator: with financial set-up, regulatory or not.	Owner and Operator: New Jersey American Water (a wholly owned subsidiary of American Water—a private water utility). NJAW is the largest investor-owned water utility in the state of New Jersey
4	Size: flows and loads or population equivalent:	Average capacity—38 MGD Design capacity—80 MGD (expansion in 2007)
5	Energy Provider: with costs, incentives, taxes and conditions:	Public Service Electric and Gas (PSE&G) company, with energy purchase from Constellation Energy
6	Process: physical, chemical, or biological description:	Physical: Installation of solar panels.
7	Component: all or part of the works:	Not applicable
8	Specific energy problem: including quality or consent details:	NJAW wanted to address rising energy costs and promote environmental stewardship.
9	Process/Plant changes: mechanical, electrical or controls:	In 2005, NJAW installed a 502 kW dc ground-mounted dual-array PV system. One array is located on the north side of the main building, and the other to the south. The system includes two 225 kW ac inverters, revenue-grade metering, and an Internet-based data-acquisition system. The solar array consists of 2,871 solar PV modules, each rated at 175 watts for a total direct current output of 502 kW. The system was expanded by 87 kW (a 17% increase) in 2007 for overall output of 590 kW. A third expansion of 109 kW dc was constructed on top of the filter basins in 2008 to increase the overall capacity of the site to 698 kW dc. The system provides power output to the WTP's 4,160-volt distribution network—all of the solar energy is used on-site. NJAW installed a 99 kW solar PV system at the adjacent Raritan-Millstone Water Treatment Plant in 2008. There, the PV energy generated is used to power electric golf carts used for employee transportation around this large facility. This displaces the fossil fuels that would otherwise be used, saving the associated GHGe.

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New Jersey American Water, NJ (Continued)

Ref	Enquiry Item	Response information, description, and remarks
10	Civil/Physical Changes: to water/effluent quality, civil works, or process:	Not applicable
11	Operational Changes: skill levels, procedures and maintenance routines:	No operator actions are required. A service agreement is in place for the limited annual service that is required.
12	Risks and Dependencies: risk assessment of project and changes.	The risk assessment found no operational risks from this project.
13	Implementation: design, build, procurement, installation and commissioning:	The project was procured via Design/Build. The contractor was responsible for all activities through acceptance testing.
14	Energy Efficiency gains: kWh & kWh/m ³ before and after implementation	Energy efficiency gains result from energy saved from purchase = 818,000 kWh/yr. This amount lowers the water production electrical intensity by 0.01kWh/m ³ . The systems supplements approximately 20% of the Canal Road WTP's peak usage and powers electric golf carts for employee transportation.
15	Cost/Benefit analysis: financial appraisal or payback time.	NJAW received a \$2.438 million rebate from the New Jersey Clean Energy Program, which reduced the design and construction costs for NJAW to approximately \$2.556 million. NJAW also took advantage of a 30% federal tax credit (10% of project). Estimated payback in less than 5 years.
16	Project review: could it be improved or developed?	The PV installation continues to perform above design expectations.
17	Confidence grade: on data provided.	High

Queensbury Water District, NY

Ref.	Enquiry Item	Response information, description, and remarks
1	Location: Country, urban or rural and small, medium or large system:	USA, northeastern, suburban, medium system
2	Sector: drinking water [clean], wastewater [waste] or sludge:	Drinking Water
3	[Utility] Works Owner or Operator: with financial set-up, regulatory or not.	Town of Queensbury—Town Water District
4	Size: flows and loads or population equivalent:	35,000 population, 4.0 MGD winter average, 7.5 MGD average summer demand.
5	Energy Provider: with costs, incentives, taxes and conditions:	National Grid
6	Process: physical, chemical, or biological description:	Full conventional filtration facility
7	Component: all or part of the works:	Part: distribution system
8	Specific energy problem: including quality or consent details:	Significant difference in summer and winter demands. Hydraulic bottleneck in distribution system.
9	Process/Plant changes: mechanical, electrical or controls:	<ol style="list-style-type: none"> 1. Replaced its 400 hp raw water pumps with two more efficient 300 hp pumps for winter use. 2. Installed an altitude valve at the Luzerne Road tank to allow filling of remote Gurney Lane tank to optimize tank storage, enabling increased off-peak pumping. 3. Modified pumping patterns to maximize the use of off-peak pumping to take advantage of lower cost off-peak power.

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Queensbury Water District, NY (Continued)

Ref.	Enquiry Item	Response information, description, and remarks
10	Civil/Physical Changes: to water/effluent quality, civil works, or process:	None, except to balance impact on trihalomethane formation.
11	Operational Changes: skill levels, procedures and maintenance routines:	Same skill level, but additional operation attention—monitoring pump rates and usage
12	Risks and Dependencies: risk assessment of project and changes.	Effective implementation depends on operator acceptance and long-term buy-in.
13	Implementation: design, build, procurement, installation and commissioning:	Energy audit, Town Board acceptance, NYSERDA partnership, consultant studies and design, pump evaluation and purchase, installation and implementation, including operational changes.
14	Energy Efficiency gains: kWh & kWh/m ³ before and after implementation	Preliminary analyses indicated that the pump changes could result in an energy savings of approximately 473,500 kWh, while optimizing off-peak pumping could reduce peak demands by 363 kW.
15	Cost/Benefit analysis: financial appraisal or payback time.	<ol style="list-style-type: none"> 1. Pump replacement: estimated savings of \$35,000 annually. 2. Altitude valve: estimated savings of \$12,500 annually. 3. Contracted with Energy Curtailment Specialists, Inc. to sell emergency generator capacity twice a year to generate revenue for the QWD. Approximately \$4,500 in annual revenue is anticipated. 4. Incentives under the NYSERDA funding programs are anticipated at approximately \$47,500 for the Enhanced Commercial and Industrial Performance Program and \$18,000 for the Peak Load Reduction Program. Payback on pump change—4 years Payback on altitude valve—2 years
16	Project review: could it be improved or developed?	Only with continued aggressive oversight of pumping practices and maximizing off-peak pumping year-round.
17	Confidence grade: on data provided.	High

Suffolk County Water Authority, NY

Ref.	Enquiry Item	Response information, description, and remarks
1	Location: Country, urban or rural and small, medium or large system:	USA, northeastern, suburban, large system
2	Sector: drinking water [clean], wastewater [waste] or sludge:	Drinking Water
3	[Utility] Works Owner or Operator: with financial set-up, regulatory or not.	Suffolk County Water Authority—State created Special Regional Authority
4	Size: flows and loads or population equivalent:	1.2 million population; 180 MGD
5	Energy Provider: with costs, incentives, taxes and conditions:	Long Island Power Authority (LIPA)
6	Process: physical, chemical, or biological description:	Groundwater pumping, chlorination, GAC treatment (115 facilities), 26 iron removal facilities, 3 nitrate removal facilities
7	Component: all or part of the works:	Part: Pumping
8	Specific energy problem: including quality or consent details:	Increased energy costs
9	Process/Plant changes: mechanical, electrical or controls:	Improved SCADA system and increased reliance on SCADA system
10	Civil/Physical Changes: to water/effluent quality, civil works, or process:	None

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Suffolk County Water Authority, NY (Continued)

Ref.	Enquiry Item	Response information, description, and remarks
11	Operational Changes: skill levels, procedures and maintenance routines:	No increases in skills, but closer operational control and observation, 20 to 40% of a man-year added (supervisor level).
12	Risks and Dependencies: risk assessment of project and changes.	Reducing the safety buffer of reserve storage capacity increases water system vulnerability in the event of some kind of pump failure or other type of supply emergency.
13	Implementation: design, build, procurement, installation and commissioning:	Not applicable
14	Energy Efficiency gains: kWh & kWh/m ³ before and after implementation	Evaluation pending
15	Cost/Benefit analysis: financial appraisal or payback time.	Preliminary assessment, 9% savings (\$1.8 million for four summer months)
16	Project review: could it be improved or developed?	Evaluation pending
17	Confidence grade: on data provided.	High

Village of Waterloo, NY

Ref.	Enquiry Item	Response information, description, and remarks
1	Location: Country, urban or rural and small, medium or large system:	USA, small urban and rural system
2	Sector: drinking water [clean], wastewater [waste] or sludge:	Drinking Water
3	[Utility] Works Owner or Operator: with financial set-up, regulatory or not.	Village of Waterloo, New York
4	Size: flows and loads or population equivalent:	1.2 million gallons per day water treated; system serves 9,500 people
5	Energy Provider: with costs, incentives, taxes and conditions:	New York State Electric and Gas (NYSEG)
6	Process: physical, chemical, or biological description:	Not applicable
7	Component: all or part of the works:	Not applicable
8	Specific energy problem: including quality or consent details:	Excessive driving to storage tanks and other distribution system locations to manually operate, manage, and measure water in the system. Delay in detection of leaks and tank issues resulting in excess water and thus energy loss.
9	Process/Plant changes: mechanical, electrical or controls:	Replaced the system's existing filter master control panel with a new, state-of-the-art Programmable Logic Controller (PLC). Main computer, operating system software, and SCADA system were also updated. Improvements enable the Village to monitor and control tank levels and pump status for real-time daily operations, increasing system efficiency, reducing energy usage due to driving and manual system operation, and improving security. Storage tanks could also be filled and monitored at night when energy demand costs are lower.
10	Civil/Physical Changes: to water/effluent quality, civil works, or process:	Improved management of finished water quality as a result of closer monitoring of chlorine residual, improved water level management in storage tanks to ensure turnover. Reduced water loss by quick detection of valve and main leaks.

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Village of Waterloo, NY (Continued)

Ref.	Enquiry Item	Response information, description, and remarks
11	Operational Changes: skill levels, procedures and maintenance routines:	No significant change in operational skill was necessary. Operators were self-taught and instructed on-site by company representative who installed the equipment.
12	Risks and Dependencies: risk assessment of project and changes.	No significant risks associated with the system modifications.
13	Implementation: design, build, procurement, installation and commissioning:	Design and installations were by MRB Group, Inc., Rochester, New York.
14	Energy Efficiency gains: kWh & kWh/m ³ before and after implementation	Data on energy efficiency gains are not available.
15	Cost/Benefit analysis: financial appraisal or payback time.	Cost/benefit analysis information is not available.
16	Project review: could it be improved or developed?	While narrative and anecdotal information on energy impacts and savings are described, these savings have not been formally tracked or analyzed.
17	Confidence grade: on data provided.	Confident in the information provided.

West Basin Municipal Water District, CA

Ref.	Enquiry Item	Response information, description, and remarks
1	Location: Country, urban or rural and small, medium or large system:	USA, Southern California, Urban, Large System
2	Sector: drinking water [clean], wastewater [waste] or sludge:	Drinking (Potable) Water: District imports treated water to distribute to customers and is not responsible for treatment. Recycled Water: District treats wastewater and distributes recycled water for a variety of uses and offsets the use of potable water.
3	[Utility] Works Owner or Operator: with financial set-up, regulatory or not.	Owner/Operator: West Basin Municipal Water District—public entity
4	Size: flows and loads or population equivalent:	Population: Approximately 1,000,000 persons “Potable” water: 220,000 acre-feet annually
5	Energy Provider: with costs, incentives, taxes and conditions:	Southern California Edison and Los Angeles Department of Water and Power
6	Process: physical, chemical, or biological description:	Not applicable for drinking water treatment facilities Recycled water facility—Title 22 water, seawater barrier water, nitrified water, and high and low pressure boiler feed water <ul style="list-style-type: none"> • Title 22 water: high rate clarification, mono media filtration and disinfection • Seawater barrier water: microfiltration, reverse osmosis, hydrogen peroxide/ultraviolet disinfection/oxidation • High and low pressure boiler feed water: microfiltration, reverse osmosis (single pass/double pass) • Nitrified water: biological nitrification process.
7	Component: all or part of the works:	Not applicable

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West Basin Municipal Water District, CA (Continued)

Ref.	Enquiry Item	Response information, description, and remarks
8	Specific energy problem: including quality or consent details:	West Basin is focused on ensuring that it is fully compliant with existing and future regulations. The most current regulation is the California Global Warming Solutions Act of 2006 (AB 32) that seeks to reduce GHGe to 1990 levels by 2020. West Basin will not know what the regulatory requirements are until 2011. Until then, West Basin is reducing its overall energy consumption and carbon footprint. In addition to taking a leadership role in energy conservation, the following are examples of what West Basin is doing: <ul style="list-style-type: none"> • Installation of photovoltaic solar generating station at the recycled water facility to help reduce GHGe and reduce energy costs over time. • Reducing reliance on imported water through developing a more reliable local supply by 2020. This water resource mix has an added benefit of reduced energy use.
9	Process/Plant changes: mechanical, electrical or controls:	Installed photovoltaic solar system at recycled water facility. <ul style="list-style-type: none"> • 36,156 square feet of fixed-tilt photovoltaic panels (2,828 modules) • Designed to produce ~564 kilowatts (kW) which translates into 500 kilowatt system output (kWSO). • Designed to reduce peak power demands by 10%. Maintenance for the solar generating system is contracted out.
10	Civil/Physical Changes: to water/effluent quality, civil works, or process:	Not applicable
11	Operational Changes: skill levels, procedures and maintenance routines:	Solar associated with recycled water facility—maintenance contracted out.
12	Risks and Dependencies: risk assessment of project and changes.	Not applicable
13	Implementation: design, build, procurement, installation and commissioning:	The design/build of the self-generation power system was awarded in February 2006 to the Powerlight Corporation after a bidding process. The objective was to design a system of fixed-tilt photovoltaic panels to generate approximately 500 kilowatts system output (kWSO) of energy. After optimizing the available space and the capacity of the technology, the design was set to produce approximately 564 kilowatts (kW) which translates into 500 kilowatt system output (kWSO). The project was completed in December 2006 and followed immediately by a 14-day testing period. Since then, the solar power system has remained in operation.
14	Energy Efficiency gains: kWh & kWh/m ³ before and after implementation	Installation of a solar power generating system reduces 10% off the peak power demands during the most expensive hours. The system has been in continuous operation since it was installed (December 2006) and through July 2009, has produced approximately 2.21 Gigawatt-hours of energy, enough power to supply over 200 homes in one year. West Basin's use of solar power in its recycled water operations has kept 1,173 tons of carbon dioxide from being released into the environment that would otherwise have been released through the use of traditional energy sources.
15	Cost/Benefit analysis: financial appraisal or payback time.	Solar power generating system costs \$4.3 million and West Basin received a \$1.9 million incentive from Southern California Edison. The first year of operation realized \$90,000 in annual savings.

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West Basin Municipal Water District, CA (Continued)

Ref.	Enquiry Item	Response information, description, and remarks
16	Project review: could it be improved or developed?	The solar powered system has been in continuous operation since it was installed. In the first year of operation, the system produced 11% more electricity than expected. Any renewable resource that can be developed will further contribute to West Basin's reduction objective. This is because getting to the 2020 goal is not the end of California's effort. California will have to cut emissions by 80 percent from 1990 levels by 2050. Therefore, West Basin is not only focused on its 2020 target, but 2050 as well.
17	Confidence grade: on data provided.	Highly confident

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ABBREVIATIONS

AC	alternating current
AMI	automatic metering infrastructure
AMR	automatic meter reading
ARRA	American Recovery and Reinvestment Act of 2009
ASR	aquifer storage and recovery
AWWA	American Water Works Association
AwwaRF	Awwa Research Foundation (now Water Research Foundation)
BEP	best efficiency point
CCR	consumer confidence reports
CEC	California Energy Commission
CEE	Consortium for Energy Efficiency
CFL	compact fluorescent lamp
CMMS	computerized maintenance management system
CPUC	California Public Utilities Commission
CSI	California Solar Institute
CWSRF	Clean Water State Revolving Fund
DADRP	Day Ahead Demand Response Program
DBP	disinfection by-product
DE	diatomaceous earth
DMA	district metered area
DOE	U.S. Department of Energy
DWSRF	Drinking Water State Revolving Fund
EAM	enterprise asset management
ECM	energy conservation measure
EERE	energy efficiency and renewable energy
EFC	New York State Environmental Facilities Corporation
EMS	energy management system
EPA	U.S. Environmental Protection Agency
EPC	Energy Performance Contracting
EPRI	Electric Power Research Institute
ESCOs	Energy Service Companies
EWQMS	Energy and Water Management System
FEMP	Federal Energy Management Program
FO	forward osmosis
FOE	focus on energy
GAC	granular activated carbon

GHG	greenhouse gases
GPR	Green Project Reserve
GSHP	ground-source heat pump
GWRC	Global Water Research Coalition
HI	Hydraulic Institute
HIDL	high-intensity discharge lamp
HP	horsepower
HVAC	heating, ventilation, and air conditioning
ID	inside diameter
kWh	kilowatt hour
LED	light-emitting diode
LIPA	Long Island Power Authority
LP	low pressure
LP-HO	low pressure/high output
MCWA	Monroe County Water Authority
MF	microfiltration
MG	million gallons
MGD	million gallons per day
MP	medium pressure
MWCO	nominal molecular weight cutoff
MWh	megawatt hour
NF	nanofiltration
NPV	net present value
NRW	non-revenue water
NYISO	New York Independent System Operator
NYPA	New York Power Authority
NYSERDA	New York State Energy Research and Development Authority
OD	outside diameter
O&M	operation and maintenance
OPS	operations planning and scheduler
PAC	polyaluminum chloride; Project Advisory Committee
PSAT	pumping system asset tool
PV	photovoltaics
RBF	river bank filtration
REC	Renewable Energy Certificate
RO	reverse osmosis

ROI	return on investment
RTP	real-time pricing
SCADA	supervisory control and data acquisition
SECO	State Energy Conservation Office
SNWS	Southern Nevada Water System
SOP	standard operating procedure
SSF	slow sand filtration
TDS	total dissolved solids
THM	total trihalomethanes
TOC	total organic carbon
TOU	time of use
UF	ultrafiltration
UKWIR	U.K. Water Industry Research Limited
USGS	United States Geologic Survey
UV	ultraviolet
VFD	variable frequency drive
VSD	variable speed drive
WERF	Water Environment Research Foundation
WSSC	Washington Suburban Sanitary Commission
ZLD	zero liquid discharge



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ISBN 978-1-60573-159-9

