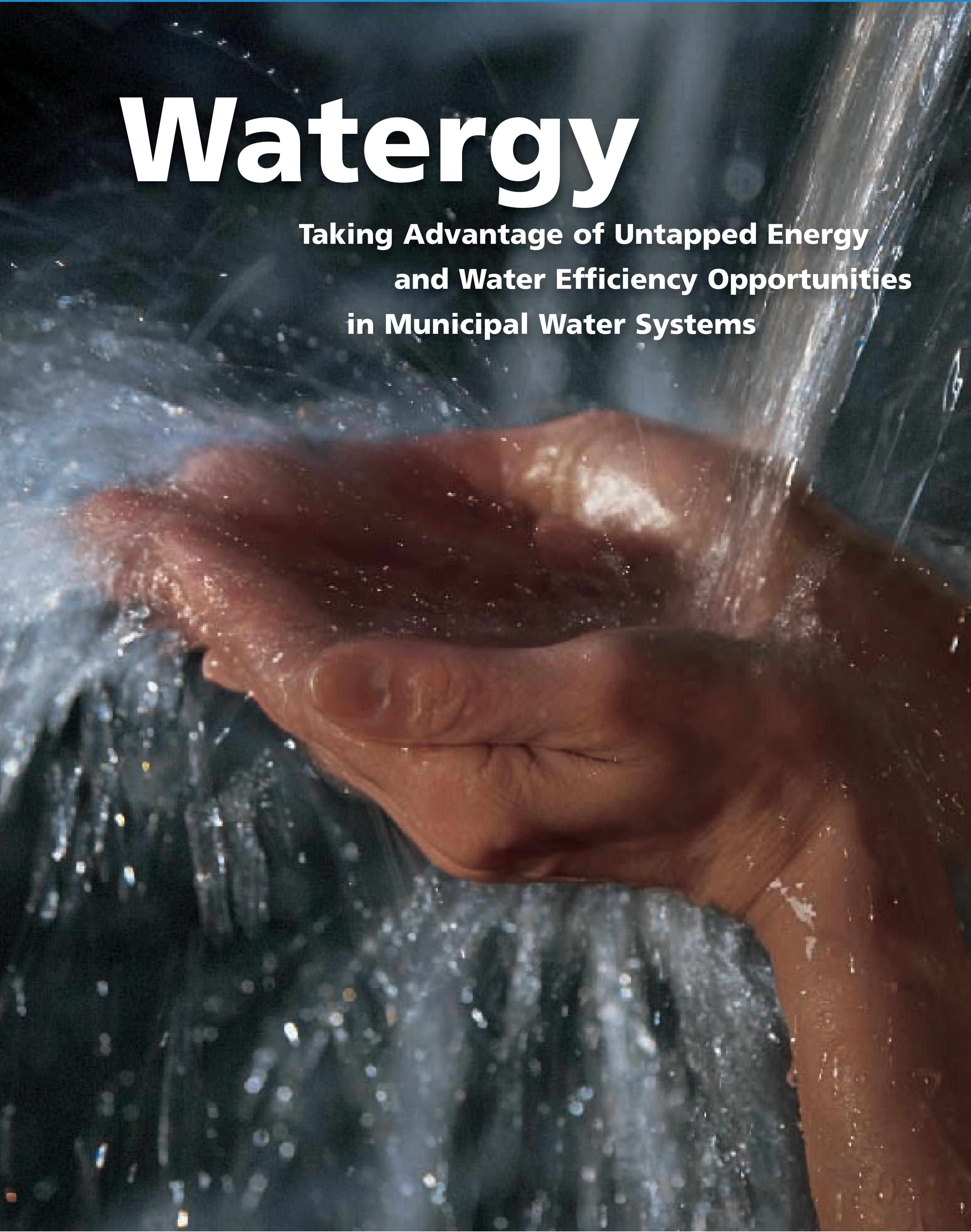
Watergy

Taking Advantage of Untapped Energy and Water Efficiency Opportunities in Municipal Water Systems



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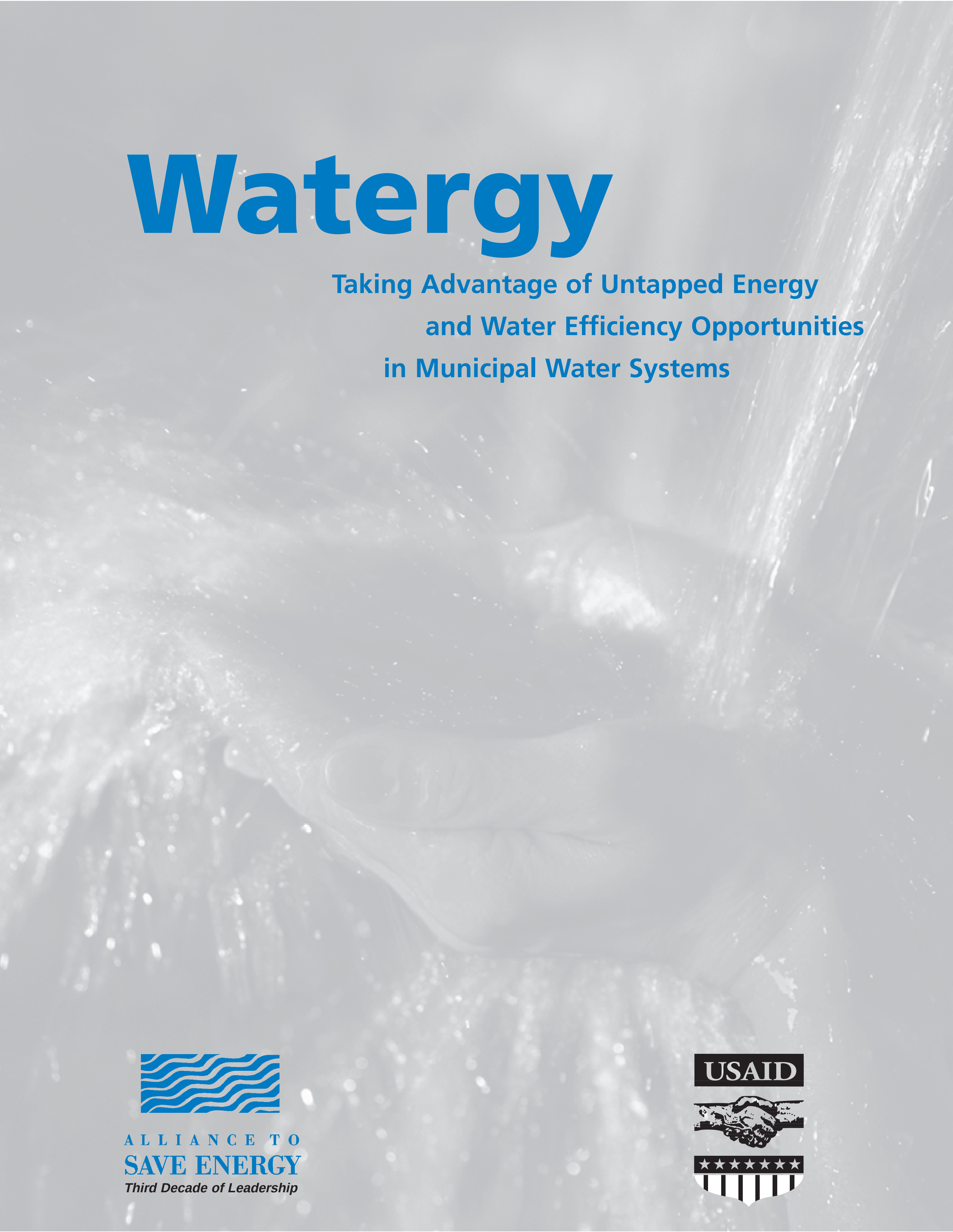

ALLIANCE TO SAVE ENERGY

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Third Decade of Leadership

The Alliance to Save Energy is a coalition of prominent business, government, environmental, and consumer leaders who promote the efficient and clean use of energy worldwide to benefit consumers, the environment, the economy, and national security.

The Alliance International Program is helping to save energy around the world, working on five continents. The International Team boasts activities in over 25 countries with nearly 30 staff located in seven countries. Its programmatic work falls into six areas: Education and Outreach, NGO Development and Capacity Building, Energy Efficient Industry Partnerships, Policy Reform, Sustainable Cities Initiative, and the Municipal Water Efficiency Program.

The Alliance's Sustainable Cities Initiative and Municipal Water Pumping Efficiency programs, which provide the context for this document, focus on capacity development at the municipal level and creating critical links among the public, private, and non-governmental organization (NGO) sectors. The efforts under way engage each of these sectors by touting the multiple benefits of energy efficiency. By helping these sectors find common cause through energy efficiency, the Alliance mobilizes community-wide activity to improve the environment, reduce electricity use and costs, and improve provision of critical water and energy services in municipalities.

The Alliance is currently chaired by United States Senator Byron L. Dorgan and co-chaired by Dean T. Langford, former president of OSRAM Sylvania. United States Senator James M. Jeffords, United States Senator Jeff Bingaman, and United States Representative Edward J. Markey are vice chairs. David M. Nemtzow is the President.

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eface

The Alliance to Save Energy is pleased to publish *Watergy: Taking Advantage of Untapped Energy and Water Efficiency Opportunities in Municipal Water Systems*. This document is the result of a yearlong effort that has sought to draw on the experience of municipal water utilities around the world. It highlights the innovative ways water utilities are reducing their energy use at the same time that they are being asked to increase and improve service.

The recommendations contained within this document offer a new perspective on the relationship between water and energy. By linking the management of water and energy resources, water utilities have the potential to increase the efficiency in which these two critical resources are employed. The potential benefits to individuals around the world from improving the management of water and energy resources range from cleaner air to improved economic opportunity to better utility service for lower costs.

It is our hope that this document will attract the attention of decision makers charged with the management of water resources in many parts of the world, as well as here at home. We certainly look forward to future examples of "watergy efficiency" innovations that this work may inspire and that may lead us all toward a more efficient, productive, and sustainable world.

Honorable Byron L. Dorgan
Chair

Dean T. Langford
Co-Chair

The Alliance to Save Energy gratefully acknowledges the efforts of all those who played a part during the many stages of this document's development. Many individuals made valuable contributions to the final product during the initial conceptual phases, development of the case studies, as well as in the final review process.

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oreword

The initial concept for this report developed around the Alliance's work with municipal water utilities in India and Brazil. The Alliance was originally drawn to the municipal water sector in these two countries because of the tremendous potential for energy savings. The significant results and lessons learned through this work provide the impetus and the foundation for this report.

As part of its ongoing programs in India and Brazil, the Alliance began to research the experiences of other municipalities around the world. The goal of this effort was to identify best practices promoting energy and water efficiency. It became clear that the same opportunities for energy and water efficiency in India and Brazil were common not only in other developing countries, but also in countries in transition and the developed world.

As the Alliance researched success stories to share with municipalities in India and Brazil, it became apparent that first and foremost the key to success of each effort was good management. An examination of all the commonalities among management structures of water and energy efficiency programs provided the foundation for the concepts in this report.

The Alliance to Save Energy in its mission to save energy around the world has found the energy intensive municipal water sector to be fertile ground for sowing the seeds of energy efficiency. This report, as part of the Alliance's comprehensive effort to propagate energy efficiency, seeks to:

- Advocate for improving municipal water utility management structures to facilitate energy efficiency actions;
- Educate municipalities and the global community on the potential benefits of saving water and energy in water utilities and methods to accomplish this aim; and
- Solicit thoughts and ideas from a wider audience on how best to take advantage of the opportunity for energy savings in municipal water utilities.

AMC	Ahmedabad Municipal Corporation
ASD	adjustable speed drive
CAGECE	Companhia de Água e Esgoto do Ceará
CEMP	corporate energy management program
CII	Confederation of Indian Industry
EEPPM	Empresas Públicas de Medellín
EMC	energy management cell
EPRI	Electric Power Research Institute
ESCO	energy service company
gpcd	gallons per capita per day
GWC	Ghana Water Company
IAMU	Iowa Association of Municipal Utilities
IMC	Indore Municipal Corporation
kgf/cm^2	kilogram-force per square centimeter
kVA	one thousand volt-amps
kVAR	one thousand volt-amps reactive power
kW	kilowatt
KWh	kilowatt-hour
MWWD	Metropolitan Wastewater Management Department
NAESCO	National Association of Energy Service Companies
NGO	nongovernmental organization
NSW	New South Wales
O&M	operation and maintenance
PID	proportional, integral, derivative
PMC	Pune Municipal Corporation
PSAT	Pumping System Assessment Tool
PSI	pounds per square inch
PUB	Public Utilities Board
SCADA	Supervisory Control and Data Acquisition
SEWA	Self-Employed Women's Association
UFW	unaccounted-for water
USAID	United States Agency for International Development
UV	ultraviolet
VFD	variable frequency drive

1 inch (in) = 2.54 centimeters (cm) = 25.4 millimeters (mm)

1 foot (ft) = 30.5 centimeters (cm) = 0.305 meters (m)

1 yard (yd) = 36 inches (in) = 0.914 meters (m)

1 mile (mi) = 5,280 feet (ft) = 1.61 kilometers (km)

1 square yard (yd^2) = 9 square feet (ft^2) = 0.836 square meters (m^2)

1 acre (ac) = 43,560 square feet (ft^2) = 0.405 hectares (ha) = 4,050 square meters (m^2)

1 square mile (mi^2) = 640 acres (ac) = 259 hectares (ha)

1 cubic foot (ft^3) = 7.48 gallons (gal) = 28.3 liters (l)

1 cubic yard (yd^3) = 27 cubic feet (ft^3) = 202 gallons (gal) = 0.765 cubic meters (m^3)

1 gallon (gal) = 0.137 cubic feet (ft^3) = 8.33 pounds (lbs) water = 3.78 liters (l)

1 acre-inch (ac-in) = 3,630 cubic feet (ft^3) = 27,154 gallons (gal) = 102.8 cubic meters (m^3)

1 acre-foot (ac-ft) = 43,560 cubic feet (ft^3) = 325,851 gallons (gal) = 1,234 cubic meters (m^3)

1 pound (lb) = 454 grams (g) = 0.454 kilograms (kg)

1 ton (ton) = 2,000 pounds (lbs) = 907 kilograms (kg) = 0.907 megagrams (Mg)

1 pound per acre (lb/ac) = 1.12 kilograms per hectare (kg/ha)

1 cubic foot per second (cfs) = 449 gallons per minute (gpm) = 28.32 liters per second (l/s)

1 million gallons per day (MGD) = 1.55 cubic feet per second (cfs) = 3,785 cubic meters per day (m^3/day)

1 milligram per liter (mg/l) = 1 part per million (ppm) = 1,000 parts per billion (ppb)

1 pound per square inch (psi) = 2.04 inches mercury (in Hg) = 27.7 inches water (in H_2O)

1 Quad = 10^{15} BTU

Watergy: energy used in water systems

Watergy efficiency: optimizing energy use to cost-effectively meet water needs

Between 2 and 3 percent* of the world's energy consumption is used to pump and treat water for urban residents and industry.[1] Energy consumption in most water systems worldwide could be reduced by at least 25 percent through cost-effective efficiency actions.[2] Water utilities globally have the potential to cost-effectively save more energy than the entire country of Thailand uses annually.[3] Unfortunately, relatively little attention has been given to reducing energy use in municipal water systems.

Energy costs draw precious budgetary resources from other important municipal functions such as education, public transportation, and health care. In the developing world, the cost of energy to supply water may easily consume half of a municipality's total budget. Even in developed countries' municipal water systems, energy is typically the second largest cost after labor.

The burning of fossil fuels to generate the energy used to supply water affects local and global air quality. Emissions from power plants contribute to already high levels of pollutants in the urban environment and the acidification of lakes and forests. In addition, millions of tons of carbon dioxide are emitted every year, contributing to global climate change. Global climate change has the potential to reduce water tables and disrupt water supplies in many areas, making water even more costly and energy intensive to obtain in the future.

* About 8 Quads (1 Quad = 10^{15} BTU)

Some Utilities Are Leading the Way

Some municipal water managers in cities such as Austin, United States; Toronto, Canada; Stockholm, Sweden; and Sydney, Australia are aggressively taking advantage of opportunities to save energy in their facilities. The Alliance to Save Energy identified more than 30 municipalities implementing a range of simple, cost-effective actions to reduce energy use, while maintaining or even improving service.

Energy consumption in most water systems worldwide could be reduced by at least 25 percent through cost-effective efficiency actions

The Alliance has worked with several municipalities in the past five years learning about both the potential opportunity for energy savings and the difficulties in achieving them. Fortaleza, Brazil, has dramatically reduced total energy use by 5 MW in its first year after adopting energy efficiency goals, while actually increasing service connections. The city of Indore, India, was able to save 1.6 million rupees (US$35,000) within the first three months of action with no investment cost just by improving the way existing pumps worked together. The city of Pune, India, quickly identified more than 7 million rupees (US$150,000) of energy savings opportunities after kicking off an energy efficiency program but has only managed to implement one-fifth of the projects.

The utilities we have identified stand in stark contrast to the vast majority of municipal water utilities around the world that have not taken basic measures to reduce energy use. Water system managers frequently do not have the technical knowledge or capacity needed to tackle the numerous efficiency opportunities. In many cases, they lack the necessary metering and monitoring systems to collect data, establish baselines and metrics, and conduct facility assessments. Often when data do exist, they are not shared among departments and groups within a municipal water utility.

Blueprint for Success

This report outlines the elements of a "watergy efficiency" system optimizing energy use to cost-effectively meet water needs. These elements reflect many of the approaches taken by the water utilities outlined in the case studies boasting the most comprehensive programs.

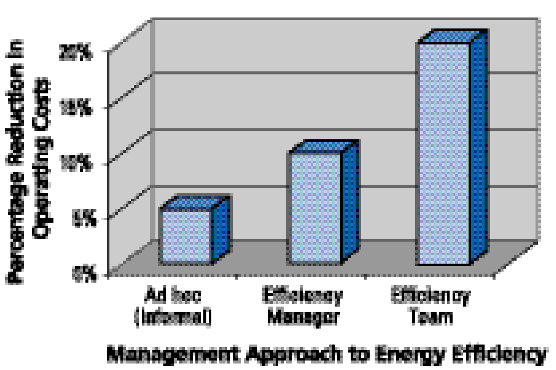
Utilities employing cross-cutting teams have found that additional energy and capital savings can be achieved when they analyze potential water delivery system improvements while simultaneously promoting more efficient water use by customers. In some instances, reducing the consumer's demand for water may allow for reductions in the capacity needs of pumps and pipes.

Critical steps in building the capacity of the team include supplying the tools to meter and monitor energy and water use, training in energy efficiency techniques, and providing adequate resources to invest in identified projects.

Many worthwhile energy efficiency actions can be completed for little or no cost. In fact, installing metering and monitoring systems can save ten percent of energy costs simply through behavioral changes and improved maintenance. While some simple improvements can easily be detected just by metering, many opportunities will remain unexploited without further analysis of data. Many utilities have found benchmarking similar systems within their own operations to be an excellent way to measure energy efficiency progress.

For larger projects, investment capital is commonly a key stumbling block. Finding funds to implement more costly efficiency projects can often be found through savings resulting from other

Expected Efficiency Gains by Water Utility Management Approach to Energy Efficiency



Source: Based on documented gains from corporate energy management programs highlighted in a study by the American Gas Association extrapolated to the municipal water sector.

"watergy" efficiency actions such as reducing water waste and theft, improving basic maintenance practices, reducing subsidies, and optimizing system performance.

Identifying Opportunities

Some of the specific water system energy saving opportunities are easy to identify, such as leaks and malfunctioning equipment. Other energy saving actions are more difficult to detect, such as improper system layout or degraded pipes.

Common problems include:

- Leaks
- Low c-value for pipes (high level of friction inside pipes)
- Improper system layout
- System overdesign
- Incorrect equipment selection
- Old, outdated equipment
- Poor maintenance
- Waste of usable water.

Remedies may involve:

- System redesign and retrofitting of equipment
- Pump impeller reduction
- Leak and loss reductions
- Equipment upgrades
- Low-friction pipe
- Efficient pumps
- Adjustable speed drive motors
- Capacitors
- Transformers
- Maintenance and operation practices improvements
- Water reclamation and reuse.

Water utilities often overlook the potential of saving energy and money by reducing the water consumption of their customers. Helping customers do more

with less water, using technologies such as low-flush toilets, low-flow showerheads, and energy efficient washing machines is often the most cost-effective way to save energy.

This Problem Is Not Going Away

The urban population of the world is expected to double within the next 40 years.[4] If we continue on the current path, energy consumption by municipal water utilities will double as well. Only half of urban dwellers currently have water connections. Energy prices are rising. Water resources are dwindling at the same time that urban populations are swelling. Municipal water utilities, customers, politicians, the environment, and just about everyone else will pay the price for continued waste. Municipal water utilities therefore have a powerful incentive to pursue the potential of watergy efficiency.

A tremendous amount of energy is used to provide water services globally.

- Energy consumed worldwide for delivering water—more than 26 Quads (1 Quad = 10^{15} BTU)—approximately equals the total amount of energy used in Japan and Taiwan combined, on the order of 7 percent of total world consumption.[5]
- In the United States, the water and wastewater sector annually consumes 75 billion kWh—3 percent of the total consumption of electricity[6] or equal to the total electricity consumed by the pulp and paper and petroleum sectors.[7]

Water is becoming scarcer, often making it more energy intensive to procure.

- Less than 1 percent of the world's freshwater—about 0.008 percent of all water on earth—is readily accessible for direct human use.[8]
- Average annual global renewable water resources equaled 7,045 m^3 per person in the year 2000,[9] a drop of 40 percent per person since 1970, due to growing world population.
- Twenty countries (most of them in Africa and the Middle East) suffer chronic water scarcity, causing severe damage to food production and stunted economic development.[10]
- More energy is required to pump water greater distances and from deeper in the ground.

Major segments of the urban population are not getting adequate service.

- The average city only provides electricity connections to about 85 percent of urban households[11] and may lack sufficient energy supplies to meet existing demand.
- Only about half of urban dwellers in developing countries currently have water connections in their homes and more then one-quarter have no access to safe drinking water.[12]
- To reach universal coverage by 2025, almost 3 billion people need to be linked with water supply and more than 4 billion with sanitation.[13]
- Low-income urban dwellers not connected to water systems often must turn to alternative supplies, such as water vendors who may charge 16 times or more than the formal piped water tariff.[14]

Urban demand for both water and energy resources is expected to grow dramatically.

- Energy use world-wide is expected to grow by more than 60 percent over the next 20 years.[15]
- By 2020 more than 50 percent of the population in developing countries will be urban.[16]
- The total electricity consumption of the water and wastewater sectors will grow globally by a predicted 33 percent in the next 20 years.[17]
- Global water consumption grew sixfold between 1900 and 1995.[18]
- In 2025 one-third of the global population is expected to live in chronic water shortage areas.[19]

To help meet the water and energy resource needs, municipalities can reduce energy and water waste.

- Municipal water utilities alone can cost-effectively save more energy (on the order of 2.5 Quads) than the entire country of Thailand consumes in a year through simple efficiency steps.[20]
- Eliminating unaccounted-for water (leaks, theft, etc.) in many large cities in developing countries would more than double the amount of water available for delivery[21] and drastically reduce energy use.

Introduction

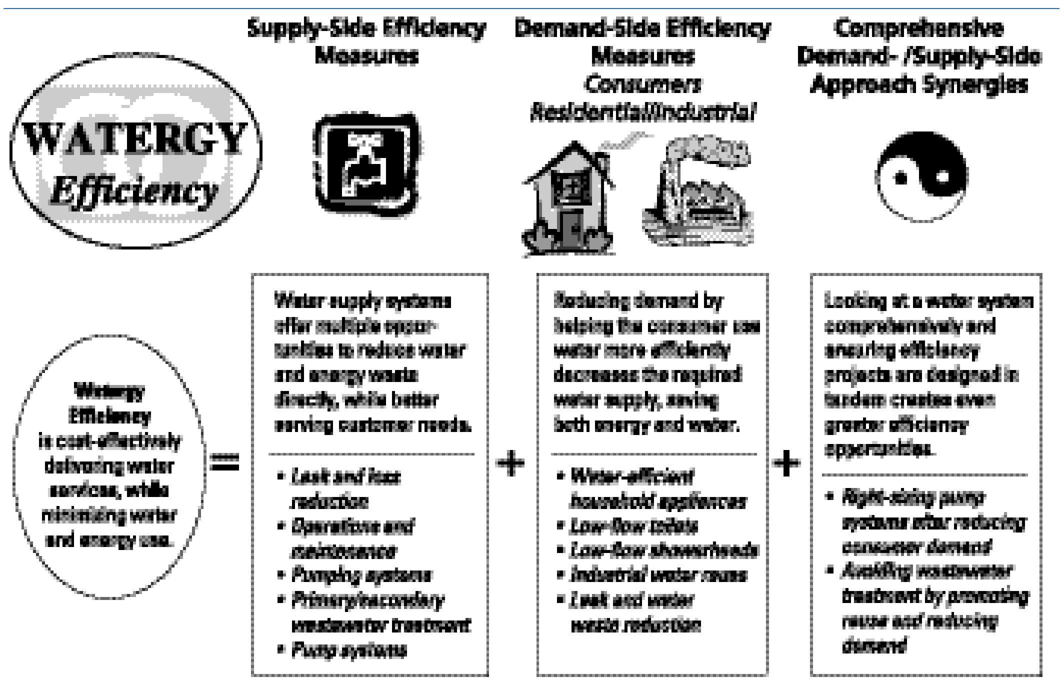
In their role as water providers for almost 50 percent of the world's population, municipal water utilities play a vital role in managing this often-scarce resource. As global urbanization continues, municipal water utilities have the complex task of cost-effectively providing water to keep cities functioning. Limited energy resources, sparse freshwater supplies, and mounting environmental concerns make water delivery even more challenging.

Most water utilities in the world neither maximize the benefits of energy and water resources, nor minimize their negative environmental impacts. By creating and empowering comprehensive "watergy" efficiency management structures, municipal water utilities can cost-effectively provide water services, reduce energy consumption, and protect the environment.

The term "watergy" is used in this paper to describe the linkage that exists between water and energy in the context of municipal water utilities. This linkage of water and energy exists given the part that energy plays in conveying water to the end user as well as its role in potable water dis infection and wastewater treatment. When water is wasted in a municipal water sys tem, energy is almost always squandered as well. See figure 1 for a pictorial description of this relationship.

For this discussion, "watergy efficiency" means cost-effectively providing the consumer with the desired services associated with water, while using the least amount of water and energy possible. "Watergy efficiency" encompasses the spectrum of water efficiency activities, energy efficiency activities, and resulting synergies from comanaging water and energy resources. By understanding all of the existing link ages between water and energy within a water delivery system, water utilities have a tremendous opportunity to adapt their policies and practices to improve efficiency

Figure 1: Description of Watergy



compared with simply addressing water and energy needs separately.

The need for maximizing the potential of existing water and energy resources is critical. The average amount of renewable water* per person in the world has dropped by 40 percent since 1970, due mainly to increases in population.[22] Twenty countries, most of them in Africa and the Middle East, currently face chronic water shortages that severely disrupt economic development. This number will more than double in the next 25 years, as more than three billion people around the world will lack access to safe, adequate water supplies.[23] Many of these same countries face similarly crippling energy shortages that disrupt business and lives. In fact, on the order of 7 percent of worldwide energy production is used to pump water.

Municipalities are important actors in efforts to improve the efficient utilization of water and energy. By the year 2020, more than half of the developing world population is expected to live in cities.[24] With increased urban populations and growing municipal industrial sectors, the amount of water and energy use will grow steadily. Furthermore, although the propor tion of water consumed by the agricultural sector currently represents 70–80 percent of water use worldwide, urban and indus trial users will continue to place ever-greater demands on increasingly scarce water resources.

The potential for watergy efficiency improvements is tremendous. In India, for example, the Confederation of Indian Industry (CII) estimates that the typical Indian municipal water utility has the potential to improve water system efficiency by 25 percent.[25] Because many municipal water utilities in India spend upward of 60 percent of their energy budgets for water pumping, this significant savings could be used to improve service. Based on a recent study of watergy efficiency opportunities in Texas (see page 9) water utilities in the United States could easily reduce 15 percent of total electricity use, saving almost US$1 billion. Latin Americans spend US$1 to $1.5 billion annually just to pump water that never reaches the end user due to sys tem leaks, theft, and faulty equipment. Coincidently, US$1 to $1.5 billion is also the amount needed annually to provide water and sanitation services to all Latin America's currently unserved citizens.[26]

This document includes seven sections:

1. Section One defines the concept of watergy efficiency and justifies the need for efficient water and energy resource management.
2. Section Two lists various water and energy efficiency management models used by municipalities.
3. Section Three describes how to craft an efficient watergy management structure.
4. Section Four reviews the process for developing the appropriate institu tional capacity to carry out watergy efficiency actions.
5. Sections Five and Six outline steps municipalities can take to address efficiency opportunities on both the supply side and demand side.
6. Section Seven presents the report's conclusion.

Following Section Seven, a case study-compendium outlines the watergy efficien - cy activities of 17 cities around the world.-

* The amount of *renewable water* over a period of time at a specific location corresponds to the quantity of water that is naturally replaced in that same timeframe through-natural processes, such as rain, runoff, or snowmelt.

Appendixes A–F list additional technical resources.

Although this document is a resource for building appropriate water efficiency programs, it is not a blueprint. Because the problems and resources of each municipal water authority are unique, the best prac tices and case studies described must be adapted to fit the realities of a given situation. For example, vast differences can occur among existing infrastructure, financial resources and other aspects of water utilities in developing and developed countries; however, many of the basic prin ciples covered in this report are equally applicable. In addition, the report does not distinguish between public and private management structures, but instead is intended to deliver information valuable to any variant of public and private delivery systems.

Case Study of Indore Municipal Corporation

In the 1970s the Indore Municipal Corporation in Indore, India, built an expensive 70 km water line over a mountain to deliver additional water resources to meet an expected increase in demand from a growing population. The actual population increase, however, far exceeded anticipated growth, and Indore is again facing a water shortage. Additional capacity will take years and cost millions of rupees to bring on line. New capacity would also have a significant impact on the availability of electricity resources in Indore for years to come. Efficiency efforts with immediate impact are now under way to try to get more benefit from existing resources. Had Indore planned for efficiency from the outset, its capital investments might still be adequate to serve city needs.

1.1 THE LINK BETWEEN ENERGY AND WATER: "WATERGY EFFICIENCY"

In the process of improving overall water system efficiency, municipal water authori ties should view energy and water con sumption as linked inputs, rather than viewing them as separate and unrelated. Energy is necessary for moving water through municipal water systems, making water potable, and removing waste from water. Each liter of water moving through a system represents a significant energy cost. Water losses in the form of leakage, theft, consumer waste, and inefficient delivery all directly affect the amount of energy required to deliver water to the consumer. Wastage of water regularly leads to a waste of energy.

Activities undertaken to save water and those to save energy can have a greater impact when they are planned together. For example, a leak reduction program alone will likely save water and reduce pressure losses leading to energy savings from reduced pumping demand. Replacing a pump with a more efficient one by itself will likely save energy. If the two are coor dinated together through a watergy effi ciency program, the reduction in pressure losses from leaks will allow smaller pumps to be purchased for the upgrade than oth erwise possible, saving additional energy and money.

1.2 THE CASE FOR WATERGY EFFICIENCY

Incentives for municipal water authorities to improve water efficiency include lower ing costs, ensuring energy and water secu rity, and reducing environmental impacts.

The Most Cost-Effective Option

Watergy efficiency is often the most cost-effective way to improve water delivery services to existing consumers and at the same time meet the needs of growing pop ulations. Comprehensive water efficiency efforts reduce costs, increase the service capacity of the existing system, and improve customer satisfaction.

Cities can provide additional water for growing consumption by installing new capacity, although this has sustainability implications, as natural water supplies from any source are finite. The other option is to get more from existing capacity by imple menting water utility efficiency programs. For example, many municipal water utili ties in developing countries typically have system water losses between 30 and 60 percent. Even many municipalities in developed countries see water losses between 15 and 25 percent.[27]

Toronto estimates that saving water through its efficiency program costs one-third less than developing new capacity. By choosing to focus on efficiency, the City of Toronto has chosen to maintain and improve the benefits consumers currently receive, while minimizing costs.[28]

Ensuring Adequate Energy Supply

The energy savings realized through water efficiency can play a significant part in ensuring an adequate supply of energy for the entire municipality. Many municipali ties throughout the world currently either face energy shortages or will in the near future. Generating new power supplies takes large amounts of time and money. Because water systems use a significant amount of energy, municipalities can quickly help reduce the potential for energy shortfalls and the need for expen sive new energy infrastructure through watergy efficiency.

In the central and northern parts of Brazil, for example, low rainfall created a crisis situation for electricity supply in 2001 by limiting available power from hydroelectric plants. The City of Fortaleza in the northeast State of Ceará faced potential blackouts due to an estimated 20 percent electric power shortfall. In an effort to reduce the impact of the electrici ty shortage, the state identified Fortaleza's water utility as a major potential source of electricity demand reductions. The water utility is a key player in Ceará's efforts, both because it is one of the largest elec tricity consumers and because it holds so many opportunities to reduce electricity use rapidly through efficiency.

Maintaining Sufficient Water Supplies

As many municipalities around the world face water shortages, watergy efficiency will become an even more important tool in ensuring the availability of water.

More than 40 percent of the world's population currently lives in water-stressed areas; this percentage is likely to increase to 50 percent by the year 2025, as demand for water grows. Municipalities in particu lar have seen an increase in water demand, due mostly to population growth, burgeon ing rural to urban migration, and industri-alization.[29] Many municipalities are finding it harder to secure adequate sources of water to meet this growing demand.

Watergy efficiency is one of the major tools municipalities have to maintain water supplies large enough to meet demand. Reducing system water losses and waste can have the same effect as increasing supply: more water is available to go to the consumer. In addition, water utilities can help ensure municipal water supplies by working with consumers to get more benefit from each unit of water used through water-efficient technologies and reduced waste.

Minimizing Environmental Impacts

Municipal water authorities must not only consider financial and resource security benefits resulting from using water more efficiently, but also need to recognize the environmental risks from energy use and overharvesting of water resources.

Energy is predominantly produced by burning fossil fuels, such as coal, oil, and natural gas, which, when burned, release high quantities of sulfur dioxide (SO_2), nitrogen oxides (NO_x), carbon dioxide (CO_2), carbon monoxide (CO), particulates, mercury, and other dangerous pollutants.

The Scope of the Opportunity: The Case of the State of Texas, United States

Fact:

By striving to achieve very modest efficiency targets, Texas could not only improve its water resource situation, but could also plan on saving at least 1.6 billion kWh and 7 billion ft^3 (200 million m^3) of gas annually in a very cost-effective manner.

Texas, located in the southern United States, has a relatively dry climate and limited water resources. It encompasses 261,914 square miles and is home to 20.1 million people. To address its burgeoning water needs, the state has taken an aggressive approach to water efficiency. In spite of this, huge opportunities still exist for municipalities in this state to save water and reduce energy usage

Overview of Municipal Water Utilities in Texas

- Water utilities in Texas use 2.5 kWh –4.0 kWh per 1,000 gal pumped (.66 kWh–1.05 kWh per 1,000 liters).
- Nearly 3.0 billion gal of treated water is delivered for municipal and industrial purposes.
- Total electricity usage for water delivery is 2.8–4.8 billion kWh a year.
- Water authorities spend $180–288 million yearly for electricity.
- The electricity needed to produce chlorine and other water and wastewater treatment chemicals is equal to an additional 0.02–0.10 kWh per 1,000 gal of water used (0.005 to 0.028 kWh per 1,000 liters).

Potential Energy and Water Savings by Sector

Water Utilities

By reducing water utility losses by an amount equal to 5 percent of water distributed, Texas could save 140–240 million kWh of electricity annually with a cost savings of approximately US$9–$14 million. Energy efficiency improvements of 10 percent in the delivery system could save an additional 300 million kWh.

Residential

Studies conducted in Texas and supported by other sources document the opportunity for reductions of 10–20 percent in residential hot water usage. This is possible through programs such as retrofitting of showerheads, installing faucet aerators, promoting efficient appliances, and so on. By promoting these technologies, Texas could save annually 1 billion kWh of electricity, 7 billion $ft^3$of gas, and US$21 million.

Industrial

The industrial sector currently uses 2.8 billion gal (10.6 billion liters) of water daily and has pumping and treating energy requirements of 0.5–2.0 kWh for every 1,000 gallons used (0.13 kWh–0.53 kWh per 1,000 liters). Reducing this amount by even 10 percent would save around 100 million kWh per year.

Source: Texas Water Development Agency, no date, *Relationships between Water and Energy Use in Texas,* unpublished.

Emissions of SO_2 and NO_x from burning fossil fuels are specifically responsible for many urban air quality problems. Burning of coal remains one of the most prolific sources of mercury contamination worldwide. In addition, CO_2 is the primary gas responsible for global climate change; it will, it is believed, have future adverse impacts on the world's cities through more extreme weather events, such as droughts, heat waves, floods, and storms.

Overharvesting of water is also envi ronmentally risky. Removing too much water from the ground, lakes, and rivers can devastate local ecosystems and lead to soil salinization and even desertification. The Aral Sea in Central Asia is an ominous reminder of the potential dangers of exces sive water harvesting. The lake and its freshwater sources, once teeming with life and aquatic resources, were diverted, plundered and polluted to the point that the lake has shrunk to less than half its original size. What remains is virtually a dead body of brackish water.

Municipal water authorities considering watergy efficiency actions will find them even more attractive after taking into account the reduction of environmental risks and impacts.

Water Management Models

Municipal water utilities, both publicly and privately owned, often lack sufficient institutional capacity to develop practical approaches for maximizing watergy efficiency, even after recognizing the potential benefits. The failure is mainly rooted in management structures that do not empower staff to address efficiency issues directly.

The management models that most water utilities employ to deal with efficiency, irrespective of the composition of their ownership, fall somewhere among three general approaches: ad hoc, single manager, and team (see table 1). Municipal water authorities have found that the further they move from ad hoc decision making to a holistic team approach, the more watergy efficiency gains they realize.

2.1 THE AD HOC APPROACH

Water utilities relying on ad hoc responses to promote water and energy efficiency lack the institutional capacity and commitment to take advantage of the vast majority of efficiency opportunities. Utilities operating in this mode may have no comprehensive management plan. Instead, the responsibility for initiating water and energy efficiency

Table 1: Watergy Efficiency Management Structures

	Type of Management Response	Key Characteristics	Tools and Resources
LOW EFFICIENCY POTENTIAL	Ad Hoc	• This is often the default approach. • Upper-level management focus is limited. • Efficiency activities are done without considering systemwide impacts. • System maintenance is done on a reactive basis. • Little or no communication takes place among operating units.	• Water and energy metering or monitoring infrastructure is limited or nonexistent. • Water and energy data available are neither widely shared nor prepared in usable form. • Project funds are often unavailable.
	Single Manager	• Response is often focused on one particular efficiency opportunity (location or technology). • Upper-level management recognizes the need to focus on efficiency. • Limited communication, but insignificant level of collaboration takes place among operating units. • Efficiency manager has little direct control over key personnel.	• Financing is available on the merits of the actual project. • Data gathering occurs, but is limited in scope and distribution. • Some personnel and equipment are designated for specific projects. • Projects are funded on a case-by-case basis.
HIGH EFFICIENCY POTENTIAL	Team	• Response approaches efficiency as a systemwide issue; all operating units promote efficiency. • Upper-level management makes efficiency a priority and regularly checks progress. • System maintenance is an integral part of day-to-day activities. • Managers and staff recognize interconnection of various parts of the system in designing efficiency projects. • Watergy utility efficiency team leadership has some control over key personnel.	• Access to personnel with broad range of skills • Major data collection program with well-designed and distributed reports • Efficiency is a key component of all financial decisions. • Cost savings from projects are often put back into a fund for additional upgrades. • Other innovative funding mechanisms are often available to implement projects.

improvements typically falls to staff that can only react to problems as they occur. Energy and water projects are often implemented without consciously addressing efficiency and are unlikely to be proactively linked with other efforts to maximize savings.

The ad hoc approach is characterized by a scarcity of water and energy use data, lack of coordination among various departments, and limited capital allocation to efficiency projects. Top managers do not focus on watergy efficiency and do not assign resources to this purpose.

Most municipal water authorities will find that the further they move from ad hoc decision making to a holistic team approach, the more watergy efficiency gains they realize.

For example, the Indore Municipal Corporation, prior to its recent efforts to create a water utility efficiency team, had not been measuring or tracking any of its energy use data. Instead, it relied on the electric utility to quantify its use of electricity for pumping water. One of the first things the team discovered after instituting a metering and monitoring program was that it was being charged for more electricity than it actually used.[30]

2.2 SINGLE MANAGER APPROACH

Municipal water authorities may choose to appoint an individual to address specific concerns, such as pump efficiency, water conservation, or wastewater treatment. In many cases, the creation of a dedicated efficiency manager is a positive step in addressing key watergy efficiency issues. An individual focused on a single issue can deliver significant savings to the utility. An efficiency manager will likely stimulate increased levels of data collection and sharing. This can help other departments improve efficiency.

The appointment of an efficiency manager, however, does not go far enough in bringing together all the resources required to maximize watergy efficiency. The weaknesses of the efficiency manager approach stem from the limited involvement of key staff members in the watergy efficiency process. Simply hiring an energy efficiency manager does not stimulate the comprehensive effort by multiple departments and staff needed to achieve the greatest savings.

Some common complaints from efficiency managers employed in this type of system include:

- Sufficient control over resources and other staff's time is lacking for efficiency efforts.
- Many stakeholders from numerous departments are often left underinvolved and unempowered on water and energy efficiency issues, because watergy efficiency is not a direct part of their job.
- Limited interaction, planning, and coordination among various departments is detrimental to promoting the effectiveness of systemwide efficiency measures.
- Efficiency projects are more likely to fail if they lack buy-in and coordination among departments.

In Fortaleza, Brazil, the municipal water authority, Companhia de Água e Esgoto do Ceará (CAGECE), employs an energy efficiency manager who promotes several successful programs. One of the manager's important achievements was including energy efficiency as a key element in the municipal water authority's strategic plan for improvement; this included establishing goals for energy efficiency. Although the goals themselves are impressive and improvements have been made, the energy efficiency manager has encountered a number of impediments.

The first problem involved information sharing. CAGECE invested in a sophisticated metering and monitoring system, but the information it provided only went to certain individuals. The energy efficiency manager did not receive the required data in a usable format.

The second problem was how little input the energy efficiency manager had into key investment decisions that critically affected energy efficiency throughout the system. For example, maintenance staff made repair decisions for motors and pumps based solely on the cost of the repair, compared with the cost of purchasing new, more efficient equipment. They did not take into account the depreciated value of older equipment and potential additional savings from upgrading to more efficient equipment. In effect, a 10-year-old inefficient motor requiring the same repair as a 1-year-old, high-efficiency motor was given similar consideration for replacement.

A third problem involved the fact that many of the ideas, proposals, and decisions coming from the energy efficiency manager were not completely coordinated with other investments in water supply, system pressure, and water treatment. These investments typically did not capture the maximum potential efficiency improvements.

The appointment of an energy efficiency manager has been a significant step in improving CAGECE's water efficiency. Nonetheless, both senior managers and the energy efficiency manager recognize the need to include additional resources, ideas, and participation to make further progress.

2.3 THE WATERGY EFFICIENCY TEAM APPROACH

Based on the experiences of numerous water utilities and lessons learned under similar circumstances in the private sector, water utilities employing a team management approach to watergy efficiency will be better positioned to take advantage of efficiency opportunities.

The experiences of many municipal water authorities, such as those documented in this report indicate that the team approach to watergy efficiency is an integral part of successful operational

Champions of Water Efficiency:
The Case of Columbus, Georgia, United States

At Columbus Water Works (CWW) in Columbus, Georgia, energy costs are the largest single expenditure. CWW has greatly benefited from the efforts of water efficiency champions. It took the leadership of President Billy Turner, senior vice president of operations, Cliff Arnett, and others to make the transition to an energy-efficient operation.

These senior leaders encourage operators, team leaders, and other staff members to propose plans to increase efficiency. Mr. Arnett has to be sold on a proposal; he then takes it to the president. Managers and team leaders also have biannual seminars on energy-efficient training.

The results of this system have been impressive. CWW has re-engineered and fully automated the entire plant. They retrofitted older equipment, installed adjustable speed drives, and automated speed controls for pumps. They have made significant investments in energy-efficient motors, including an upgrade of their 750 HP motor, which saved them $200,000, reduced their energy costs by 20 percent, and realized a 1-year payback.

In a five-year period CWW has saved more than $1 million by changing its rate structure, optimizing processes, and adding efficient technologies to blowers, motors, and pumps. With a view to introducing new ideas and insight, the utility employs an energy consultant quarterly to review the energy situation.

Source: Cliff Arnett, senior vice president of operations, Columbus Water Works.

strategies. Even though each of the munici pal water authorities highlighted in the case studies took a unique approach to creating the watergy efficiency team infrastructure, a number of similarities underscore the benefits of this methodology.

The watergy efficiency team originates from strong advocates or "champions" at the senior and middle management levels. A senior manager may identify comprehen sive water and energy efficiency as a core function of the water authority and ensure that appropriate resources are dedicated to achieving this goal. Middle-level manage ment provides the day-to-day leadership and does the actual work of incorporating energy efficiency into water system man agement duties.

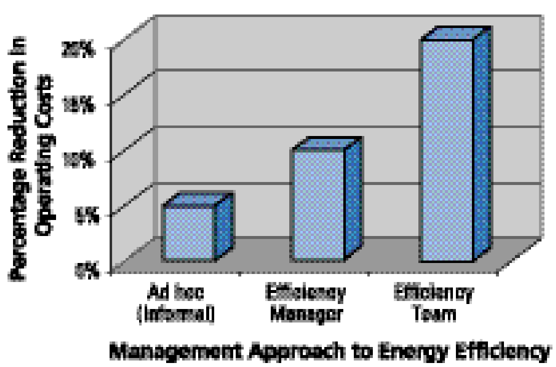
Watergy efficiency teams can mobilize a wide variety of resources and staff to improve communication throughout the company. In addition, teams are able to streamline efficiency project identification and implementation and ensure the coor dination of activities. A functioning team will make water and energy efficiency part of the core business of the water utility.

Lessons from the Private Sector: Corporate Energy Management Programs

The team concept to promote efficiency is not new. In fact, the private sector has long been using corporate energy management programs (CEMP) to great effect in ways that mirror and add credence to the water-utility efficiency team concept. Several manufacturing companies, including Owens Corning, Johnson & Johnson, and 3M, have found that it makes good busi ness sense to adopt comprehensive corpo rate energy management programs.[31] These companies have reduced operating costs to well below the levels of competition that lack institutionalized energy management programs.

A key lesson of CEMP systems for watergy efficiency teams is that continuous improvement requires a management struc ture that combines the technical aspects of energy efficiency with effective operational management. As a recent study by the American Gas Association highlights, many facilities concerned about operating costs often identify and implement energy effi ciency opportunities on an ad hoc basis.

Table 2: Expected Benefits from Watergy Efficiency Management Approach Based on CEMP Experience



Source: Based on documented gains to CEMPs highlighted in a study by the American Gas Association extrapolated to the municipal water sector.

Initial savings from this approach generally total between 5 and 10 percent of energy costs. Through CEMPs, however, compa nies not only realize the initial 5–10 percent savings, but another 5–15 percent (see table 2) in improved operations and maintenance practices.[32] Additionally, because energy production and use at a facility is not static, facility performance can deteriorate to crisis proportions in a few years without ongoing management.[33]

Characteristics of an Effective Watergy Efficiency Team

A recent report by the Alliance to Save Energy on corporate energy management characterized eight key elements in corpo rate energy management programs. These critical CEMP components are all essential for creating a successful watergy efficiency management program:[34]

1. Commitment by top-level management
2. Clearly defined energy reduction goals
3. Communication of the goals throughout all levels in the company
4. Assignment of project responsibility and accountability at the proper level
5. Formulation and tracking of energy-use metrics
6. Identification of all potential projects on a continuous basis
7. Adoption of project investment crite ria, reflecting project risks and returns
8. Provision of recognition and reward for achieving the goals.

One element of an effective watergy efficiency team that directly parallels the CEMP structure is the enactment of a metering and monitoring system to pinpoint energy and water waste. This system pro vides key members of affected departments with an integrated view of pertinent infor mation. The City of Austin, for example, has developed an aggressive monitoring program to provide its staff the maximum opportunity to enact efficiency gains. Austin's water utility provides a regular stream of appropriate data to staff via e-mail to empower its managers and employees. Data, such as specific pumping information, customer sales, and system performance, are constantly sent to appro priate staff who can then optimize their water and energy efficiency efforts. These data are stored in accessible databases that provide benchmarks on efficiency efforts.

An excellent example of the success of Austin's data-sharing system comes in the area of leak reduction. By installing multiple submeters and coordinating the flow of pertinent information directly from meters to crews that repair lines, Austin has reduced system losses to only 8 percent.

Austin also has an advanced consumer monitoring system that helps focus the resources of their demand-side efficiency programs. Employees are able to differenti ate up to 30 categories of water users, such as hospitals and schools. This information allows Austin's staff to target resources better to inefficient water users, either by comparing sectors or by benchmarking customers within a sector. For example, a hospital using more water than its counterparts would be a likely candidate for a water audit.

Corporate energy management programs have been documented as excellent vehicles to reach maximum efficiency gains. Just as industries have found this management approach empowering, municipal water authorities will find some hybrid of the management team approach to be the most effective methodology to promote water and energy efficiency.

3. Crafting a Watergy Efficiency Team Infrastructure

3.1 THE GOAL OF A WATERGY EFFICIENCY TEAM

The purpose of creating a watergy efficiency team is to marshal resources and tools to maximize efficiency. The end result is to provide the same or greater benefit to the water end user while reducing operating costs, energy use, waste, and per capita energy and water consumption. The watergy efficiency team's role is to:

- Organize and coordinate water and energy efficiency efforts
- Generate a pool of technical know-how to identify and implement projects
- Assemble pertinent data to identify inefficiencies
- Create a management focus on water and energy efficiency.

3.2 THE FORMATION OF A WATERGY EFFICIENCY TEAM

Creating a watergy efficiency team involves putting together the right group of people, armed with the appropriate resources, to identify opportunities, develop and implement projects, and track results.

No single correct approach exists to building a watergy efficiency team. Many variables, including size, financial capabilities, and experience with watergy efficiency, will dictate how individual utilities approach the effort. As part of the planning process to build a watergy efficiency program, serious consideration should be given to available staff and financial resources and the opportunity costs of engaging these resources in the pursuit of efficiency.

The team-building process for CAGECE, the water utility in Fortaleza, Brazil, began with management recognition of the key role of energy in their water system. That led to the appointment of an energy efficiency manager. Initial steps to gain credibility included improving operational efficiency of several components of the water system and getting energy-use reduction targets adopted by senior management. The energy efficiency manager, however, recognized the limitations of his position in terms of gathering data and enacting systemwide efficiency measures. The energy manager was limited by the fact that senior management did not identify efficiency as part of the core jobs of several key staff members.

Creating a water utility efficiency team involves putting together the right group of people armed with the appropriate resources to identify opportunities, develop and implement projects, and track results.

After deciding to adopt a team approach, CAGECE went through a planning process to determine the critical aspects of their water system that needed improvement. From this process, CAGECE was able to establish its measures of success, including specific energy-use reduction goals, and target priority areas of initial work. The planning process provided the link to identifying the key players the utility needed to mobilize for their watergy efficiency team.

Table 3 lists likely key players and their roles on a watergy efficiency team based on findings from many of the successful programs canvassed in this study. Few water utilities will have the resources to allow

Table 3: Human Resources Required for Watergy Efficiency Team

Potential Team Member	Description of Role
Top management	• Sell to mayor and other city officials • Break bottlenecks • Advocate for project funding • Ensure a team budget • Track progress
Watergy efficiency manager	• Motivate team members • Provide team vision and create goals • Develop a work plan and implementation schedule • Assign tasks • Coordinate information flows • Evaluate systemwide opportunities • Advocate for project financing • Facilitate interdepartmental cooperation
Unit level managers (water supply plant, treatment plant, delivery operations, and so on)	• Provide critical data • Identify and involve key technical staff • Implement and maintain projects • Discover critical design efficiency issues
Hydrology staff	• Contribute key technical know-how • Provide an important data source • Offer significant contribution to water supply/sanitation systemwide planning • Liaison with a basin-level resource planning entity
Maintenance staff	• Identify and implement efficiency opportunities • Provide critical data
Energy staff	• Supply a major component of data • Contribute to project identification and implementation • Serve as resource for technology option
Data collection/ input staff	• Perform basic data management and distribution functions
System planner	• Offer long-term investment awareness to watergy efficiency process
Finance staff	• Prioritize activities based on cost-effectiveness • Assess project-financing opportunities
Customer outreach staff	• Create demand-side awareness and reductions
Private sector	• Undertake consumption reductions as appropriate • Offer efficiency know-how and resources
Electric utility	• Provide expertise and means to promote efficiency • Potential source of financing

each of the suggested members to work on efficiency for a major proportion of their time. The core team members, however, will be better off developing links and working relations with as many colleagues as possible to improve the exchange of information and facilitate the team's activities. The list offers a starting point for utilities looking to develop a watergy efficiency team, but every successful team will clearly have its own identity and may be phased in over a period of time.

Outsourcing

As a watergy program develops, it may become clear that a municipal water utility lacks the resources, expertise, and/or time to staff and implement the activities of a watergy efficiency team effectively. Outsourcing work to companies that specialize in needed areas is often a cost-effective way to enable a water authority to pursue water and energy reductions aggressively.

A municipal water authority can outsource anything from a small specific need to the majority of functions of an efficiency team.

The Municipal Water Company of Columbus, Georgia, in the United States provides one example of a water utility using outsourcing to address a particular need. In Columbus, the water utility has an energy consultant conduct an efficiency audit on a quarterly basis to look for additional energy efficiency opportunities. The consultant's additional set of eyes and their outsider perspective allows them to check and ensure that staff concerned with day-to-day operations of the system have not overlooked saving opportunities.

In contrast, the City of Toronto used outside consultants to help draft its entire water efficiency plan. Bulawayo, Zimbabwe, employed outside consultants to help develop its efficiency program and train local staff to implement it. Instead of appointing a full-time staff person, the Ahmedabad Municipal Corporation in India used an outside consultant as its energy manager for 2 years. This allowed the energy manager to focus on efficiency without getting pulled into other projects.

Outsourcing, however, involves some key constraints, so managers should give special consideration to creating ground rules for outsourced activities. Outsourcing may require even greater management supervision to make certain activities are successful. To manage outsourced activities properly and ensure results, managers need to confirm baselines and create mechanisms to verify work and savings. Outsourcing activities also require the vigilant attention of senior managers to ensure that activities progress as scheduled and that they interface with other related measures.

Outsourcing work to companies that specialize in needed areas is often a cost-effective way to enable a municipal water authority to continue to pursue water efficiency aggressively and help galvanize the team's activities.

3.3 TOOLS AND RESOURCES OF A WATERGY MANAGEMENT TEAM

During the process of organizing a watergy efficiency team and programming its activities, managers also need to recognize and provide the multiple resources that the

team requires for success. Below is a list of common resources required.

- **Budget.** Ensuring an annual budget is an important part of institutionalization in any bureaucracy. For a municipal watergy efficiency team, a budget is critical to acquiring appropriate tools and expertise, commissioning technical studies, implementing appropriate projects, and providing continuity.
- **Time.** Team members need to be allotted time to focus their efforts on efficiency. In Indore, India, key team members repeatedly pointed out that their workloads often did not allow them the necessary time to focus on accomplishing water and energy efficiency activities.
- **Access to key staff.** To empower a watergy efficiency team fully, management should allow the team the ability to access and task key people from both inside and outside the team.
- **Training.** Appropriate training empowers team members to achieve efficiency goals. Training can acquaint team members with up to date efficiency technologies, teach up to date operations and maintenance practices, and show managers how best to enable their staff to achieve efficiency gains.
- **Metering and monitoring equipment.** One of the first tasks of the team should be to assess the current metering and monitoring system to identify areas for improvement and determine additional equipment needs (flow meters, pressure gauges, and so on). Data can always be improved by increasing the scope and accuracy of the system's measuring capacity.
- **Database management tools.** Raw data are ineffectual unless they are recorded and manipulated into a usable form. Technologies to track and analyze systemwide data, such as computers, database software, and report generators, are vital resources for improving efficiency. If funds are limited, leasing this type of equipment is an option.
- **Project financing.** To prevent a team's efforts from turning into a strictly academic exercise, identified opportunities need to be implemented. The team needs a mechanism to fund worthy projects. This could include some combination of the following: developing a relationship with a water and/or energy service company, leasing equipment, creating a separate budget within the utility for efficiency projects, fast tracking projects that meet certain payback goals, and using savings from low- or no-cost projects to help fund new projects.

- **Office space.** Office space can be an important institutional building block for a watergy efficiency team. The office serves as a meeting point and an information hub. In the Indian cities of Pune and Indore, creation of an actual office space has been important to institutionalizing the water and energy efficiency team. Phones, computers, staff, and other data collection resources followed the allocation of office space.

The examples of Pune and Indore in India provide excellent insights into the importance of endowing the team with the proper resources and tools. In many respects, the progress of these two municipal water companies in implementing watergy efficiency measures can be directly correlated to their ability to engage the appropriate tools and resources.

In the year 2000, the Pune and Indore Municipal Corporations began working with an NGO to develop management capacity to address water and energy efficiency. Each of these municipalities had strong leadership at the senior management level that recognized the potential for savings based on initial assessments of their operations. Each recognized the data gaps and measuring inadequacies in their existing system. By deciding to address these problems by building a water and energy efficiency team, these municipalities began to reap significant savings as the most easily addressed projects were implemented.

As the team-building effort ensued, however, the lack of certain measurement equipment and their inability to procure necessary resources quickly began to hamper efforts. Data collection, a key element of earlier success, could not be improved. To address these issues, both Pune and Indore developed operating plans that included budget, staff, equipment, and training to empower the team to achieve even greater success.

In Pune, for example, the water and energy efficiency management team was at a near standstill until it procured computer and database systems to track and analyze data. Once data were gathered and entered in the system, the energy management team started to identify additional savings opportunities and recognize areas needing further attention. The Indore Municipal Corporation facing a similar lack of equipment, created a line item in the municipal budget for water and energy efficiency work. In the first year, the corporation provided about US$100,000, which is being programmed to support the team's activities. By making these additional investments, both Indore and Pune have been able to take advantage of additional savings opportunities and discover billing errors made by the electric utility.

Developing an accurate understanding of current operating conditions is the first step for a water utility to create and implement a watergy efficiency strategy. To understand the potential of water and energy efficiency and implement effective solutions, water utilities need to create a water-metering and -monitoring system, develop baselines and metrics, carry out facility assessments, and analyze data to determine the appropriate allocation of resources.

4.1 WATERGY METERING AND MONITORING SYSTEM

An accurate metering and monitoring system empowers watergy efficiency teams to become aware of system problems and bottlenecks, identify the cause of problems, and take corrective actions. Metering and monitoring systems alone have allowed many organizations to cut energy consumption by 10 percent.[35]

Resolution of technical issues such as isolating water losses and system pumping requirements relies on valid metering data on water flow and electricity use. For example, in wastewater systems, regular monitoring of flows can indicate problems with water from the outside infiltrating the system. Increased water flow can indicate that groundwater is seeping into collection mains through loose joints, main breaks, and cracks. It can also stem from rainfall runoff that enters from manholes or connections such as eave spouts or sump pumps. Water infiltration can create excessive demand on system equipment, wasting energy and money.[36]

The first task in establishing a metering and monitoring system is to create a network of meters and submeters measuring water flow and energy use. Although the technology employed and the number of meters will vary depending on each water utility's access to resources, this network must measure water and energy entering into the system and calculate the water delivered to users. In the best-case scenario, the metering system will extend throughout the facility to areas where water and energy are used. Separating the system and plants into discrete areas (e.g., specific equipment or section of a building) can facilitate the measurement of energy and water inputs and outputs.[37]

Key Steps to Building Institutional Capacity

- **Create a watergy metering and monitoring system.** Many potential supply-side and demand-side savings opportunities can be identified, implemented, and verified by developing comprehensive data collection and management systems.
- **Develop a baseline and metrics.** By creating a baseline and metrics, water management teams can better identify efficiencies, sell projects to management, and track success.
- **Carry out facility assessments.** Water efficiency management teams can gain a more detailed understanding of where opportunities lie within the water system by conducting facility assessments.
- **Analyze data.** Once all the data are collected, water utility efficiency teams need to be able to use them to make decisions on where to focus resources and efforts.

The quality of the data will be greatly affected by the quantity, quality, and placement of measurement equipment. To maintain accuracy, meters need to be checked regularly and recalibrated as necessary.

Factors to consider when selecting measurement equipment include:

- Type of instrument for a given parameter
- Portable compared with stationary
- Accuracy compared with cost
- Operating environment (e.g., physical stresses or corrosion potential)
- Physical location and space in the system.

Table 4 summarizes common types of instruments available for a given parameter.

Because several tools exist that can often offer similar measurements, water utilities must identify the best equipment for the specific job based on internal criteria.

Permanently installed meters can be extremely useful in creating a functional metering system. These meters can be consistently monitored by staff or electronically to maintain a reasonably reliable data set. Portable instrumentation, however, is often advisable for better accuracy. Portable instruments are easier to maintain and calibrate and should be used where possible to check the precision of installed meters.

Certain tasks may require extremely accurate measurement equipment, whereas others may just require reasonable estimates. Similarly, more physically demanding system areas that subject equipment to considerable physical stress and potential damage might require more durable and expensive meters. Water utilities will need to develop criteria to select equipment based on their needs compared with product costs.

It is also important to determine the proper locations to take measurements. Measurements for flow and pressure are generally taken around major pumps to assess their efficiency. In fact, major pumps may warrant further analysis to identify optimal performance conditions.[39]

Meters cannot provide every measurement required. Estimates are necessary for such quantities as the vertical rise between the water source and the destination (head*) and in those cases where it is not practical to take measurements due to piping layout or the physical space available.

* Head is the vertical distance between the water source and its destination.

Table 4: Watergy Efficiency Performance Measurements

Parameters	Typical Measurement Instruments
Water flow rate *Comparing water flow rates in different parts of the system can help pinpoint leaks, high pipe friction, and real-time pumping requirements.*	• Differential pressure devices, such as orifice meters and Venturi meters • Velocity flow meters, such as pitot tubes • Open flow meters • Positive displacement meters
Water pressure *Monitoring water pressure can help find leaks, reduce unneeded pumping, and maintain constant service.*	• Bourdon tubes • Bellows • Diaphragm • Piezo-resistive transducers
Motor input power *Input power readings can help determine if a motor is operating at its optimal efficiency.*	• Ammeters • Voltmeters • Power factor meters
Pump rotating speed *Rotating speed data can help determine if a motor is operating at its optimal efficiency.*	• Strobe light
Equipment nameplate information • Rated motor speed, horsepower, full load amperage, and nominal efficiency • Pump flow, head, and speed *This information is vital in determining the optimal efficiency point for equipment.*	Ongoing monitoring
Head[38] *Pumps need to be fitted to match the system's head requirements.*	Estimated

In addition to the physical installation of a metering and monitoring system, it is important to institutionalize the operation and management of the metering system. Whether checking instruments by hand, using portable tools to take measurements, or receiving data automatically through computer systems, individuals need to be responsible for accurately recording measurements. Maintaining trained and motivated staff in these crucial functions will greatly improve the quality of the data output.

4.2 BASELINES AND METRICS

To measure progress on efficiency, it is critical to develop water- and energy-use metrics and then create a baseline to compare these metrics with future improvements. Tracking water efficiency metrics, such as those listed in table 5, can provide critical information about a system's efficiency. By selecting a set of metrics to gauge improvements and identify inefficiencies, water utility efficiency management teams will be able to prioritize opportunities and assess their progress better. To provide an accurate comparison, water and energy consumption baselines must account for intraday, daily, and seasonal fluctuations in demand. Development of metrics and baselines is necessary for both water delivery facilities and customers.

Sydney Water in Australia tracks their water and wastewater system performance based on a number of indicators:

- Overflows and leakage from the sewer system
- Sewage treatment effluent quality
- Greenhouse gases
- Energy used
- Biosolids generated
- Sewer discharge reductions at source
- Environmental management and performance
- Species impact.

Using this data, Sydney Water tracks several metrics including those related to facility energy consumption:

- Per capita electricity consumption
- Electricity consumed per unit of service delivered
- Percentage of electricity purchased as green power (electricity from renewable sources)
- Greenhouse gases generated both directly and indirectly from the system's consumption of energy.

Progress on these indicators is reported in Sydney Water's annual environment report.

4.3 FACILITY ASSESSMENT

As part of the process of identifying a comprehensive inventory of measures to reduce operating costs, watergy efficiency management teams need to undertake in-depth facility assessments. These assessments should cover all equipment and devices involved with the processing, delivery, and treatment of water.

Table 5: Typical Metrics for Tracking Watergy Efficiency

Cost	Supply	Demand
Total Water Delivered Total Cost* *Example: liters per dollar*	**Total Water Delivered** Total Amount of Energy Used *Example: liters per kWh*	**Total Water Delivered** Total Population *Example: liters per person*
Total Cost Total Water Delivered *Example: dollars per liter*	**Total Water Delivered** Total Input Water *Example: liters per liter entering system*	**Total Water Delivered** Number of Connections *Example: liters per connection*

* Including energy, water, capital depreciation, and maintenance

For example, the Confederation of Indian Industry's Energy Management Cell, by conducting facility energy audits, estimates an annual potential savings of 1.5 billion rupees (US$32 million) in Indian public waterworks in pumping systems alone. The confederation estimates that a systematic approach to identifying energy savings opportunities often yields savings as high as 25 percent.[40]

To complete an accurate analysis of current operating efficiencies, it is vital to verify such equipment data as hours of operation, equipment type, efficiency rating, and other basic information. In addition, factoring in the current operating conditions for equipment will improve the accuracy of the efficiency analysis.

To identify opportunities correctly, the facility assessment team must know how to take accurate measurements, where the meters are located, and when measurements are to be taken. Proper staff training needs to cover the techniques involved in monitoring equipment selected for the plant. In addition, managers need to develop systems to ensure that accurate measurements are being taken. Plant managers typically cite human error in collection as a major contributing factor to inaccurate data.

Case Study: Bunbury, Australia

Bunbury relies totally on electricity to extract and move water through the city's distribution system. The city's water board set a goal minimizing water costs to the community. It determined the best way to achieve this was to use life-cycle operating costs as the basis for decision making. Their investment decisions, therefore, minimize both energy input costs and maintenance costs. At times, this has required greater capital outlay than other investment options.

Bunbury monitors the ratio of treatment plant energy consumption to water production as a performance metric to help reduce costs. The city also undertakes an annual review of energy consumption trends and performance against a 5 percent reduction goal. Energy audits pinpointed the following specific areas of energy savings:

- Using smaller, more efficient pumps in water treatment plants
- Replacing fixed-speed drive pumps with adjustable speed drives
- Optimizing sand filter backwashing
- Establishing a preferred sequence of water treatment plant start-up based on the plant energy efficiency ratings
- Modifying pipes to reduce head loss.

These measures, implemented during four years, saved $164,000 (US$83,000). With a total outlay of $115,000 (US$53,000), this amount equals a payback of 2.8 years.

Source: Center for the Analysis and Dissemination of Demonstrated Energy Technologies, "Energy Management by a Water Supply Utility" (Center for the Analysis and Dissemination of Demonstrated Energy Technologies, Netherlands, March 1999).

4.4 DATA ANALYSIS

After implementing a system to gather accurate data, the team must develop a process for using the data to maximize their efficiency efforts. To use the data to isolate efficiency opportunities, the actual levels of energy consumption and water flows should be compared with the optimal theoretical consumption.

To determine the optimal consumption, the team will have to use:

- Engineering calculations
- Equipment manufacturers' standards
- Internal norms and standards
- External standards and benchmarks
- A systems analysis approach.[41]

Engineering Calculations

Technical tools such as pump nomographs, optimization software, and fluid dynamics engineering formulae can assist with the engineering assessments of both specific equipment and of particular parts of water systems. The U.S. Department of Energy, for example, offers a software package called the Pumping System Assessment

Tool that allows the user to create performance curves for pumps and motors to gauge their actual operating efficiency.

Equipment Standards

Equipment standards and norms provided by the manufacturer also provide valuable information concerning the optimal operating efficiency of certain equipment. A pump, for example, operating at an efficiency level well below its manufacturer's specifications may be an ideal candidate for maintenance or replacement. It may also indicate the need for system redesign.

Internal Norms and Standards

Water and energy use information can also be compared with similar facilities within the company to assess opportunities for improvements. For example, Fortaleza, Brazil is helping to prioritize pumping stations that need efficiency upgrades, simply by comparing them with each other in terms of cost per unit of water pumped.

External Benchmarking

Alternatively, water utility efficiency teams might choose to contact other companies to solicit operating standards and benchmarks. They may also speak to trade organizations, such as the American Water Works Association or international groups to gather similar information.

A World Bank–led effort focusing on 12 countries in Africa is sharing operating data and benchmarking water facility performance. The participating water utilities have been able to measure their performance with that of their peers, while gathering information on innovative ideas to improve efficiency and service.[42]

In addition, in the Baltic region, several utilities are benchmarking water utility performance with each other by compiling an array of identical water and wastewater performance indicators. Several Estonian, Latvian, and Lithuanian utilities measure their performance both internally and externally for the following metrics:

- Percentage of population served (water supply)
- Total water produced per capita per day
- Unaccounted-for water losses
- Population of cities served
- Nitrogen removal rate (yearly average)

Major systems that offer significant efficiency improvement opportunities in water and wastewater facilities include:
- *Piping systems*
- *Pumps*
- *Motors*
- *Compressors*
- *Primary treatment equipment*
- *Secondary treatment equipment, such as aerators and blowers*
- *Disinfection equipment such as chlorine mixers, ozonation, and ultraviolet equipment.*

Potential for Pumping System Improvements in the United States

A common area for improvement in the municipal water system is the pumping system. Pumping systems comprise an estimated 70 to 90 percent of electrical energy costs for U.S. municipal water companies. In groundwater systems that only use disinfection and no other treatment, almost all of the energy used is for pumping. With 60,000 water supply plants and 15,000 wastewater treatment plants in operation in the U.S., municipal water pumping accounts for nearly 2.5 percent of U.S. electricity use.

Sources: Oliver and Putnam 1997 and IAMU 1998.

- Phosphorus removal rate (yearly average).

By aggregating these data, the Baltic utilities can compare their performance with their peers to give them an indication of their potential for improvement.[43]

Systems Approach

In looking for water savings, it is important to view potential measures in the context of their overall impact on the water and energy inputs for the water system as a whole. For example, separate assessments might indicate that changing a pump in one part of the system and making a piping size change in another will augment efficiency. Not coordinating the two efforts, however, may actually reduce overall system efficiency and waste resources.

A good illustration of the potential impact of one capital improvement on other efficiency projects can be found in Pune, India. A recent assessment of one of Pune's water-pumping stations uncovered a substantial savings opportunity from relining a rising main to reduce frictional losses. Relining the main would reduce electricity consumption by an estimated 500,000 kWh and save 2 million rupees (US$45,000) annually. The assessment also recommended redistributing pumping loads more efficiently among the different existing pumps and potentially replacing some of the pumps with more efficient units. To maximize efficiency gains from both projects, the calculation of the redistribution of the pumping load and determination of what size pumps should be purchased needs to be coordinated with the results of the relining project. The reduction in friction from the relining will reduce pumping requirements and allow for employment of fewer and/or smaller pumps.

Although the improvement opportunities discussed in the following two sections all offer potential savings, maximizing benefits with limited resources requires well-planned activities based on accurate data inputs. Once the watergy efficiency team has developed a fundamental understanding of the operations of the water utility, it can prioritize and coordinate the most appropriate supply-side and demand-side efficiency improvements.

Case Study: Sydney Water
Use of Technology for Facility Assessment

Based in the largest city of Australia, Sydney Water provides drinking water and wastewater services to more than four million people. Being a major user of electricity, the company rigorously pursues cost-effective energy efficiency initiatives. It manages energy use through its IICATS telemetry and control system. The hydraulic system is continually and comprehensively monitored. This has enabled scheduling of water pumping stations to:

- Maximize off-peak operation
- Minimize costs stemming from the maximum demand component of electricity supply charges.

Monitoring has led the company to undertake energy audits of a number of operational facilities. Based on these audits, Sydney Water came up with quite a few interesting project recommendations. For example, aeration blowers are the major electricity consumers in inland sewage treatment plants. Additional dissolved oxygen probes were used for more accurate monitoring in the inlets and outlets of the aeration tanks. This allowed the blower to run at minimum speed for most of the day, saving energy and money. In six years (1994–2000), Sydney Water decreased electricity consumption per unit of service delivered by 14.6 percent for wastewater and 7 percent for water delivery.

Source: Sydney Water, "Environmental Impact of Using Energy" (Sydney, Australia: Annual Environment and Public Health Report 2000) at <www.sydneywater.com.au/html/Environment/enviro_index.htm>.

5. Supply-Side Improvement Opportunities

"Power's one of our three biggest expenses, along with chemicals and labor."
—Carl Stonoff, Water Plant Supervisor, Burlington, Iowa, United States

This section provides an overview of many of the common supply-side steps that water utilities can take to reduce the energy used for pumping water. Supply-side measures are designed to improve the efficiency of the water supply system, making each unit of water delivered less energy intensive.

It is important to remember that making individual improvements without examining the impact on the entire system can actually lead to significant inefficiencies and wasted capital. The order in which utilities pursue solutions for improvement is also important.

A watergy efficiency team or manager needs to prioritize opportunities with the highest savings potential and schedule activities in the correct chronological order to maximize energy efficiency benefits. For example, in many cases, leak reduction should take place prior to system redesign and installation of new equipment. Otherwise, the specification and size of equipment will be based on parameters that may change after the leaks are fixed. Prioritizing opportunities also includes coordinating supply-side measures with the demand-side activities discussed in the next section.

5.1 INTRODUCTION TO SUPPLY-SIDE ACTIVITIES

Major supply-side improvement opportunities lie in operations and maintenance practices, system redesign, and wastewater treatment processes. The task of the watergy efficiency team or manager is to identify and prioritize improvement opportunities. The planning process should recognize the impacts of improvements in one area on other parts of the system.

5.2 MAINTENANCE AND OPERATIONAL PRACTICES

Often the least expensive efficiency opportunities come from improvements in operations and maintenance practices. One such task that is critical for water utilities is reducing leaks and losses.

Valuable water and energy inputs are commonly wasted through system leaks, poorly maintained equipment, defective meters, unused machines left idling, and

Common problems include:

- Leaks
- Low c-value for pipes (high level of friction inside pipes)
- Improper system layout
- System overdesign
- Incorrect equipment selection
- Old, outdated equipment
- Poor maintenance
- Waste of usable water

Remedies may involve:

- System redesign and retrofitting of equipment
- Pump impeller reduction
- Leak and loss reductions
- Equipment upgrades
- Low-friction pipe
- Efficient pumps
- Adjustable speed drive motors
- Capacitors
- Transformers
- Maintenance and operation practices improvements
- Water reclamation and reuse

systems improperly operated. To alleviate these problems, a watergy management team can create a procedures manual outlining operating norms, maintenance schedules, oversight mechanisms and employee-training modules.

Beneficial practices in such a procedures manual might include:

- Guidance on managing the system to meet flow needs without excessive pressure
- Schedules for surveying equipment and piping for leaks
- Measures for replacing cracked water mains and fixing manholes
- Timetables for checking meter accuracy and cleaning equipment
- Advice for identifying and replacing inefficient equipment
- Regulations for switching off wastewater treatment equipment, motors, HVAC, and other equipment not in use
- Guidelines for using water storage and hours of operation to reduce peak system operation requirements.

For a water utility, reducing system water pressure has several positive impacts on system efficiency. Reduced water pressure can lead to decreases in leakage, stress on pipes and joints, and flow through the end user's open water fixtures. Pressure reduction also extends the life of equipment, decreases system deterioration, and diminishes the need for repairs. Small water-use customers with system pressures greater than 80 pounds per square inch (psi) or 5.62 kilogram-force per square centimeter (kgf/cm^2) should be considered candidates for water pressure reduction, as long as any reduction does not compromise the quality of service to the customer.[44]

Water systems that have multiple pressure zones often have higher energy costs due to the operation of booster pumping stations that increase water pressure. Adjustable speed drives (ASD) for pumps compensate for different flow and pressure conditions and offer one energy-saving solution. Pressure-reducing valves may also prove beneficial.

Groundwater and rainfall infiltration into the system causes pumps in lift stations to operate longer and may require larger pumps or multiple pumps to handle the higher flows. Replacing cracked mains and fixing manholes reduces inflow and infiltration problems, decreasing the energy used for pumps at lift stations and treatment plants.[45]

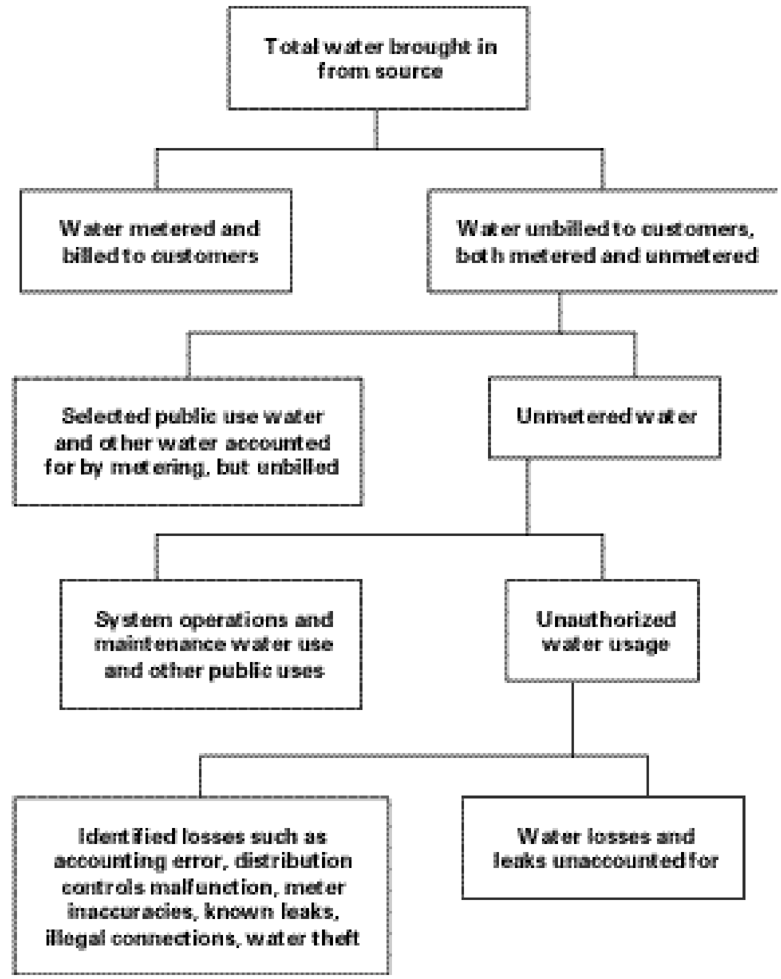
All meters, especially older meters, should be tested for accuracy on a regular basis. Meters should also be appropriately sized, as meters that are too large for a customer's level of use can underregister water use. Regular meter recalibration is also helpful to ensure accurate water accounting and billing.[46]

Leak and Loss Reduction

Reducing leaks and losses is a critical part of any water utility's watergy efficiency strategy. Although vast differences exist among water utilities in unaccounted-for water rates, no utility is immune to expensive, inefficient water leaks and losses.

In countries such as the United States and Israel, 85 percent or more of the water entering the system commonly reaches the end user. Austin, Texas, for example, boasts only 8 percent unaccounted-for water in its system, maintaining this rate through an aggressive leak reduction program. The figure for unaccounted-for water, however, goes as high as 50 percent in many other countries, such as Turkey and Egypt. A review of 54 developing

Figure 2: Water Accounting System[48]



country projects financed by the World Bank found the average water loss in water supply and treatment was 34 percent.[47] In many cases, significant losses are caused by poor system maintenance, especially where metering systems are weak or nonexistent. Reducing these losses will enhance the overall efficiency of the system.

In addition, water utilities with leakage problems are forced not only to pump more water than is actually needed, but also to increase system pressure to assure that the water reaches the consumer. Increasing pressure is usually less cost-effective than fixing the leaks and maintaining a lower pressure. Furthermore, higher system pressure actually exacerbates the leakage, wasting even more water and energy.

Water Accounting Systems

Implementing a system of water accounting is a valuable first step in controlling losses. Water accounting should ideally begin at the source and extend to end users to determine water losses. Figure 2, which maps the flow of water entering through the system, can provide a framework for water utilities in measuring unaccounted-for water.

By quantifying the known and unknown delivered water deficit, loss accounting can give the watergy efficiency management team an idea of how much leakage exists in the distribution system. Losses should be tracked monthly, especially in high-risk areas, to help identify new leaks, inaccurate meters, and illegal water diversions. A comparison of the amount of water leaving the system with that sold to customers will help quantify losses.

Even under good management conditions, unaccounted-for water normally constitutes 10–15 percent of the water produced; thus, if water loss is greater than 15–20 percent of water produced, corrective action is necessary.[49] It is important to stress that unaccounted-for water reduction programs need constant maintenance; leaks will reoccur if water utilities are not vigilant.

Leak Detection and Repair Strategy

A comprehensive leak detection and repair strategy allows the watergy efficiency management team to take advantage of the information gleaned from loss accounting by coupling it with specific action to reduce losses. This strategy may include regular on-site testing using computer-assisted leak detection equipment, a sonic leak-detection survey, or any other acceptable method for detecting leaks. Leak reduction can involve pipe inspection, equipment cleaning, and other maintenance efforts to improve the distribution system as it currently operates and prevent future leaks and ruptures from occurring.[50]

Seepage from canals is a common water loss problem for both rural and urban water systems. Both canal lining and piping can reduce seepage. Unlined canals often lose 30 to 50 percent of water, depending on the type of soil, but a well-operated and -lined system can keep losses to less than 10 percent. Using buried pipes rather than canals can similarly result in distribution efficiency improvement on the order of 30 percent.[51] This can also have a significant impact on water quality and reduce water theft.

Leak Detection Equipment

Although some leaks that occur are visible through general inspection of leak-prone areas, many leaks occur in pipes underground. Some of these leaks may be detected as water flows to the surface, but often leaks go undetected for long periods of time. Municipalities can employ a variety of flow measurement devices and can utilize sonic and acoustic leak detection equipment to pinpoint leaks. Although these devices require an initial investment of at least several thousand dollars, they quickly pay for themselves.

A sonic leak correlator measures the time it takes for the leak's sound to travel to sonic sensors on both sides of the leak

Case Study: Bulawayo, Zimbabwe, Leak Detection Program

Bulawayo is a city of approximately one million people in Southwest Zimbabwe. The City Council is responsible for providing water and sewerage services. Rainfall has historically been very erratic, leading to water shortages. Stringent rationing has, therefore, been in force for most of the past two decades. Water efficiency efforts in Bulawayo began in 1998 at the height of a serious drought. The city council approached the Norwegian Embassy for assistance in relieving pressure on water resources. A water management study for Bulawayo that had been funded by the British government in 1992 provided the basis for the city's actions.

Losses from the system were estimated to be on the order of 22 million liters per day (MLD), about 25 percent of the rationed and restricted supply. The city set a target of reducing this to 6–7.5 MLD. This will also have a significant impact on energy use, which currently accounts for about 50 percent of delivery costs.

Water loss reduction is the city's primary water management objective. A water management system was designed to assist the city in increasing its capacity for water loss control.

To begin with, the city established a Leak Detection Division in the Engineering Services Department. Significant work was also carried out to map the water and sewer utility using computer-assisted design, because previously available maps were inaccurate and out of date.

Calibration of a water network computer model is also being undertaken. For continuity and institutionalization of management efforts, the project managers document their actions, submit project policy documents, and construct procedure manuals.

The actual repair of leaks and breaks was identified as the main system management bottleneck. Efforts are currently under way to streamline the process of identifying leaks and breaks and having them repaired as soon as possible.

Operations and maintenance of the water distribution system is also a major area of focus to prevent leaks and improve efficiency. Ensuring allocation of more resources for operations and maintenance is a major responsibility of the project managers.

Additionally, in recognition of the need to measure bulk water flow and distribution, the city has been divided into about 50 metered zones. These will be equipped with management meters to be read monthly. Recorded flow will be compared with predicted average flow and billed consumption. Minimum night flow measurements will also be taken at least annually. The city plans to undertake a series of water supply audits at the city level in addition to the meter zone level. Pressures are also being controlled with more accuracy with the introduction of 20 or so new pressure zones to control static pressures within the range of 30–60 meters.

Sources: Jeff Broome, project coordinator of the Bulawayo Water Conservation and Sector Services Upgrading Project, February 2001.

in order to pinpoint accurately the leak's location. In order for the correlator to take accurate measurements, the user requires detailed information on the type, size, and layout of the pipe being measured.[52]

Flow-metering equipment can be used to help isolate leaks by determining how much water is entering a certain part of the water system and how much is being delivered to the end user. Taking a variety of measurements from different access points can further isolate leaks for repair. This is the method of choice in PVC or concrete pipe systems that do not carry sound well.

In one study funded by USAID in Galati, Romania, the consulting company Cadmus

Group discovered energy conservation measures that would cost about US$665,000, but save US$400,000 in electricity costs annually—a payback of 1.6 years. The measure with the quickest payback was leak detection. Because the parts to fix leaks are cheap (washers, seals, and so on), a leak detection and elimination program would rapidly pay for itself. With simple measures, US$13,000 per year savings were possible with only US$5,000 of investment.[53]

Leaks can occur in many different areas, but common leak-prone areas include:

- *Water distribution mains and pipelines*
- *Piping and equipment connections*
- *Valves*
- *Meters*
- *Corroded or damaged system areas*

5.3 SYSTEM REDESIGN

Municipal water utilities are often made up of complex, engineered infrastructure systems. The overall design of these systems is one of the most critical features in a water utility in terms of efficiency. This is one feature that most operators or managers unfortunately have little noticeable control over, unless in the midst of a system upgrade. Redesigning the entire system or just improving the design of specific areas can lead to major savings opportunities.

In the area of pump-system design, for example, The Confederation of Indian Industry recommends a systems approach to determine potential efficiency opportunities. Based on its experience, the confederation estimates that energy savings of up to 25 percent are possible by following the systematic methodology summarized in these six questions:

1. Is the pump really required?
2. Is the pump correctly designed?
3. Is the pump really efficient?
4. Are the heads matched? (pump heads with system heads)
5. Is a variable speed drive installed to match varying capacities?
6. Are controls efficient?[54]

These questions, although designed specifically in reference to pumps, raise interesting concerns valid for the entire water system.

Is the System Really Required?

Examining the question of whether a system is really needed or not can potentially lead to the largest saving opportunities. Does the system really require all of its present pumps, valves, bypass lines, and so on, or can it be redesigned to make better use of gravity and reduce frictional losses? For instance, many municipal water authorities have been able to remove pumps by taking greater advantage of gravity or by making better use of other existing pumps.

Is the System Correctly Designed?

Once it is determined that a system is actually necessary, a watergy efficiency team needs to determine if the system is designed correctly. For example, system designers often intentionally oversize equipment to ensure the equipment meets maximum system requirements. In some cases, the excess margins are as high as 50 percent. Besides being inefficient, operational problems of overdesign can include excess flow noise, pipe vibrations, and poor performance. Overdesign can also result in unnecessarily large costs for materials, installation, and operation.

Corrections to overdesign of pumping systems include:

- Installing a correctly sized pump
- Installing an adjustable speed drive (ASD) motor
- Reducing impellers
- Adding a smaller pump to reduce intermittent operation.[55]

Is the Equipment Efficient?

Upgrading to newer, higher efficiency equipment will likely improve system performance if correctly sized and integrated into the entire water system. Equipment likely to produce the most savings include:

- Energy-efficient motors
- Adjustable speed drives
- Impellers
- Lower friction pipes and coatings
- Valves
- Capacitors.

Efficient Motors

Choosing a pump motor with a higher operating efficiency will add to the overall efficiency of the pumping system. In addition, to function efficiently, the motor must be selected to work correctly with the pump, that is, to match various requirements of the pump, such as start-up time, numbers of stops and starts, pump speed, and required torque.[56]

Adjustable Speed Drives

To match varying load requirements, one of the best available options to improving efficiency is to install an ASD motor. As the name implies, ASDs make pump speed adjustments to meet the particular requirements of a given system at a given time. One popular type of ASD is the variable frequency drive (VFD), which uses electronic controls to regulate motor speed. By slowing an oversized pump, a VFD reduces energy losses in pump operation. In addition to pumps, ASDs can reduce water treatment costs in aerated grit chamber blowers. ASDs work best in systems with large frictional head. They may, in fact, prove less efficient than other options in systems with large static head.[57]

Impellers

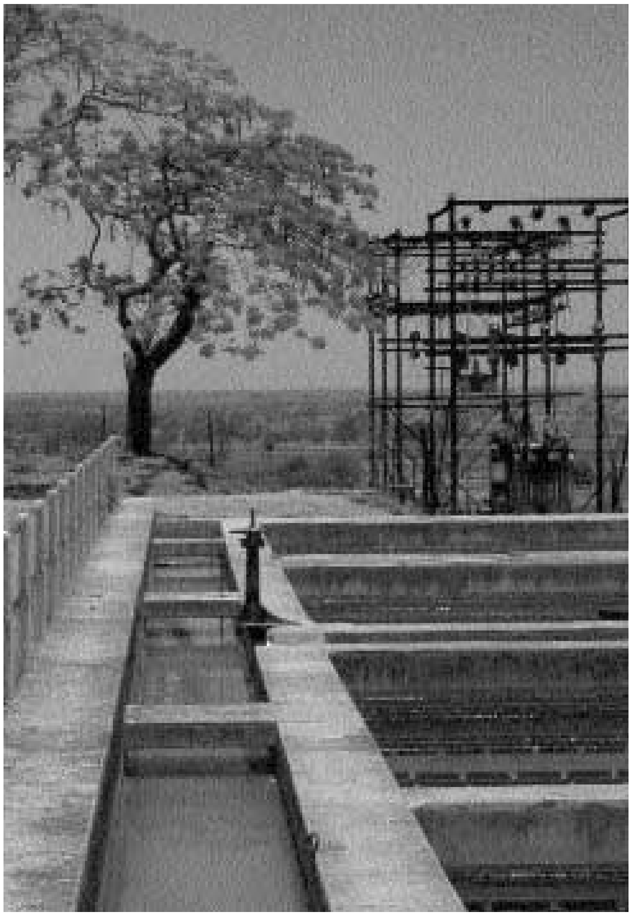
Another alternative to improve efficiency is installing a smaller impeller or trimming the impeller in the existing pump. An impeller is the spinning component in a centrifugal-type pump that pushes fluid through the system. Similar to the VFD motor, a smaller or trimmed impeller decreases the speed of the fluid to reduce energy losses. Because trimming the impeller reduces flow, frictional losses from bypass lines and throttle valves are reduced.[58]

Lower Friction Pipe and Coatings

Pipes made of smooth material, such as polyvinyl chloride, when compared with traditional cast iron pipes, can reduce friction losses. Lower friction pipes can increase energy savings by 6 to 8 percent. Applying certain resin and polymer coatings to the insides of a pump can achieve another 1 to 3 percent improvement. Coatings can also reduce erosion and corrosion in pipes and pumps.[59]

Valves

Valves play a critical role in any water system by controlling flow and pressure. There are numerous types of valves for different functions. In choosing the proper valve for a specific purpose, however, the impact of the valve on system efficiency



should be considered. Some valves add more friction to the system than others. For example, throttle valves are more efficient than bypass valves. This is the case, because, as a throttle valve is closed, it is still able to maintain an upstream pressure that can assist in moving water through parallel parts of the system. The energy used to pump water that is bypassed in a system using a bypass valve is wasted. As the main option to control flow and pressure, water utilities may find it more efficient to use ASDs instead of valves.[60]

Capacitors

Installing capacitors can reduce the energy required to run certain equipment. Capacitors are devices that store electrical energy and are used to correct low power factors. Certain electrical equipment, such as transformers, motors, and high intensity lighting, create magnetic fields in their operation that cause low power factors. Often this equipment represents a major portion of the electricity used at a facility. Besides wasting energy, a low power factor can cause premature equipment failure. Additionally, electric utilities often levy penalty fees for low power factors, so use of capacitors may avoid unnecessary expenses.[61] The Ahmedabad Municipal Corporation in India found significant benefits in terms of cost savings and equipment performance by installing capacitors on some of its major pumps.

Is the Equipment Matched to the Task?

Even if equipment is deemed efficient, the system's efficiency will suffer if it is not appropriately matched to the task. This means that pumps need to correspond to the system's requirements, impellers need to be sized to create desired flow rates, and VFDs must be installed in areas with high frictional head to be effective.

Cost-effectively matching water pressure and flow-rate requirements with, for example, pump and motor characteristics is one of the most critical efficiency steps in system design.[62] Pumps will more often work at their best efficiency point if a water utility is able to analyze water system requirements accurately and match them with the appropriate pumps using pump performance curves. Software packages, such as the U.S. Department of Energy's Pumping System Assessment Tool, are designed to help users assess the efficiency of a pumping system's design.

Pune, India, provides an example of equipment not being matched to a task. On reviewing several recent system upgrades, Pune's newly formed water utility efficiency team determined that a number of expensive pumps added to a water intake station were not properly designed to work in tandem with the existing pumps. Even though these new pumps were operating 24 hours every day, they were, in fact, not moving any water through the pipeline. Simply by turning them off, the Pune Municipal Corporation saved US$35,000 annually with no reduction in water delivered.

Is the Equipment Flexible to Changing System Demands?

System demands are not static. Even though water systems are designed to meet the requirements of peak usage, they do not operate at their peak load for a majority of the time. A watergy efficiency team needs to determine how to optimize efficiency across the entire load cycle. Using gravity storage, multiple pump arrangements, small pumps for off-peak use, and ASDs, systems can be designed to reduce or eliminate efficiency losses from changing system demands.

In the case of Kolhapur, India, for example, an assessment was carried out with support from USAID to maximize the efficiency of the current pumping system by improving the division load requirements among eight pumps. It was determined that the utility could annually save more than 2 million kWh and 8 million rupees (US$180,000) by simply matching the most efficient pump combinations to the required load.[63]

Are Controls Efficient?

Computerized control systems can help reduce energy use by monitoring pump efficiencies, managing pump operation, shifting loads to off-peak times, and controlling VFDs for pumps.[64] For example, programmable logic controls applied to electrically controlled equipment such as VFDs for pumps can help minimize equipment-operating time. They also allow utilities to take advantage of lower electricity prices if the electrical utility charges different prices per kilowatt-hour in the course of the day.

Another type of control is the proportional, integral, and derivative (PID) control. PIDs can be used to moderate wastewater flows rather than allow wastewater to surge and then stop. Not only is this less energy intensive, but also can avoid offensive sewage odor. The Moulton Niguel Water District and the Madera Valley Water Company are two water utilities based in California that have significantly cut operating costs by using PID controls.

5.4 MUNICIPAL WASTEWATER TREATMENT–SPECIFIC PROCESSES

Implementing energy efficiency measures in wastewater treatment plants is important, as wastewater treatment often accounts for 25 to 50 percent of a plant's operating budget. Some processes consume more energy than others and should receive more concentrated attention. For example, in an activated sludge treatment plant, the biological phase accounts for 30–80 percent of a facility's power costs.[65]

Groundwater and rainfall infiltration into the collection system is another important consideration, as this infiltration increases the flow and load in the wastewater treatment plants, overloading equipment and pumps. Use of appropriate pipes and joints, such as PVC pipes in sewers, decreases infiltration, and use of an appropriate bypass at the plant entrance diverts excess flow from the pump station.

Preliminary and Primary Treatment

Preliminary treatment of domestic sewage physically removes solids through processes such as screening, influent pumping, and grit removal. In primary treatment, solids and floating materials are removed in settling tanks.

Although most primary treatment processes are not energy intensive, opportunities to increase efficiency still exist. For example, debris in wastewater is sometimes ground up into finer particles with comminutors as an alternative to using screens to remove the debris from the water. By using comminutors, more energy is later required in the secondary treatment stage to remove this material. A preferred alternative is removal of the debris using a screen.[66]

Secondary treatment is much more energy-intensive than primary treatment, so efficiency improvements can present sizable cost savings.

For further reduction of operating costs in primary treatment:

- Remove as much debris from the water as possible in the primary stage to avoid increased secondary treatment operating costs.
- Reduce water in the processed sludge, because lower water content can reduce pumping needs and disposal costs.
- Use variable speed drives with aerated grit chamber blowers.

Secondary Treatment

Secondary wastewater treatment includes biological water purification. These biological processes are either a suspended-growth biological type, such as activated sludge, or an attached-growth type, such as trickling filters or biological contactors. The latter, usually applicable in medium-sized plant operations, is less energy consuming than activated sludge. The energy costs associated with each of these options will obviously be a deciding factor on the ultimate selection of an option.

Secondary treatment is much more energy intensive than primary treatment, so efficiency improvements can present sizable cost savings. For example, aeration devices, such as nozzles, diffusers, or mechanical agitators, which provide oxygen for microorganisms and mix wastewater sludge, use large amounts of energy.

The choice of agitation devices should be considered carefully. Fine bubble diffusers have a tendency to be more energy efficient than coarse bubble diffusers, because smaller bubbles result in greater oxygen transfer. Conversion from coarse-bubble diffusers or agitators to a fine-bubble system should lower energy costs for sewage aeration by at least 25 percent. Fine bubble diffusers, however, may require more maintenance than coarse-bubble diffusers to keep them clean and operating at optimal efficiency. For a particular facility, the type and makeup of the wastewater will dictate the best choice.[67]

There are other actions that can be taken to improve secondary treatment efficiency:

- *Install aeration control systems.* These systems optimize water treatment performance by controlling and adjusting the amount of air put into wastewater basins.
- *Investigate an oxidation ditch,* if the facility operates a lagoon system. Oxidation ditch systems are considered efficient and easy to operate. They also create no noise or odor problems, if operated properly. For lagoon systems, in contrast with tanks, care must also be taken not to pollute aquifers, lakes, or rivers.
- *Optimize water flow,* if the facility has trickling filters that require wastewater to be recirculated over the filter. Wastewater recirculation can be reduced when a facility's wastewater load is lower, such as at night; however, flow rates must be adequate to maintain bacteria growth.
- *Reduce water in secondary sludge* to minimize pumping and disposal costs.[68]
- If extended-aeration activated sludge is considered, *evaluate the conventional activated sludge option as well,* because extended aeration requires aeration tanks four to six times greater than the conventional system, consuming four to six times more energy.
- If land is available and a pond system is an option, it is important to note that anaerobic and facultative ponds do not consume energy, whereas aerated ponds require around 3–6 kWh/m^3.[69]

After primary and secondary treatment, the solids removed from the water or sludge generally require further processing, offering additional opportunities for efficiency improvements. Several methods of sludge treatment are options, such as dewatering, digestion, stabilization, air drying and incineration, and thickening. In sludge dewatering, different systems, such as filter presses, centrifuges, and vacuum filters, have varying energy and maintenance costs; the facility needs to assess the benefits and trade-offs that exist among the costs for energy, operations and maintenance, and disposal. Incineration, another processing choice, can reduce the sludge disposal volume considerably; however, air pollution controls should be adopted if incineration is selected to avoid degradation of water resources that can result from deposition of airborne pollutants into surface groundwater.

Disinfection Options

Any water that undergoes primary and secondary treatment must be disinfected to protect public health. The three major disinfection processes for wastewater are chlorination, ozonation, and ultraviolet (UV) irradiation.

Many municipal water and wastewater treatment systems globally use the chlorination disinfection method. Although a common option, it should be noted that the Organochlorine chemicals that accompany this disinfection process can cause public health problems, jeopardize aquatic life, and reside in the environment for extended periods of time. Given the interest in balancing the environmental impacts of chlorination with the ongoing need for effective disinfection, many water utilities have begun to turn to other disinfection options.

Ozonation and UV radiation are two additional disinfection options that do not result in deposition of any residual chemicals to treated water. Ozonation treatment systems have been employed in water treatment operations since the early 1900s. Only in the 1970s did design engineers in the United States begin to look at using ozone as an alternative to chlorine for wastewater disinfection. Ozone disinfection systems produce ozone by creating a corona discharge, similar to lightening during electrical storms.[70] The ozone is then mixed with water or wastewater to achieve the desired disinfection.

In the UV radiation process, UV rays act to disinfect wastewater by inactivating the pathogenic organisms through induced photochemical changes within the organism's cells. UV disinfection functions differently from chlorination and ozonation, in that, during the UV process, pathogens are not destroyed, but instead lose their ability to replicate. In a UV wastewater disinfection system, the natural action of UV disinfection is sped up through the intense concentration of UV rays.

UV systems are typically less costly to build and operate when compared with ozonation. Both UV and ozonation O&M and power costs depend on water quality, but final comparisons generally favor UV disinfection.[71] In the U.S. context, UV also tends to be less expensive compared with the costs of running a chlorination system. This is largely due to the hazards associated with handling the chlorine feedstock and the costs of insuring against possible accidents at the facility. The Electric Power Research Institute expects UV to become more accepted, as wastewater facilities grapple with the environmental concerns associated with chlorination.[72]

Producing Energy from Wastewater

Not only are multiple energy-cost reductions possible in the wastewater treatment process, but utilities may also be able to produce energy at some facilities using existing processes. The anaerobic digestion option for sludge processing, for example, produces methane that can be burned as a fuel source. Capturing digester gas can produce both heat and electricity through cogeneration. In addition, installing a turbine to generate electricity on the effluent outfall can generate hydropower in select facilities. Plants with a 57-million-liter (15-million-gallon) per day flow and a vertical drop of 15 ft could be candidates

Case Study: Des Moines, Iowa, United States Methane Generation at Central Iowa Plant Turns Trash to Treasure

At the Integrated Community Area Regional Wastewater Treatment Plant serving central Iowa, operators are turning trash into treasure with an anaerobic digester system. Anaerobic digestion is a biological process in which microorganisms feed on organic matter, converting it to methane gas and carbon dioxide. The anaerobic digesters in Des Moines produce an average of 26,200 ft^3 per hour of methane gas. The gas fuels three 600 kW engines.

In a wastewater treatment facility, sludge provides the organic matter. Thickened biological sludge, which is bacteria used to treat wastewater, is blended with primary sludge and pumped into an anaerobic digester. This digestion process works without oxygen. One type of bacteria converts the organic material to organic acids. A second type of bacteria consumes the organic acids and produces methane. The methane gas is collected, stored, and burned in diesel generators, producing electricity for use at the regional facility. Heat from the combustion of the gas is not wasted; it is used to heat the sludge entering the digesters as well as to heat buildings. The digested sludge is dewatered and belt pressed to produce cake that is applied to land as fertilizer.

Source: IAMU 1998.

for effluent hydropower, generating about 24 kW of power.[73]

Water Reclamation and Reuse

"Gray water"—treated wastewater from a utility plant that is not quite potable—has a variety of applications. These include recharging groundwater aquifers, supplying industrial processes, irrigating certain crops and possibly even augmenting potable supplies. Although reclamation of gray water may not change the amount of water used by the customer, it does save energy and reduces treatment costs for that use of the water.

Pure water is very often used in applications in which lower-grade water could be just as effective. In Namibia, since 1968, residents have even used treated wastewater to supplement up to 30 percent of the city's potable water supply. Seventy percent of Israeli municipal wastewater is treated and reused, mainly for agricultural irrigation of nonfood crops. In addition, extensive agricultural areas surrounding Mexico City (Mexico), Melbourne (Australia), Santiago (Chile), and multiple Chinese cities are similarly irrigated with wastewater.[74] And, as of the mid-1990s in California, more than 606 billion liters (160 billion gal) of reclaimed water are annually used for irrigation and groundwater recharge and in industrial processes.[75]

It is important to note that reused water must meet water quality standards to avoid public health problems and prevent surface water pollution. Many countries have their own water quality criteria and standards, based on either effluent standards or water quality–limited bodies of water. For agricultural water reuse or for irrigation purposes, the World Health Organization has established specific guidelines defining acceptable microbiological limits for reclaimed water.[76]

The city of Austin, Texas recently put out a municipal bond issue to install a water pipeline for the city center, solely for reclaimed water. This new pipeline will provide end users with a cheaper source of water for lawns and gardens and other functions that do not require potable water. Austin plans to recoup its investment quickly by spending significantly less on delivering potable water from freshwater sources and greatly reducing demands on the entire system.

Case Study: Beijing, China, Industrial Water Reclamation

Industries in Beijing have historically reclaimed water for a variety of processes. From 1978 to 1984, the percentage of reused industrial water rose from 46 to 72 percent. Manufacturing sectors, such as metal refining, metal products, and chemicals, had higher than 80 percent reuse; power generation, coal mining, and textile manufacturing were other key reuse sectors. Because of the water savings, even though industrial output increased 80 percent during this timeframe, water consumption actually declined slightly. The experience of Beijing's industry shows that water recycling can be less expensive than transporting water over long distances.

Sources: Xie, Kuffner, and LeMoigne 1993, p. 25.

5.5 PROJECT IMPLEMENTATION

After developing a sizable list of potential efficiency opportunities, a water utility must make well-informed decisions on which opportunities to implement and how to make the projects happen. Cost along with several other factors will play a significant role in determining what really gets done.

A watergy efficiency management team must now play the role of salesperson in trying to convince a funding source to provide resources to implement projects. The team must prepare itself with critical information that will make the project more attractive to potential funders. To this end, it may be useful for the watergy management team to solicit input from key financial personnel.

To get approval, a project proposal will likely need to address the following key issues:

- Equipment sizing and specification
- Impact of projects on other parts of the system
- Planning for growth
- Maintenance scheduling and accounting for depreciation
- Prioritization in accordance with:
  - — Company financial and maintenance resources
  - — Available financing
  - — Project return on investment
  - — Overall capital investment needed
  - — System technical constraints.

Doing the Financial Analysis

Many water companies may be limited in the amount of resources they can devote to improvement projects; thus, after identifying improvements, the company should prioritize projects and implement options for which it has the required resources. Measurements and monitoring not only provide data for technical analysis, but also yield figures for an economic analysis. To allow the project financial decision makers to assess projects, the expected cost and savings for the project must be quantified.

Furthermore, identifying project costs and savings allows for the calculation of payback, return on investment, or whatever financial metric the company uses to assess projects. As with many private sector financial decisions, various inflation adjustments may be made to identify results more accurately.

Project implementation will also depend on the ability of the facility to make any operating changes needed for equipment installation. Not only does new equipment often need to be fitted correctly to work with existing systems, operators also need substantial training to make the equipment work.

Should You Start with Pilot Projects?

To reduce risk and develop the appropriate capacity to implement projects on a large scale, many municipal utilities test ideas and potential actions on a small "pilot" level, before they commit to a large investment. On the downside, pilot projects, due to their size, cannot deliver the immediate savings that larger projects might offer. Pilot projects nonetheless provide advantages such as:

- Verifying technology and savings
- Identifying unforeseen technical or logistical problems
- Gauging public acceptance.

How Sure Are the Savings?

Even though the best engineers can never be 100 percent sure of the potential calculated savings for a given project, a few practical rules exist for improving the long-term success of a watergy efficiency management program:

- Start small and build a track record of success.

- Be conservative with estimates; if a technology promises 10–15 percent savings, assume 10 percent.
- Check with peers to verify technology and results of similar projects.

Project Funding

To fund a project, water utilities may have to investigate a broad array of internal and external funding options. Many municipalities have experience borrowing money and may choose to address water efficiency opportunities by approaching lending institutions directly or issuing municipal bonds. Several innovative approaches, however, have been developed to provide greater flexibility to water utilities to finance efficiency projects.

One internal funding mechanism that can help provide support for new efficiency projects involves returning a portion of efficiency project savings into an account to be used exclusively for more efficiency activities. After managers have shown some initial success in reducing operating costs through efficiency, they can utilize previous project savings to pay for additional activities.

Another alternative designed to streamline funding for efficiency projects (see Fairfield, Ohio text box) is setting a payback threshold. Because efficiency projects often pay for themselves through savings, utilities can automatically fund projects that pay for themselves within a certain amount of time. Utilities generally set a maximum investment amount along with the threshold. Payback thresholds allow efficiency projects to be initiated without waiting for decisions from higher management.

Case Study: City of Fairfield, Ohio, United States
Technical Upgrades at a Small Facility

In 1986 the Fairfield Wastewater Treatment Facility got a new superintendent with a private business background. In an attempt to be proactive and innovative in reducing operating costs, he decided to investigate peak electrical demand and a costly power factor penalty. In the process of pinpointing viable options for improvements, the superintendent targeted several areas for enhancement.

He first convinced the utility to move to an automated data collection system and update their process equipment.

Fairfield Wastewater also adopted a 3–5 year payback threshold for project investments. As a policy, if a project falls within this range it is easily financed and if the overall costs are less than $15,000, it is automatically authorized. This policy gives project managers more flexibility to work within a budget, with less micromanagement from company executives.

To create cross-fertilization opportunities between employees and departments, Fairfield holds weekly operations team meetings at which employees can discuss new technology and energy efficiency ideas.

As one of their first projects, facility engineers carried out individual equipment tests (for example, on motors 10 HP and up) to measure their efficiency. Now, they use those data trends to monitor if operating equipment falls within a reasonable band of operation. If there is any discrepancy, they carry out further investigations. Fairfield has also created a system to document and validate the savings from energy efficiency measures.

Fairfield has also used load shifting and real-time pricing to achieve up to a 21–22 percent reduction in energy costs. When electricity prices peak, the facility can opt to use its automated system to shut down for 3–4 hours. Fairfield managers have compared their operations with those of other managers in Ohio, and estimate that most other facilities have wastewater costs that are twice as high.

Source: Drew Young, Fairfield Wastewater Treatment Facility, February 2001.

If an important project does not meet this threshold, managers can opt to bundle several smaller projects together into a larger project. For example, a pipe-relining project may have a payback of 6 years and not meet the threshold of implementation alone. By including the lining project with an energy-efficient pump and a variable frequency drive project with a much shorter payback, the combined project may meet the payback threshold required to receive funding.

Financing through Energy Service Contracts

If the municipality lacks the needed financial resources and/or technical capacity to implement a project, a range of financing arrangements may be possible through energy service companies (ESCOs). Energy service contracts take many forms, but the basic concept entails agreement by an outside entity to take on part or all of the risk in implementing an efficiency project by investing some combination of money, equipment, and know-how into the customer's facility. The customer then pays the investment back along with some preset profit from the savings resulting from the project. In most cases the outside entity only makes its money back if the savings actually occur.

Each municipal water company will need to investigate the potential and applicability of ESCOs in their own particular circumstances. The following is a list of some of the organizations working to expand the reach of ESCOs around the world. These organizations can also be valuable resources to help educate interested municipalities on ESCOs and link them to potential ESCO partners.

- **Brazil:** Association of Brazilian ESCOs (ABESCO) (<www.abesco.com.br>)
- **Canada:** Canadian Association of Energy Service Companies (CAESCO) (<www.ardron.com/caesco/>)
- **Egypt:** Egyptian Energy Service Business Association (EESBA) (<www.eesba.org/>)
- **India:** Council of Energy Efficiency Companies (CEEC) (<www.ase.org/ceeci/index.htm>)
- **Japan:** Japanese Association of Energy Service Companies (JAESCO) (<www.jaesco.gr.jp/>)
- **Korea:** Korean Association of ESCOs (KORESCO) (<www.energycenter.co.kr/>)
- **United Kingdom:** Energy Systems Trade Association (ESTA) (<www.esta.org.uk/>)
- **United States:** National Association of ESCOs (NAESCO), which has conducted trade missions to Mexico, Japan, Thailand, Australia, Brazil, and the Philippines (<www.naesco.org>)[77]

Equipment Leasing

Leasing equipment, such as capacitors, VSDs, and energy-efficient motors and pumps, is an additional mechanism available to municipal water utilities to address energy efficiency opportunities. Municipal water utilities that lack funding or access to credit or are interested in testing technologies before making large purchases may be especially interested in leasing energy-efficient equipment.

Through leasing, municipalities can determine in a real working environment if a vendor's product performance claims are accurate without making long-term financial commitments. In addition, municipal water utilities can eliminate the risk of purchasing faulty equipment. Municipalities having trouble raising capital or securing a loan to purchase equipment may find vendors still interested in leasing equipment, because of the relative ease in reposing leased equipment.

In many cases, the municipality can even pay for the cost of the lease through energy savings. One study done by the Ahmedabad Municipal Corporation in India concerning the potential of leasing 89 capacitors for water pumps found that even with the most conservative estimates, energy savings from the capacitors would cover the lease costs.[78]

Leasing is not always the best option. The same study in Ahmedabad mentioned above showed a simple payback of between 1.5 to 3 years for purchasing the capacitors, which could be even more financially attractive for the municipality.

Technology and Vendor Selection

Once a project has been selected and financed, the choice of technology and vendor must be made. It is important to remember that vendors often make an array of claims on the performance of their product. After installation, however, product performance in the facility commonly can vary from the vendor's claim. To mitigate project risks and make the best investment:

- Contact peers who have implemented similar projects to gain their advice about technology and vendors
- Talk to peers about product benefits and drawbacks
- Contact other clients of the vendor
- Check with local NGOs or trade associations where available
- Ask the vendor for performance guarantees and a warranty.

6. Demand-Side Improvement Opportunities

"Water is precious and scarce. If we all work together in the spirit of '*izandla ziyagezana*' ('one hand washes the other') to pay for water and use it wisely, we can all contribute to the task of managing water for the future... The undertaking of a Water Demand Management Programme to save water through the efficient use of water is not a luxury but an absolute necessity."

—*Water Wiser Program, Johannesburg, South Africa*

6.1 INTRODUCTION

Reducing the amount of water consumed, while maintaining the level of benefit to the customer can greatly reduce both the consumer's and utility's cost. Water utilities can save money, because reducing demand effectively creates more system capacity. By decreasing demand, a water utility can help avoid investments in new facilities and equipment. In addition, reducing the amount of water flowing through a system will likely reduce frictional energy losses, thereby reducing the cost of pumping. The consumer benefits from demand reduction through the reduced cost of delivery, the diminished chance of water shortfalls, and the decreased likelihood of major investment expenditures. Although some utilities are wary of demand-side programs that may affect revenue, in most cases, both the short- and long-term savings from demand-side programs far outweigh costs.

This section describes several cost-effective methods and technologies that can be helpful in reducing municipal demand on both water and energy resources. The cost-effectiveness of many of these methods and technologies in practice, however, requires accurate pricing of water to consumers to convey the true cost of the water supplied by water treatment and delivery systems.

In addition to proper pricing, other factors that determine the applicability of certain demand-side measures to water utilities include the market penetration of water-using appliances, the types of industries linked to the system, and the technologies available for the domestic market.

In Australia, for example, Sydney Water's Mt. Victoria treatment plant was operating at close to capacity, so the utility conducted a least-cost capacity upgrading study. The study found that the most cost-effective option to increasing capacity combined several demand management programs that would significantly reduce water consumption, wastewater discharges, and nutrient loading. By turning to demand-side actions, the utility could defer and reduce the costs of expanding the treatment plant.[79]

A "Win-Win" for Utilities and Customers

The goal of demand-side management is to provide the customer the same or greater benefit using less water. In most cases, a water customer derives no additional value from using water inefficiently.

For example, a consumer flushing a toilet does not get any added benefit from a toilet that wastes water.

Water use can be reduced through relatively simple customer actions, such as turning off the faucet while brushing teeth or using nontoxic wastewater to water plants. In addition, such water-saving devices as horizontal axis washing machines, low-flow showerheads, faucet aerators, and ultralow flush toilets can reduce consumption. Ensuring each water customer uses water efficiently will help optimize the performance of the entire utility's system. It may also defer or eliminate the need for spending large amounts of capital for added capacity.

Reducing the amount of water consumed, while maintaining the level of benefit to the customer can greatly reduce both the consumer's and the utility's cost.

The City of Toronto , for example, has been actively pursuing demand-side management activities. The city has invested in programs such as ultralow flush toilet incentives, industrial water capacity buy-back, and horizontal axis washing machine promotion, with the goal of reducing peak water demand by 15 percent. Toronto estimates that its demand-side reduction efforts will cost about one-third as much as creating an equal amount of new capacity. In addition, thousands of dollars in savings have accrued to end users using less water.

Mexico City offers another example of how reducing demand can increase capacity. Because of the difficulty of finding new water sources for a burgeoning and increasingly middle class population, city officials launched a water conservation program that involved replacing 350,000 old toilets. These replacements have already saved enough water to supply 250,000 additional residents.[80]

Cobenefits

The impacts of demand-side measures can actually be much greater when organized in conjunction with supply-side actions. For example, by coordinating a major demand-side program with the purchase of new energy-efficient pumps, the water utility will not only save energy from the reduction of water moving through the system, but can also buy smaller, less expensive pumps to meet the reduced pumping demand. In many cases, demand reduction should precede system upgrades to help determine what the real baseline water demand is on the system.

One of the most appealing aspects of demand-side management activities compared with investing major capital improvements is the ability of the water utility to develop, expand, or reduce a given demand-side program quickly to meet current conditions. Demand-side programs can have a major impact within a year, whereas major capital development projects must be made years in advance and are hard to alter to meet changing circumstances.

The City of Toronto cited flexibility as one of the critical benefits to its demand-side project. With many uncertainties surrounding future demand, Toronto was much more comfortable making smaller and incremental investments in demand-side management instead of making a 5- or 6-year investment for new capacity.

Another cobenefit of decreasing water use is the reduced demands on rivers, lakes, and groundwater resources. This is especially important considering the number of major lakes and waterways that are disappearing and aquifers that are declining due to overuse of water resources.

For example, the largest natural lake in northern China, Lake Baiyangdian in the Hebei province is likely to dry out completely due to a combination of overdrafting and diminished rainfall. This will likely have a major negative effect on the populace and stability of the region.[81]

An example of the overuse of groundwater can be found in Ahmedabad, India, where overextraction has caused the city's water table to drop an average of 7 ft per year in the past 20 years. Not only does this put the future of the regional aquifer in jeopardy, but it also forces consumers who rely on groundwater to pay more to get it. The local power company estimates that it requires an additional 0.04723 watts per gallon to pump water to the surface with every 7 ft drop in the water table. This translates into an additional 1 million kWh per year to bring the same amount of water to the surface at an added annual cost of more than US$60,000.[82]

6.2 DEMAND-SIDE TECHNOLOGIES: RESIDENTIAL AND COMMERCIAL

A multitude of residential and commercial technologies exist that can help achieve significant water savings and reduce costs. Some of these measures may actually save the consumer additional money by reducing energy expended to heat greater quantities of hot water.

One example of the enormous water savings potential of these technologies can be found in a March 2000 USAID study on the opportunity for water efficiency improvements in the hotel industry in Barbados. The study found that hotels that aggressively use water-saving technologies, such as low-flow toilets, faucet aerators, and drip irrigation, consume as little as one-fifth of the water per guest as similar hotels with less aggressive water efficiency actions; guests at the more water-efficient hotels noticed no reduction in service. In addition, the study estimated that the least-efficient hotel surveyed could achieve more than US$250,000 in savings per year in water bills alone if it emulated the most efficient hotel.[83]

A water utility demand-side program may promote one or more of several available efficiency technologies.

Case Study: Tampa, Florida, United States Comprehensive Approach

Since 1989 Tampa's water efficiency program has promoted revised rate structures, retrofits, xeriscaping, and consumer education. Within the first 9 months, water consumption fell from 320.2 million liters to 274.4 million liters (84.6 million to 72.5 million gal). During the dry months of March through June, a 15–18 percent reduction in demand was achieved. The average reduction for the year was 7 percent.

In addition, Tampa has adopted an increasing block-rate structure, irrigation restrictions, landscape codes, and ultralow-volume plumbing requirements. Voluntary xeriscape programs advocate corporate landscape conversions and state-of-the-art irrigation and design for new construction.

In December 1989 water-saving kits were delivered to about 10,000 Tampa homes. Each kit included two toilet tank dams, two low-flow showerheads, two lavatory faucet aerators, some Teflon tape to seal connections, a pamphlet on finding and fixing leaks with a general "water-saving tips" card, an installation instruction folder, a window display card, and leak detection dye tablets. The kit came with instructions in both Spanish and English and included a letter from the mayor encouraging participation. This effort resulted in more than 94 percent of the recipients installing the devices and a savings of 7–10 gal of water per person, per day. Tampa estimates similar retrofitting of all the homes in Tampa will realize savings of more than 2.1 million gal of water per day.

Additional efforts in Tampa include school water conservation poster and limerick contests, an expanded retrofit program, toilet-replacement incentive projects including a rebate program, implementation of water checkups for large residential water users, and enhanced in-school curriculum-based education.

Source: Rocky Mountain Institute, Water Efficiency: A Resource for Utility Managers, Community Planners, and Other Decision Makers, (Snowmass, CO: Rocky Mountain Institute, The Water Program, 1991).

Common Water-Saving Technologies

Several technologies are available to save water:

Ultralow Flow Toilets

In the past, typical toilets have used between 19 and 26 liters (5–7 gal) per flush. Ultralow flush toilets can do the same job using as little as 3 liters (0.8 gal) per flush. Consideration should be given to the model(s) of toilet selected for any ultralow flow toilet programs, given a wide discrepancy in performance.

Toilet Dams or Other Water Displacement Devices

Toilet dams are devices that block part of the tank so that less water is required to fill the toilet following each flush. Other water displacement devices simply reduce the amount of space in a toilet's holding tank so that each flush uses less water. A plastic bottle filled with water does a good job in limiting the tank's capacity. Some problems may occur with the need to double flush, but water savings from these devices are estimated at about 10 percent.

Low-Flow Showerheads

Typical showerheads use about 17 to 30 liters (4.5–8 gal) per minute. Low-flow showerheads use less than 9.5 liters (2.5 gal) per minute with no marked reduction in quality or service. These devices save both water and reduce water heating bills.

Efficient Faucet Aerators

These devices can easily be installed on the ends of most faucet systems to replace existing aerators. Even though these devices allow less water to flow through the faucet, most consumers will not notice a difference, except in the reduction in their water and water heating bills. These devices can save between 12 and 65 liters (3.2–17.2 gal) per day.

Efficient Clothes Washers

Water- and energy-efficient clothes washers can save tremendous amounts of energy and water. Front-loading clothes washers use up to 40 percent less water than their top-loading peers.

Tables 6 and 7, taken from the American Water Works Association's *Water Conservation Guidebook*, highlight the saving potential of some of these technologies in both new homes and existing home retrofits.[84]

Xeriscaping

Planting native plant species that are able to survive under local rain and climate conditions can save large amounts of irrigation water.

Drip Irrigation

Using an underground drip irrigation watering system that tightly controls the amounts of water delivered to specific locations can save between 15–40 percent of water use compared with other watering systems.[85]

Other Energy Efficiency Measures

Several other technologies may be of interest to consumers looking to save energy and water, but do not usually have a major impact on the water utility. Energy-efficient water heaters,* hot water pipe insulation, and hot water-on-demand systems can help save both energy and water, and the consumer receives the bulk of the benefit. These technologies may be of considerably more interest to a natural gas or electric utility for demand-side actions.

Case Study: Community Involvement in Ahmedabad, India

Self-Employed Women's Association (SEWA), an Ahmedabad-based organization, has launched a water campaign in Gujarat to empower women, the primary user group, to demand a safe and sustainable water supply at the village level. The campaign is intended to integrate the three "Ws": women, water and work. Mobilizing women to manage local water resources has made this possible, enhancing income levels and creating new economic opportunities.

As part of SEWA's water campaign, women have successfully constructed plastic-lined pond and rooftop water harvesting tanks in a number of arid villages. Efforts have also been made toward implementing watershed development measures to conserve water. Unused wells are being repaired, tanks desilted and check dams constructed. Women have formed water committees and set up water funds for the maintenance of water structures. There have been instances in which women have been trained as 'barefoot technicians' to repair and maintain hand pumps.

The impact of SEWA's intervention is apparent with the transformation in the socioeconomic conditions of the villages. Apart from developing water sources at the village level, women have largely benefited from the employment opportunities that have been generated. Women have been employed in artisan work, handicrafts, gum collection, and salt manufacture. Productivity has increased, which in turn, has led to enhanced incomes and increased savings. Other benefits of this water initiative are exemplified by improved women's health (normally the lowest priority); safe motherhood; safe childbirth; lower infant mortality; increased social security for woman and child; and, most important, reduced migration during the lean season. Augmentation of water sources has also ensured food and fodder security.

Source: Self-Employed Women's Association, <www.sewa.org> (accessed December 2001).

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* Efficient hot water heaters are rated at 234 therms per year for a 40 gal/152 liter gas water heater or 4,671 kWh per year for a 40 gal/152 liter electric unit (American Council for an Energy Efficient Economy, 2001, *Consumer Guide to Home Energy Savings*, <www.aceee.org>).

Table 6: Water-Saving Devices for Existing Houses[86]

Application	Water-Saving Device	Function	Water Savings	Estimated Per Person Water Savings in gpcd and (lpcd)
Toilet	Two toilet tank displacement bottles	Reduce flush volume	1.5 gal/flush (5.7 l/flush)	2.0 (7.6)
Toilet	Toilet tank dam	Reduce flush volume	1 gal/flush (3.8 l/flush)	4.0 (15.1)
Toilet	Toilet tank bag	Reduce flush	0.7 gal/flush (2.6 l/flush)	2.8 (10.6)
Shower	Flow restrictor	Limit flow to 2.75 gal/min (10.4 l/min)	1.5 gal/min (5.7 l/min)	3.7[a] (13.2)
Shower	Reduced-flow showerhead	Limit flow to 2.75 gal/min (10.4 l/min)	1.5 gal/min (5.7 l/min)	7.2 (27.2)
Faucet	Aerator with flow control	Reduced splashing, create appearance of greater flow	1.2–2.5 gal/min (4.5–9.5 l/min)	0.5 (1.9)
Toilet	Ball cocks, flapper valves	Stop leaks	24 gal/day/toilets (91 l/flush)	4.8[b] (18.2)

a. Shower time increases over that for reduced-flow showerhead
b. Assumes one person per toilet and 20 percent leakage rate of toilets
Note: gpcd = gallons per capita per day
lpcd = liters per capita per day

Table 7: Water-Saving Devices for New Construction[87]

Application	Water-Saving Device	Function	Water Savings	Estimated Per Person Water Savings in gpcd and (lpcd)
Toilet	Low-flush toilet 3.5 gal/flush (13.2 l/flush)	Reduce flush volume	2 gal/flush (7.6 l/flush)	8.0 (30.3)
Toilet	Ultralow flush toilet 1.6 gal/flush (6.1 l/flush)	Reduce flush volume	4 gal/flush (15.1 l/flush)	16.0–23.1 (60.6–87.4)
Shower	Reduced-flow showerhead 2.75 gal/min (10.4 l/min)	Reduce shower flow rate	1.5 gal/min (5.7 l/min)	7.2 (27.2)
Faucet	Aerator with flow control	Reduce splashing, create appearance of greater flow	1.8–2.5 gal/min (6.8–9.5 l/min)	0.5 (1.9)
Appliances	Water-efficient dishwasher	Reduce water requirement	5 gal/load (18.9 l/load)	1.0 (3.8)
Appliances	Water-efficient clothes washing machine	Reduce water requirement	6 gal/load (22.7 l/load)	1.7 (5.6)

6.3 PROGRAMS

Municipal water utilities can undertake numerous activities to promote demand-side reductions at the residential and commercial level. These programs fall under the following areas:

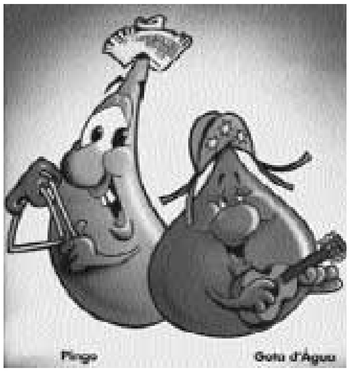
- Education and outreach
- Water audits
- Water efficiency kits
- Rebate/installation programs.

Education and Community Outreach

The consumption behavior of customers has a dramatic effect on water demand. Educating customers on ways to reduce water use and save money can, in fact, be an extremely cost-effective way to reduce demand. Many municipal water utilities have developed educational outreach programs targeted at residential and com mercial consumers. In Singapore for exam ple, such a program developed a water efficiency curriculum, including textbook, workbooks, and experiments, for school children and routinely distributed informa tional pamphlets on water savings oppor tunities to all residences. As a result of this program, a survey conducted in 1999 showed that 84 percent of the respondents had taken some action to save water.[88]

Programs, such as the one in Singapore, have communicated the importance of water efficiency through a host of activities such as:

- Giving educational talks at schools and community organization meetings
- Participating in speakers' bureaus
- Operating booths at community events
- Organizing water efficiency workshops for plumbers, landscapers, and builders
- Advertising on radio and television and in newspapers



Many utilities employ mascots, such as CAGECE's two water efficiency gurus, Pingo and Gota d'Agua, for their water-saving outreach programs.

- Organizing a committee of local stakeholders to provide feedback and review of water use activities
- Producing materials for school science and environmental curricula
- Including water efficiency tips in billing statements.

Water Audits

Through water audits and implementation assistance, a water utility can work with residential and commercial water users to improve watergy efficiency. In many cases, water audits can direct the end user to the greatest savings opportunities and act as a catalyst to induce implementation of efficiency measures.

Residential water audits can produce major water savings. Residential audits are often critical in detecting leaky toilets, faucets, and pipes and informing residents of the savings opportunities associated with taking action. It is also a good way to edu cate consumers on many of the water-saving technologies available. It may be advisable to target water audits at groups that might get the most benefit from the audits, such as older homes or apartments that may have more opportunities for improvements.

For example, a four-month water audit pilot project in Thokoza (township), South Africa, resulted in savings of 195 million liters of water and 2 million South African Rands (US$250,000) a year for about 2,000 homeowners. During this time, 24 township entrepreneurs were also trained in basic plumbing skills, enabling them to continue with their own small businesses.[89]

Offering Efficiency Kits to Customers

In many cases, it is cost-effective to offer free or low-cost water efficiency kits to customers. These kits may contain inex pensive water-saving devices such as:

- Toilet water displacement bags or toilet dams
- Leak detection tablets
- Low-flow faucet aerators
- Low-flow showerheads.

Rebate/Installation Programs

Rebate and installation programs are often one of the most effective measures to ensure demand-side reductions. Municipal water utilities can offer to cover part or all of the costs of water-saving equipment and installation. Some of the most com mon equipment covered under these programs are:

- Low-flow faucets
- Ultralow flush toilets
- Efficient washing machines in apart ment buildings.

In Toronto, for example, one pilot program installed 16,000 ultralow-flush toilets at no cost to the end user and tracked savings of 3.6 million liters per day. The tracking of savings will continue for the long term to make sure that investment by the city is maintained.

6.4 INDUSTRIAL

Many of the same tools municipal water authorities have in reducing demand in the residential and commercial sector also apply to the industrial sector. Water efficiency in the industrial sector can be enhanced through water audits, capacity buyback programs, and incentives to reuse wastewater. Similar to the residential and commercial sectors, water efficiency can be augmented in the industrial sector through education, outreach, and financial incentives.

Water Audits

Water audits can help bigger water cus tomers, such as large farms, manufacturing facilities, building complexes, and universi ties, institute their own water management programs.

For example, a water and energy audit at a textile mill in Ecuador identified measures to reduce water use by almost 25 percent. The recommendations included reusing water from the rinse and coloring processes, optimizing washing equipment, minimizing water-pumping operations, and replacing inefficient pump motors. The water-saving measures cost only US$2,652 to implement and annually save almost US$22,000.[90]

Table 8 (next page) shows commonly implemented industrial efficiency measures.

Capacity Buyback Programs

Water utilities that are especially conscien tious of water supply issues can turn to water capacity buyback programs to help induce water efficiency in the industrial sector. This type of program pays indus tries to reduce their water demand signifi cantly on a permanent basis. In Austin, Texas, industries of all sizes are offered a dollar for every gallon (3.8 liters) of water

Table 8: Most Common Efficiency Measures by Business and Industry[91]

- Recycle process water
- Improve equipment and part replacement practices
- Use domestic water efficiency techniques, such as low-flush toilets and urinals, faucet aerators, low-flow showerheads, and so on
- Change operational practices
- Adjust cooling tower blow down
- Reduce landscaping irrigation time schedules
- Adjust equipment
- Repair leaks
- Install spray nozzles
- Install and replace automatic shut-off nozzles
- Turn off equipment when not in use.

use they reduce per day. The municipal water company tracks the consumption of participating industries and does on-site verifications up to 5 years after installation to ensure water savings have occurred. All this is done, while still saving the municipal water company significant amounts of money from reduced capital expenditures.

Wastewater Reuse

The industrial sector is an excellent candi date for municipalities to promote reusing processed wastewater not fit for drinking. Many industrial processes requiring water can be undertaken with less expensive reprocessed water that may not be potable. By capturing this "gray water" internally or purchasing it from outside sources, industries can save money by using cheap er water, municipal utilities can reduce costs by providing smaller quantities of fully processed water, and other water resources can be saved for other purposes.

One example of a company recapturing its own wastewater for reuse in its process is the Borden food company in Costa Rica. Borden uses water for cooling, cleaning, and moving food in the production process. The wastewater resulting from many of these processes is clean enough to be reused. The Borden Company invested $5,000 to purchase and install equipment to capture wastewater from the system and reuse it for cooling processes and building-cleaning activities. By installing the water recapture equipment, the company was able to cut raw water purchases by 5 per-cent, limit wastewater discharge, and reduce chemical purchases. The project paid for itself within 7 months.[92]

The municipality can play a major role in facilitating the use of gray water by link ing potential purchasers with interested buyers. In fact, Austin, Texas is developing an entirely separate piping system for this recaptured water to be used in a large vari ety of industrial and irrigation purposes throughout the city. This system will pay for itself through reduced potable water demand, lower wastewater processing costs, and a diminished need to build additional capacity.

6.5 POLICY OPTIONS

Municipal utilities have the additional option of changing local standards, codes, and fee structures to promote water efficiency.

Standards and Building Codes

Municipalities have the option to use various building, plumbing, and retrofit codes to improve water efficiency. At a bare minimum, building and plumbing codes should not hinder replacement of shower, kitchen, and bathroom fixtures with efficient replacements. As a more aggressive strategy, a municipality can enact standards for water-using appliances

Case Study: Sydney Water Active Leakage Control Program

To reduce water demand, Sydney Water has made significant efforts to minimize water delivery losses and recycle used water.

Sydney's Active Leakage Control Program is a remarkable effort. It is intended to reduce leakage from the system from an estimated 11 percent to 8 percent of total supply. Leakage studies were completed in their Vaucluse and Wiley Park reservoir zones; six more areas are scheduled for investigation in 2000 and 2001. The pilot studies discovered a range of system losses, including some large leaks. Additionally, a planned pressure reduction trial will assess the potential cost-effectiveness of reducing pressure for leak reduction.

Sydney Water has increased the volume of reused water by 60 percent since 1994–95 to approximately 27 million liters per day. Most of the diverted water from discharge is for use in sewage treatment plant processes. Recycled wastewater now makes up almost 80 percent of the water used by Sydney Water treatment plants. Furthermore, the amount of drinking-quality water used by the plants has been cut in half. Additionally, several major water recycling projects with large industrial customers in the Illawarra region and at Kurnell are expected to become operational by 2003. Contractors are completing installation of upgraded treatment facilities at Sydney's Rouse Hill recycled water plant to meet the requirements of New South Wales Health, the territory agency that protects public health. With upgrades, Rouse Hill will ultimately supply recycled water to 100,000 homes for toilet flushing and garden use.

As a component of WaterPlan 21, Sydney Water produced a 20-year strategic plan for water recycling in December 1999. WaterPlan 21 is a vision for sustainable water and wastewater management for the entire Sydney, Illawarra, and Blue Mountains region.

Source: Sydney Water, 2000, "Environmental Impact of Using Energy," *Annual Environment and Public Health Report 2000,* <www.sydneywater.com. au/html/ Environment/enviro_index.htm> (Sydney, Australia).

and fixtures in new and publicly owned buildings and mandate building retrofits for efficiency. Requirements for landscap ing, drainage, and irrigation might also be created for new development areas and public spaces.

During times of drought and other water supply emergencies, certain uses can be restricted, such as washing sidewalks, nonrecirculating fountains, and watering gardens and soccer fields.

Tax breaks for major water efficiency projects and rebates for water-efficient fixtures are also viable ways to stimulate efficient water use.

Proper Pricing and Revenue Generation

Water subsidies may be one of the strongest enemies working against water efficiency. First, sending consumers an incorrect price signal by charging a lower than cost water rate can lead to water being undervalued and wasted. Second, artificial ly low prices increase the payback time for many water efficiency projects. Third, low rates can lead to municipal water compa nies having limited resources with which to enact other efficiency measures.

By developing a price structure that reflects the true cost of water, consumers are sent the correct signal on the value of water and will be more apt to act on effi ciency opportunities. Experience shows that developing and implementing proper pricing policies takes careful thought, preparation, and consumer education. The true cost of using water may consist of multiple variables including chemical agents, electrical pumping, peak demand charges, on-site pretreatment, and related labor.[93] Prices should also include capital and environmental costs, and encourage efficient use of water.[94]

In allocating costs in a rate structure, the impact on both the quantity of water demanded and the revenue from different types of users should be considered. To determine an appropriate price, the utility can try to ascertain what percentage demand will be reduced by a given percentage of change in price. A pricing structure will ideally help:

- Meet demands on both the infra structure and natural systems in a more efficient manner
- Maintain sufficient revenue and recover costs for the company
- Allow a customer to afford payments
- Provide targeted lifeline subsidies for the very poor, developed in a transparent and equitable manner.

For example, the Ghana Water and Sewerage Corporation began a program in the early 1990s to convert water systems to community-managed services. They ran into difficulty, however, in collecting payments from poorer rural communities. Because the Water and Sewage Corporation could not recover costs, the community-managed approach could not be sustained. An important lesson to be taken from this example is that community involvement from the beginning is essential. Community input must be sought concerning all deci sions on the water systems they want, the systems they can afford, and where the sys tems should be installed. This is especially true where water users follow traditional practices, such as in rural villages, or where customers may be poor.[95]

Water subsidies may be one of the strongest enemies working against water efficiency. Prices should reflect the costs of production; sending the proper price signals can spur investment in efficiency.

Demand-side reductions offer a cost-effective mechanism for municipal water utilities to reduce costs and improve cus tomer satisfaction. Multiple technologies are available that allow the consumer to get equal or better service from water, while actually using less. Promoting these technologies often costs much less than increasing capacity. By pursuing demand-side reduction aggressively, water utilities will also be in a better position to reap supply-side savings.

Conclusion

By 2020 developing countries will join the developed world in having more than 50 percent of their populations living in urban centers.[96] As people move in ever-greater numbers to cities, the burden of providing water to growing urban populations will become even more critical to the sustainability and prosperity of municipalities. Only about half of urban dwellers in developing countries currently have water connections in their homes, and more than one-quarter have no access to safe drinking water.[97] Additionally, in many developing world cities, upward of 50 percent of water pumped into the system is lost before it ever reaches the consumer.[98] Many cities in the developed world also have water losses of more than 20 percent, underutilize potential energy-saving technologies, and have consumers who regularly waste water.

It is clear that cities, in both the developed and developing world, waste energy, water, and financial resources because of inefficiency present within public and private municipal water utilities. This report has described the many cost-effective ways available to reduce waste and expenses, while improving overall service. Many of these actions can be undertaken by utilities with limited resources. Even the most efficient municipal water authorities have a large number of options to help maximize the efficiency with which they deliver water.

Water utilities can address efficiency more successfully by creating and improving watergy efficiency management structures and capacity. In many cases, building a team of well-equipped staff willing to look holistically at the water and energy nexus, as identified by the watergy concept, can maximize efficiency gains. Additionally, by educating consumers, water utilities can continuously improve their contribution to the public good.

The ability of a municipal water utility to deliver water in a cost-effective and resource-efficient manner has a great impact on people's standard of living. By embracing opportunities to improve the efficiency of water delivery cost-effectively, municipal water utilities can help improve and ensure the quality of life for city inhabitants for generations to come.

The municipal water utilities highlighted in the following case studies represent organizations at various stages in the pro gression toward establishing dedicated watergy management structures and devel oping corresponding institutional capacity. As described earlier in the document, watergy efficiency describes the nexus between water and energy within munici pal water utilities.

These 17 case studies attempt to illus trate how the watergy efficiency concept is being applied in day-to-day operations of utilities around the globe. They collectively display the many attributes that make up the watergy efficiency concept. Each case study demonstrates innovative ways that utilities have sought to integrate watergy concepts into their operations. The com pendium includes municipal utilities from different parts of the world in both devel oped and less developed countries to offer a broad spectrum of watergy approaches. Also, the cities range from being very water and energy rich to being in the middle of severe water and energy shortages.

The case studies are divided into three sections entitled watergy efficiency, demand-side management, and supply-side management. Although all the municipal water utilities included in this study are implementing some combination of water and energy efficiency activities, few have been able to achieve a clear level of coman agement. Examples of four municipalities that have successfully begun to adopt watergy efficiency team practices are included under the watergy efficiency section. The next two sections describe municipalities that have implemented strong demand and/or supply-side efficiency programs.

CASE STUDIES

Watergy Efficiency

I. Austin, United States
II. Stockholm, Sweden
III. Sydney, Australia
IV. Toronto, Canada

Demand-Side Management

V. Medellín, Colombia
VI. Johannesburg, South Africa
VII. San Diego, United States
VIII. Singapore

Supply-Side Management

IX. Accra, Ghana
X. Ahmedabad, India
XI. Bulawayo, Zimbabwe
XII. Columbus, United States
XIII. Fairfield, United States
XIV. Fortaleza, Brazil
XV. Indore, India
XVI. Lviv, Ukraine
XVII. Pune, India

I. AUSTIN, UNITED STATES: WATERGY EFFICIENCY

Key Topics

- Water and energy use metering and monitoring
- Team building
- Water demand-side, industrial

City of Austin Water and Wastewater Utility
Bill Hoffman
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Key Results

- Developed comprehensive data system to annually report on progress and successes
- Provided monetary incentives for the industrial sector, resulting in significant savings for the city
- Installed a gray-water reuse system, which will save an estimated 150 million liters per day.

Motivation

The City of Austin Water and Wastewater Utility has created an aggressive corporate culture to promote every facet of water utility efficiency. Austin is located in a semiarid climate and is constantly aware of its limited water supply and need to maximize the potential of its existing resources. In addition, given Austin's hilly topography, the city is taking supply-side measures to reduce energy costs associated with pumping water to its final destination.

After years of developing and implementing innovative programs and projects to improve water and energy efficiency, a pervasive corporate culture appears to be dedicated to efficiency. The utility is also conscious of the air pollution associated with energy consumption of water systems; consequently, it has developed a pollutant-tracking mechanism to better account for additional benefits from its water efficiency activities. Table 9 lists key environmental statistics for Austin's water system:

Methodology

The water and wastewater utility has developed a cadre of programs designed to interface with its major customers in the residential, commercial, and industrial sectors. The utility puts in considerable effort to market its water efficiency improvement programs and educate consumers. Consumers are levied an additional 1 percent on their water bills, which

Table 9: Air Pollution Produced per 1,000 Gallons (3,785 Liters) Treated in Austin, Texas[99]

Air Pollution for Power Use for Water and Wastewater Treatment Based on Austin Mix of Power Generation					
Pollutant	SO_2	NO_x	Particulates	CO	CO_2
Grams/kWh*	1.58	1.22	0.13	0.16	540.0
Grams/1,000 gal (Grams/1,000 liters)	6.2 (1.64)	4.8 (1.27)	0.5 (0.13)	0.6 (0.16)	2,277.3 (601.67)

* Includes 7 percent line loss.

goes into a fund to support municipal water efficiency.

About the Program

Metering and Monitoring

The Austin water utility has a rigorous energy use– and water flow–monitoring program. By installing multiple submeters and coordinating transmission of pertinent information directly from meters to crews that repair lines, Austin has achieved the admirable rate of only 8 percent unac counted-for water.

The utility also has an advanced water consumption–monitoring system that helps focus the resources of its demand-side programs. It is able to track up to 30 categories of water users, such as hospitals and schools. This permits the demand-side program to target major water wasters bet ter, either by comparing across sectors or benchmarking customers within a sector. For example, if one hospital is consuming much more water than its peers, it is a prime candidate for a water audit.

To empower managers and employees, the Austin water utility also provides use ful data to employees via e-mail. Data such as specific pumping information, customer sales, and system performance are continu ously sent to designated staff, who can then optimize their water efficiency efforts. These data are stored in easy-to-access databases, which can be drawn on to provide historical perspectives on current efficiency efforts.

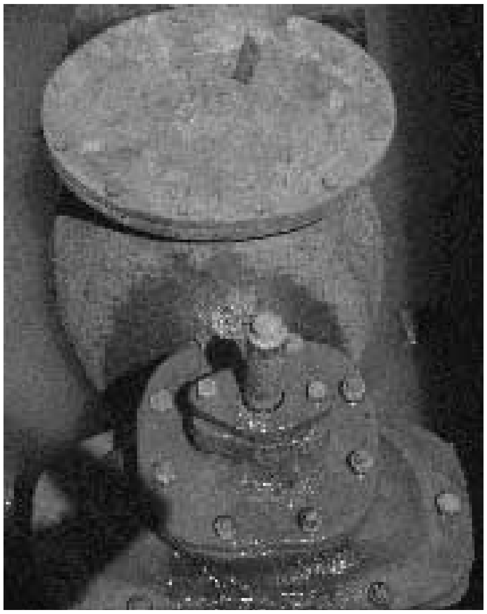
Innovative Efforts

Industrial Capacity Buyback Program

The water utility offers the industrial sector a significant incentive for reducing long-term industrial water demand. The water utility pays one dollar for every gallon (3.8 liters) of demand reduced per day for up to US$40,000 per company. Industries large and small can access this one-time payment by making lasting efficiency improvements to their systems. The utility continually monitors the company to ensure the savings continue and even does spot inspections for up to 5 years after initial implementation.

Reclaimed Water Use

The Austin water utility recently passed a municipal bond issue that has allowed the water utility to install a reclaimed water pumping system parallel to the existing potable water system. A series of blue pipes interconnect throughout the city providing industries, commercial irrigation works and other nonpotable water users with cheaper reclaimed water. The system is designed to recycle upward of 40 million gal (approximately 150 million liters) per day. This greatly reduces stress on raw water sources, decreases costs and capital expenses for wastewater treatment, and provides customers with a highly demand ed product at the right price. The utility is confident that the system will pay for itself.



Appliance Rebate Programs

The Austin water utility and Austin Energy Utility meet on a continual basis to coordi nate programs and evaluate joint program matic goals. To provide incentives to encourage customers to save water and energy, the city implements a joint appli ance rebate program for water- and energy-efficient washing machines.

Team

The Austin water utility uses a loose configuration of various departments to manage efficiency efforts. On particular efforts and projects, appropriate members of the pertinent departments work together to develop and implement both water and energy efficiency programs. Members from several departments meet frequently to find ways to improve the efficiency of their pumping system. They have taken meas ures to install energy-efficient equipment, such as variable-phase pumps, and have taken measures to limit pumping to off-peak hours.

The constant stream of data helps the team to keep these efforts on track and appropriately interlinked. Key department heads meet on an ad hoc basis to review progress and strategize new measures. In addition, the team develops an annual report of goals, progress, and successes. The Texas Water Development Board utilizes this report in a statewide water resource planning and benchmarking process.

II. STOCKHOLM, SWEDEN: WATERGY EFFICIENCY

Key Topics
- Team building
- Residential water and energy demand reductions
- Ecocycle model

Hammarby Sjöstad Project
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Background

As part of Environment 2000, the City of Stockholm is conducting an ambitious urban redevelopment project in several areas of the city. The project has been divided among three areas of the city, one newly and two already constructed zones. One area is Hammarby Sjöstad, previously a run-down port and industrial area that is being transformed into a modern, ecologically sustainable residential district. Initiated in the early 1990s, the Hammarby Sjöstad Project will be com pleted in 2010; as of June 2001, approxi mately 200 residents have moved into the residential area.

Goal

The project goals include using the best-applied technology for new building design to reduce the environmental impact (water, energy, and waste) of the new buildings by 50 percent when compared with normal construction. The Hammarby Sjöstad Project is intended to set up its own local sewage treatment plant and system for combined collection of food waste. The target for the water and sewage component of the project is a 50 percent reduction in water use in residential apartments when compared with new inner city production apartments.[100]

Key Results
- Developed a comprehensive model for energy, waste, and water management
- Involved multiple municipal stakeholders in project implementation

Motivation

The Hammarby Sjöstad Project grew out of the long-term environmental goals of the City of Stockholm established in the spring of 1995 and applicable to the entire city. The project is intended to minimize envi ronmental impact by focusing on the whole resource management system, including exploring land use planning and energy con sumption. Three organizations in the City of Stockholm—Birka Energi, the Stockholm Water Company, and the City of Stockholm Waste Management Administration—jointly developed a comprehensive model for ener gy, waste, and water management known as the Hammarby Model.

Methodology

The Hammarby Sjöstad Project will identify ways to minimize energy and water con sumption as well as waste production. The project will have a local wastewater treat ment plant where waste heat (biogas) will be extracted from the sewage treatment process. To lessen the load on this plant, surface water will be cleaned in a separate plant. In addition, the district heating plant will produce energy with a strong emphasis on using renewable fuels.[101]

About the Program

The Hammarby Sjöstad Project's overall water management program addresses both supply and demand efficiencies through:

- Strategies for encouraging efficient use of water by the residents, including promotion of reduced-flow water equipment
- Water efficiency initiatives for Stockholm Water Company's sewage treatment, which will focus on both water and energy elements.

Development Process

Project team leaders divided construction plans for the treatment plants into two phases during a 5-year period, starting in 2000. Phase I will consist of a pilot project for a small-scale sewage treatment plant. The plant will serve approximately 1,000 people, using best available technologies. After Phase I is successfully completed, the project team will commence plans for con struction of a larger plant (Phase II). The estimated investment budget for this water management program is 21.5 million Swedish kronor (US$1.95 million).[102]

The management structure for coordi nating the efforts of the water and energy components of the local sewage treatment plant is divided into two principal groups. The first team, the Sewage Treatment Plant Steering Committee, comprises a project leader from Stockholm Water Company and a large network of professionals. Such professionals include technical experts from research institutions, consultants, and technical contractors, who review process-specific, monitoring, and information tech nology subprojects. Since March 2001, this committee has been meeting on a monthly basis to review its progress toward meeting the project's goals. The second team com prises vice-presidents of the three technical organizations working on the project, namely Birka Energi, Stockholm Water Company, and the City of Stockholm Waste Management Administration. This team is responsible for general implemen tation of the Hammarby Model regarding sewage treatment, energy supply, and han dling of solid waste. The team meets every two months to review recommendations set forth by the Sewage Treatment Plant Steering Committee.[103]

Monitoring and Verification of Savings

Throughout the life of the project, moni toring and verification systems will be established on several levels to evaluate the success of the project. Due to the impor tance of Life Cycle Analysis for the devel opment and evaluation phase of the Hammarby Sjöstad Project, management teams have devised a unique metric to help evaluate all activities. The Environmental Load Profile will allow the team to evaluate different scenarios regarding design of technical infrastructure (water, heating, cooling, sewerage, and waste) as well as the lifestyles of the residents. The Sewage Treatment Plant Steering Committee has taken steps to build a monitoring station to measure the composition of the wastewater at the local sewage treatment plant. In addition, teams will monitor the residents' consumption patterns for energy and water by using an individual measuring system for each apartment.

III. SYDNEY, AUSTRALIA: WATERGY EFFICIENCY

Key Topics
- Team building
- Water and energy audits
- Educational campaigns
- Water demand-side, residential

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Website: <www.sydneywater.com.au/>

Background

Owned by the New South Wales Government, Sydney Water Corporation (Sydney Water) is the sole provider of water, wastewater, and some storm water services to more than 3.8 million people within the Sydney region. Sydney Water is also one of the largest energy users in its region, using approximately 350 million kWh of electricity per year. Sydney Water's operations include 10 water filtration plants, 135 water-pumping stations, 656 sewage-pumping stations, and 31 sewage treatment plants.

Goal

Where costs are feasible, Sydney Water's goal is to reduce energy consumption of its buildings by 25 percent of the 1995 level by 2005. Sydney Water sets energy man agement targets in line with the New South Wales Government's Energy Management Policy targets.

Motivation

Increases in environmental, drinking water, and effluent quality standards have aug mented Sydney Water's need for an energy management program. In addition, newly constructed water filtration and sewage treatment facilities have increased the utility's energy demand.

Key Results
- Developed a comprehensive supply-side and demand-side water efficiency plan
- Provide $269 worth of vouchers to con-sumers help pay for water efficiency
- Developed water efficiency standards and labels for appliances

Methodology

Sydney Water has created *WaterPlan21* and the *2000–05 Environmental Plan*[104] as a holistic approach to water management. WaterPlan 21 identifies the major projects that will be delivered in the next 20 years. As part of this overall effort, Sydney Water established an energy management policy, which set the framework for a corporate energy management program (CEMP).

About the Plan

Basic Theme

WaterPlan 21 outlines the vision for sus tainable water and wastewater management for the Sydney, Illawarra, and Blue Mountains regions. WaterPlan 21 includes projects to capture sewage overflows, han dle biosolids, and install advanced sewage treatment processes, such as ultraviolet dis infection. The plan was designed to meet water demand reduction targets for years 2004–05 and 2010–11, as mandated by the utility's operating license (364 and 329 liters per person, per day respectively).

Sydney Water is presently evaluating the establishment of additional energy mini mization, efficiency, and generation targets.

The Team

Sydney Water established a Corporate Energy Management Steering Committee to develop a sustainable energy-use strate gy and implement its energy plan. The steering committee meets on a monthly basis to evaluate energy efficiency strate gies and projects and comprises members from engineering, financial, and environ mental units. Committee members repre sent the various backgrounds of Sydney Water staff, which lends all team members and company units a sense of ownership in the strategy.

The Plan's Development Process

The plan's overall water management program addresses both supply and demand efficiencies by addressing both:

- Strategies for encouraging efficient use of water by the community
- Water efficiency initiatives for Sydney's sewage treatment and water supply operations.

Demand-Side

Sydney Water's community management strategy was developed using a least-cost planning approach. The most cost-effective programs to achieve the utility's license targets are being implemented. These include activities that cover residential, commercial, and industrial customers. The range of measures includes:

- Indoor residential retrofits for leak repair, showerheads, and flow regulators
- "Every Drop Counts" consumer educa tion campaign and website
- Voucher books worth $500 (US$260) to provide incentives for water saving
- Water audits for industrial, commercial, and government sectors
- Smart Showerheads Rebate Program (rebates for low-flow showerhead installation)
- Mt. Victoria facility customer retrofit and monitoring project to reduce wastewater flows
- Participation in national water efficiency regulation, such as:
  - Minimum performance standards for major water-using appliances
  - Local planning regulations and building codes
  - A water conservation rating and labeling scheme
  - Voluntary outdoor water-use restrictions.

Supply-Side

In 1996–97 Sydney Water Corporation released its Energy Management Policy* and initiated a formal energy management program. This policy sets the framework for a corporate energy management program (CEMP), which covers facility effi ciency measures to control both cost and quantity of energy used. CEMP energy management objectives include:

- Increases in the efficiency of Sydney Water's energy use
- Reductions in the utility's per capita consumption of energy for the same environmental outcome
- Increases in the percentage of energy obtained from renewable sources
- Increases in recovery and reuse of energy
- Reduction in the combined environ mental impact of the per capita amount of energy and water used by the corpo

* The Energy Management Policy was revised in 1999 to adopt several key principles of New South Wales Government's Energy Management Policy of 1998.

ration and other materials and substances discharged by the corporation

- Concerted efforts to meet best practices in energy management within the water and wastewater industry.

To help identify potential projects, Sydney Water hired independent auditors to perform a corporation-wide audit of energy use as well as detailed engineering and process audits of the largest energy-consuming facilities. The steering committee and the external auditor jointly review project selections. The committee has the authority to implement a broad range of programs, such as energy procurement, that is, contracting for electricity, purchasing petroleum, implementing energy efficiency conservation strategies, and developing opportunities for renewable electricity generation (hydroelectric and cogeneration).

In the past couple of years, the majority of Sydney Water's projects focused on water-pumping stations and sewage treatment plants, which account for 82 percent of total electricity consumption. To have senior management's support, the projects must meet a number of requirements, including environmental and financial criteria. Excellent short-term opportunity projects implemented to date have had relatively high commercial returns. The challenge for Sydney Water lies in upcoming years when certain projects may be more difficult to justify on purely economic grounds.

Sydney Water also held its first Energy Management Exhibition (Energy Expo) on March 7, 2001 with the goal of providing staff with information on the latest technologies and products from energy service providers. Energy Expo showcased a number of energy management projects and initiatives that have already been implemented within Sydney Water.

Monitoring and Evaluation of Savings

Monitoring of the demand-side water and energy management programs is ongoing at Sydney Water. As results become available, the measures are modified to help ensure achievement of water and energy demand reductions at the lowest cost. Some of the indicators for monitoring progress in facility energy consumption are:

- Per capita electricity consumption by operation
- Electricity consumed per unit of service delivered
- Greenhouse gases generated both directly and indirectly from consumption of energy.

The *Sydney Water Towards Sustainability* and *Sydney Water Annual Report 2001* reported on progress on these indicators.[105]

IV. TORONTO, CANADA: WATERGY EFFICIENCY

Key Topics

- Team building
- Water metering and monitoring
- Leak reduction pilot projects

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Goal

Toronto hopes to achieve a peak water demand and wastewater treatment reduction of 15 percent by 2015 (as adopted by the City Council). This translates into a reduction of 220 million liters per day or the same amount of water used daily by 525,000 people.

Key Results

- Pilot program installed 16,000 ultralow flush toilets and tracked savings of 3.6 million liters per day
- Created a cross-sectional water efficiency team.

Motivation

Increased demand due to population growth will outstrip current infrastructure capabilities at the current rate of consumption in the next 10–15 years. Reducing per capita water needs through supply- and demand-side efficiencies will postpone or eliminate the need to invest large amounts of money in new water facilities.

Methodology

Toronto 's mantra for its water efficiency programs is to create and implement a water efficiency management plan to address water goals in a cost-effective, socially acceptable, and easy-to-implement manner.

About the Program

Basic Theme

The proposed water utility efficiency plan is, first and foremost, a demand-side program, but it does include some supply-side efficiency improvements that are recommended as best practices. These include a major leak reduction effort that is targeted to reduce 30 million liters of the 220-million-liter goal. In addition, the plan is linked to a separate program (known as the "Works Best Practices Program") that focuses on supply-side efficiencies.

Development and Management Team

A consulting firm working in conjunction with staff from the Toronto Works and Emergency Department began by conducting an analysis of efficiency opportunities. To facilitate this process, Toronto Works created a project team made up of staff from several department branches: Quality Control and Systems Planning, Water Supply, and Water Pollution Control and Environmental Services. Other branches have also been consulted in developing the plan and will be a part of the review process. These groups include the Planning Department, Energy Efficiency Office, Parks and Recreation Department, and Economic

Development Office. Both a Water Efficiency Public Review Committee, made up of public interest groups, and a Peer Review Committee, made up of water efficiency specialists working in surrounding munici palities, will be established during the review process.

Development Process

Seventy measures from other cities were originally considered for inclusion in the plan. After an initial review that screened the measures for relevance to Toronto ‘s conditions and to the scope of the plan, 23 remained for further consideration. A pro-file on each measure was developed to doc ument the effects of its implementation in the other cities. In addition, the review team selected seven measures based on the criteria of technical feasibility, applicability, and social acceptability. The seven selected efficiency measures cost only an estimated one-third the cost of building comparable additional capacity. Pilot projects have test ed some of these measures; this process is critical in verifying program costs, results, and social acceptability. Some critical solu tions under consideration for residential areas include low-flow toilet rebates, pro-motion of horizontal clothes washers, and summer peak-load lawn watering reduc tions. In addition, the utility is looking at developing a capacity buyback program with the industrial sector. This would pro-vide companies a US$0.20-per-liter incen tive to reengineer industrial processes to reduce water demand.

Monitoring and Evaluation of Savings

Tracking savings is seen as critical to the ultimate success of the program. In the pilot phase, data collection and tracking methodologies were developed and fine-tuned to provide an accurate look at sav ings. Looking at water bills and reading meters on a regular basis in project imple mentation areas will identify initial savings of the project. This information will, it is hoped, encourage bill payers and con sumers to continue saving water, while retaining the desired benefit; for example, one pilot program installed 16,000 ultralow-flush toilets and tracked savings of 3.6 million liters per day. The tracking of savings will continue for the long term to encourage the city to maintain its investment.

Best Management Practices

In addition, the plan recommends a sepa rate group of best management practices, which include:

- Automatic meter reading
- Meter calibration
- Universal metering
- Water main rehabilitation
- Public education and outreach.

Works Best Practices Program

The City of Toronto is actively attempting to improve operational efficiency in its supply operations. A comprehensive system audit in the early 1990s prompted water utility management to recognize major opportunities for efficiency improvements and initiate the “Works Best Practices Program.”

Management Structure

To take advantage of these opportunities, the utility revamped its management struc ture to empower line workers to maximize efficiency in operations. Facilities have been divided into distinct geographic areas that are managed in a business unit fashion by a team of line staff. The teams meet on a daily basis to discuss operational and maintenance strategies. Team supervisors provide oversight and regularly meet among themselves to discuss interteam collaboration on efficiency projects. This team structure has helped optimize opera tional performance and provide a more rapid response to redressing inefficiencies. Staff training currently is intended to help organize team meetings and identify criti cal information needs.

Automated Data System

As part of the process to empower workers to improve efficiency, the water utility has invested in an integrated metering and process control software system.* Among other things, the system helps analyze operations, identify efficiency opportuni ties, provide critical information for line staff to optimize the systems' performance, and maintain an inventory for equipment and spare parts. When it is fully functional, this system will allow equipment operators to optimize equipment performance by comparing operational efficiencies over time under a variety of conditions to determine the ideal operational specifications.

In many cases, operators are currently using their intuition to set up equipment. With the new system, data analysts will be able to give line staff key information on a daily basis to improve operational perform ance. In addition, the software system will help maintenance staff identify problem areas and schedule repairs or replacement more efficiently. The "Works Management" piece of the software package will also identify problem equipment and compare different technology solutions to improve performance.

Empowered by the new management structure and data tools, the Toronto Water Utility is undertaking a comprehensive sys tems analysis to discover additional water and energy resource-efficiency opportuni ties. For example, the utility has analyzed the electricity cost savings from pumping more water to gravity-fed reservoirs at night and turning off equipment for main tenance during the day to cut peak elec tricity load. In the future, the utility is looking to enhance its submetering to provide even better data on the performance of various systems and equipment.

* For a listing of water pumping optimization tools, please refer to appendix B.

V. MEDELLÍN, COLOMBIA: DEMAND-SIDE MANAGEMENT

Key Topics

- Educational campaigns
- Water demand-side, residential
- Water demand-side, industrial
- Energy and water equipment upgrades

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Background

Empresas Públicas de Medellín (EEPPM) provides water services to more than 630,000 consumers in the city of Medellín, Colombia. EEPPM produces close to 9.1 m^3 of water per second through ten drinking water plants and 25 water treatment plants.

Motivation

EEPPM developed a program designed to delay investment in expansion projects, prevent future inadequate water supplies, improve the corporate image, and reduce subsidized water sales at different socio economic levels. Some legal requirements to provide public water efficiency education and to reduce water waste are also associat ed with the utility's water concession.

About the Program

Since the 1980s, EEPPM has been imple menting demand-side water activities for residential and industrial programs, such as education campaigns and water leakage prevention programs. In July 1995 they significantly expanded their educational program to promote rational water and energy use. The program was intended to control and minimize losses in industrial, commercial, and residential sectors in Medellín. EEPPM targeted its residential programs to children, adolescents, house-wives, and heads of households.

Key Results

- Reduced average residential water use by 3 percent per year in a ten-year period
- Developed a metering and monitoring system to help prioritize upgrades
- Created an energy management team

Objectives

The main objective of the educational pro-gram is to bring necessary knowledge and appreciation for the proper use of water and energy resources to all water users. The program was also intended to promote actions that will lead to changes in habits, facility maintenance, energy substitutions, improved efficiency of equipment, and loss reductions.

Work Plan

The work plan for demand-side reductions focused on three groups: children and ado lescents, housewives and heads of house-holds, and the industrial and water sectors.

Children and Adolescents

EEPPM initiated a pilot project targeted at 2,500 fourth grade students in 50 schools. The general objective of the formal educa tion programs was to promote:

- Rational use of water
- Prudent use of public services
- Maintenance of services
- Accurate valuation of services
- Legal water use.

Activities included field trips to watersheds, workshops with parents, take-home projects, and development of an efficiency manual for water consumers. Teaching materials, such as education videos and games, were also developed to help guide the teachers. EEPPM went so far as to develop a 12-segment television miniseries targeting school children to reinforce concepts and goals laid out in the school programs further. In multiple half-hour sessions held in different EEPPM locations, children received instruction on environ mental values and company investments in producing and distributing water and energy.

Homemakers and Heads of Households

EEPPM instituted various media and pub lic information campaigns to help change consumption habits and reduce water loss es. The publicity campaign focused on individual and collective economic prob lems related to water and energy waste. It provided specific instructions for rational use of water and energy. The campaign included TV and radio spots, advertise ments in subway stations, and printing of pamphlets highlighting the benefits of rational use of water and energy and outlining the legal pitfalls facing water thieves.

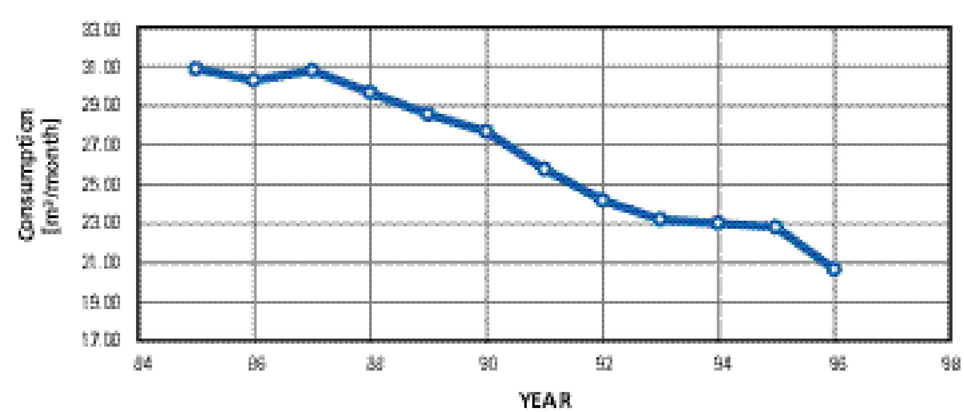
Industrial and Commercial Sector

EEPPM communicated with the industrial sector on the issue of water loss reduction and efficient use of water through a series of training workshops. These workshops were designed to educate the industrial sector on the value of reducing water waste and to provide strategies for seeking improvements.

Educational Program Results

As seen in figure 3, the past decade average residential consumption levels have decreased at a rate of 3 percent per year, due in part to the public awareness campaigns developed by EEPPM. These campaigns helped convince consumers to pay for water consumed and not water wasted—*"pagar por el servicio, no por el desperdicio."* The reduction in water con sumption demand has positively affected the utility's income related to potable water sales. Water-loss prevention programs implemented on a continual basis have resulted in reduced noninvoiced water use from 42.15 percent in 1985 to 32.95 percent in 1996. Such programs have also confirmed that water theft, internal water leaks, and the poor state of faucets and accessories contribute significantly to the total amount of noninvoiced water use.

Figure 3: Empresas Públicas de Medellín Average Residential Consumption Levels



Based on these results, EEPPM has decided to focus new educational cam paigns on normalizing service and mainte nance of internal facilities. These new campaigns will address quality service and preventive maintenance as the principal motivators for efficient use of water.

Energy Management Team[106]

EEPPM has also invested funds to reduce energy demand for its water operations. In 1999 the company set up a team to track its water-related energy use. An operational manager directs a team of civil, electrical, and mechanical engineers, technicians, and operators familiar with energy and equipment operation issues. The team is responsible for analyzing and prioritizing opportunities for energy efficiency activities in several of its water and wastewater facilities, which consume up to 146 GWh/year.

The company has installed a computer ized data-monitoring system (the SCADA System, that is, *sistema de telemetria y tele-control del acueducto*) to help them manage all the operational data. The team reviews monthly reports, which contain information on several criteria, including "energy con sumed" and "fluctuation of kWh/m3 per period of time." After analyzing the data, the team identifies the most inefficient plants and recommends corrective meas ures. Actions taken to date have ranged from installing capacitors for reducing power factor penalties to establishing man agement systems to reduce the level of motor operation during peak hours. They have also taken measures to ensure ade quate sizing of pipes and accuracy of meas urement equipment. These activities, financed in part with company resources or through multilateral bank loans have all resulted in significant energy savings for the company.

VI. JOHANNESBURG, SOUTH AFRICA: DEMAND-SIDE MANAGEMENT

Key Topics
- Educational campaigns
- Consumer programs
- Demand-side, residential

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Background

Rand Water, based in Gauteng, Johannesburg, is a nonprofit NGO that supplies potable water in bulk to local authorities. On average, Rand Water supplies more than 2,800 million liters of water daily to more than nine million people in an 18,000 km^2 supply area. The local authorities are responsible for installing and maintaining water meters in the individual households.

Motivation/Drivers

In an environment where demand is high and water is scarce, Rand Water wants to reduce water waste by educating and rais ing awareness of more than ten million industrial, commercial, and residential consumers regarding the value of water and empowering them to use it wisely. South Africa has less than 1,700 m^3 of water for each person per year, which classifies it as a water-stressed country.

About the Program

Concept

More than 3 years ago, Rand Water began investing in a water conservation program called "Water Wise" to address water scarcity issues. Rand Water has invested millions of South African Rands in the

Key Results
- Saved 195 million liters of water and $250,000 a year as a result of four-month water audit project
- Developed a water efficiency technology demo project that saved more than 25 million liters of water and $22,000.

Water Wise program, and, after 3 years, managers have seen a noticeable growth in awareness in the community about water issues. Under the Water Wise banner, Rand Water has focused on the financial and recreational benefits consumers can achieve by becoming "Water Wise" citizens.

Program Areas

Some of the water initiatives that Rand Water has carried out with the support of local councils and communities include:

- Community awareness and educational programs, which assist local govern ments and consumers to reduce water costs by fixing leaks and promoting water-saving devices, such as dual-flush toilets and aerated showerheads
- Community discussion forums, which educate consumers on environment, gardening, living, and water cycle management topics
- A school conservation program, which provides teachers with lesson plans and

wastewater kits* containing educational cartoon-style maps, hand-on activities, and a wastewater measurement tool
- An educational water conservation website designed to help consumers save water in homes and gardens and report leaks to local councils.

Methodology and Programmatic Results

All aspects of the Water Wise campaign have received widespread and favorable media coverage. They have helped strengthen Rand Water's image as an accessible organi zation active in suburbs. The campaign has won many advertising and exhibition industry awards. Furthermore, community members view the Water Wise program as a leading example and source of expertise in the water conservation field. Projects to fix leaking taps and pipes with the help of residents has saved Rand Water vast amounts of water in the past few years and has resulted in big cost savings to residents.

Details of three recent Water Wise proj ects follow:

1. In its highest profile Water Wise proj ect to date, Rand Water cooperated with Eskom (the sole electricity provider in South Africa) to turn the All-Africa Games Village in Alexandra, Johannesburg, into a showcase of water and energy efficiency. This involved installation of features such as dual-flush toilets, high efficiency shower-heads, and low-flow basin taps and strategic positioning of water heaters to reduce water waste, while waiting for tap water to heat up. As a result, total residential water savings amounted to about 175,000 South African Rands (US$22,000) a year; this is the equiva lent of conserving close to 25 million liters of water. Water Wise trainers vis ited the homes to identify and explain water efficiency designs and features. Occupants were also informed on how to start a Water Wise garden that would improve their lifestyles, save them money, and increase the value of their property.
2. A four-month water audit pilot project in Thokoza (township) resulted in savings of 195 million liters of water and two mil-lion South African Rands (US$250,000) a year for about 2,000 homeowners. During this time, 24 township entrepre neurs received training in basic plumb ing skills, enabling them to continue with their own small businesses.
3. Seven Water Wise Garden Centers have been established in partnership with nurseries. All the centers' frontline employees received training in the Water Wise way of gardening and helped to create demonstration gardens to show customers.

"Conveying the importance of water conservation to consumers in the most appealing and motivational way is what the Water Wise project is all about. Instead of warning consumers that the devastating droughts experienced in the past will cer tainly come again, Rand Water is encourag ing experiential learning through its Water Wise gardening project. By showing people how to establish water-efficient gardens, while at the same time enhancing the beauty and appeal of their gardens with the use of indigenous flora, the project has gone from strength to strength."[107]

* The Water Wise "Wastewater: The Untold Story" Educator Kit includes two educational posters titled "$H_2$0: Heights to Homes to Oceans" and "How Is Wastewater Cleaned?"

VII. SAN DIEGO, UNITED STATES: DEMAND-SIDE MANAGEMENT

Key Topics

- Water and energy equipment upgrades
- Alternative energy sources
- Team building
- Water and energy metering and monitoring

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Goal

The San Diego Metropolitan Wastewater Department (MWWD) has put together an 11-year strategic plan to prepare for future energy situations in California. One of the goals of the plan is to reduce the energy consumed at wastewater department facilities by at least 7 percent.

Key Results

- Established an energy committee
- Developed a strategic plan, which sets a 7 percent energy reduction goal at wastewater facilities
- Began water reclamation programs for landscape irrigation and industrial processes

Motivation

Many of the city's major wastewater treatment facilities and transmission pipelines, constructed in the early 1960s, need rehabilitation and replacement after more than 35 years of use. To improve and strengthen the system to meet growing demand, the city of San Diego undertook a major construction program. San Diego currently imports approximately 90 percent of its water from Northern California and the Colorado River, which also supplies other states. Increasing political pressure from other states has meant reducing the amount of water imported.

Methodology

San Diego has established a variety of supply-side measures to help improve energy efficiency and maintain facility systems to save local ecology and improve customer service. In addition, MWWD has begun a series of demand-side measures, such as water reuse, to help reduce water imports.

About the Program

Basic Theme

MWWD is attempting to maximize its water and energy efficiency through:

- Facility upgrades
- Water reclamation for landscape irrigation and industrial processes
- Biosolids production
- Cogeneration.

Demand-Side Activities

To reduce its dependence on water imported from other states and reduce the amount of sewage discharged into the ocean, MWWD is implementing a strong demand-side water program. First, the city has built water reclamation plants to treat and disinfect wastewater to a high degree for use in nonpotable purposes. One of their plants treats up to 30 million gal of wastewater per day. MWWD then sells low-cost water to customers for use in landscaping, irrigation, industrial, and agricultural purposes. Pipelines and equipment used in the

reclaimed water process are specially marked or color-coded in purple to distin guish reclaimed water pipes from drinking water pipes. Second, MWWD has installed a flow-metering alarm system with 96 detection mechanisms to minimize unde tected sewage spills.

Supply-Side Activities

MWWD has completed a comprehensive energy conservation plan and made a strong commitment to reducing power consumption. On-site power generation systems are an important element for achieving the goals of the plan. MWWD has installed cogeneration systems in sev eral plants where it uses methane from on-site production and nearby landfills to fuel generators for its operations. These energy self-sufficient plants are then able to sell excess electricity back to the electric utili ties. For example, during fiscal year 2000, one wastewater plant saved the city more than US$500,000 in energy costs to run the facility, while earning US$400,000 from selling excess power back to the energy grid.[108]

Management and Development Team

MWWD has established the Energy Committee to focus on reducing energy costs and helping to protect Southern California's ecology by participating in the Canyon Sewer Maintenance Task Force. This task force is developing a citywide policy for operating, maintaining, and accessing San Diego's sewer collection system.

The Energy Committee's core group meets on a bimonthly basis to discuss and strategize implementation of various elements of the energy plan. The group includes engineers, program managers, operating facilities, and other facility par ticipants. The separate, citywide Canyon Sewer Maintenance Task Force has been meeting since June 2000. The task force comprises representatives from the City of San Diego, other governmental agencies, environmental and community organiza tions, and community groups throughout the city.

The Energy Committee develops monthly reports and conducts targeted energy audits. After discussion of the plans, the committee must come to a con sensus about energy projects, grants, and priorities. Facility managers can authorize projects within their budgets, and project costs beyond the facility managers' budgets are forwarded to the deputy director.

VIII. SINGAPORE: DEMAND-SIDE MANAGEMENT

Key Topics

- Water and energy metering and monitoring
- Leakage control programs
- Water demand-side educational campaigns
- Energy and water equipment upgrades

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Background

The Public Utilities Board (PUB), the national water authority in Singapore, is responsible for providing an adequate and reliable supply of potable water. The water supply system that PUB manages comprises 14 raw water reservoirs, six water treatment plants, 14 storage reservoirs, and about 4,800 kilometers of pipelines. In 2000, PUB serviced more than four million people and averaged sales of 1.24 million m^3 of water per day.

Motivation

Because Singapore, a small island nation, has limited natural resources, including water, the nation has made water management one of its top priorities. The rapid industrial, economic, and social developments in Singapore have resulted in a sharp increase in water demand. In 1950, when the population was a little more than a million, the demand for potable water was 142,000 m^3 per day. By 1995 the population had gone up by about three times, but water demand increased by more than eight times to 1.19 million m^3 a day. In 1989–95, Singapore's water demand grew at about 3.5 percent a year. PUB recognizes that development of new water sources and water demand management must be carried out simultaneously to use water efficiently and achieve long-term solutions.

Key Results

- Developed water conservation plan and established water conservation unit
- Achieved a significant drop in unaccounted-for water—from 10.6 percent to 6.2 percent in six years

Methodology

To address concerns about increasing water consumption, in the past 20 years, PUB has developed a comprehensive water demand management plan. The plan has adopted a two-pronged approach—first, efficient management of its water supplies from the source through to its distribution system and, second, implementation of water conservation measures.

About the Program

Overview

Some of the water utility efficiency initiatives focused on decreasing the percentage of unaccounted-for water (UFW),* implementing public education and publicity programs on water conservation, and encouraging water recycling and the use of nonpotable water, such as industrial water and seawater, where applicable, as a substitute for potable water.[109]

* Unaccounted-for water is the difference between the amount of water supplied from the waterworks as measured through its meters and the total amount of water accounted for (which includes water consumption as recorded by customers' meters, water stored in service reservoirs, and water used for flushing and sterilization of mains, routine cleaning of service reservoirs, and so on).

A. Unaccounted-For Water

In the 1980s, to reduce the percentage of UFW, PUB began intensifying its efforts by implementing various measures, which are broadly categorized as leakage control, full and accurate metering policy, proper accounting of water used, and legal enforcement to prevent illegal draw-offs.

Under the leakage control program, PUB promoted the use of better quality pipes and fittings, pipe renewal, intensive detection of leaks, and minimizing response time to repair leaks in the water distribu tion system. The pipe renewal program involved replacing 181 km of old, unlined cast iron mains and 68,400 galvanized iron-connecting pipes between 1984 and 1993. In a 10-year period (1985–95), this effort reduced pipe leaks from 18,085 to 4,543.[110] PUB has continued its program to renew mains. PUB has recently embarked on a 5-year program to replace old pipelines beyond 50 years of age. The program, to be completed in 2004, will replace a total of 280 km of old pipelines. For more com prehensive and accurate detection of leak locations, PUB acquired high-quality devices, such as stethoscopes, geophones, electronic leak detectors, and leak noise correlators. PUB was able to carry out approximately 620 day inspections and 280 leak detection night tests covering the entire distribution system in the course of 1 year. Since the beginning of 2001, PUB has introduced leak noise localizers, which are able to identify suspected leak zones without carrying out tedious step tests.

All water supplied from the waterworks and all the water consumed by customers is 100 percent metered. To ensure accurate readings of large customers' water con sumption, PUB invested in high-quality metering equipment, such as compound meters. This comprehensive metering effort has helped PUB to bill customers and lower UFW accurately.

Significant quantities of water are used in the commissioning and filling of new mains, connections, and service reservoirs; for cleaning and flushing during mainte nance of the water distribution system; and for fire fighting. To avoid improper accounting of water used for such pur poses, PUB has put in place a monthly reporting system that ensures the correct designation of water used.

In addition, due to legislation and stringent enforcement measure, Singapore has few cases of illegal draw-offs. A would-be offender would face a fine of $50,000 (US$27,600) or imprisonment for up to 3 years.

B. Water Conservation Measures

A water conservation plan has also been in place since 1981 to check Singapore's growing water demand and ensure that water is being used efficiently. The various measures implemented under the plan are continually being reviewed and new measures introduced. Aspects covered under the plan include:

- Public education and publicity programs
- Mandatory installation of water-saving devices
- Water audits for and encouragement of water-recycling practices by customers
- Use of nonpotable water, such as indus trial water and seawater, as a substitute for potable water to the extent possible.

The public education and publicity program is an ongoing activity to educate the public on the importance of water conservation and the need to save water. The program covers a range of activities targeted at various groups of customers, such as households, industries, and schools. Activities include visits to waterworks, conducting water conservation talks at schools, holding "save water" exhibitions in community centers, and distributing "Save Water" leaflets to all households. In addition, the education system has been identified as a useful platform to educate the young on the importance of saving water, especially during their impressionable years. The program invited teachers to attend seminars on water conservation so that they can disseminate the water conservation message to their pupils and fellow teachers. Teachers received detective kits and booklets that explain the impor tance of using water wisely; these will assist teachers in the education process and, more important, help convey the message that saving water must be a lifelong habit for everyone. Save Water Campaigns were also organized when necessary to remind the public of the need to save water. The latest campaign in 1998 focused on effecting behavioral change in water use.

Management and Development Team

The Water Conservation Unit is tasked with implementing the various measures of the water conservation plan. Since the unit was set up in 1979, it has worked closely with the Public Relations Division under the guidance of senior management to promote water conservation in all sec tors of the economy. Besides the unit's staff, other PUB staff also help spread the water conservation message when dealing with the general public.

Outcome

A. Reduction of Unaccounted-For Water

PUB uses UFW as a measure of the effi ciency of its water supply system and, con sequently, its water demand programs. In 1989–95, UFW dropped from 10.6 to 6.2 percent, generating an estimated savings of about $47 million (US$26 million). This otherwise lost revenue offset any program matic investment costs and deferred invest ment in new capital projects.

B. Effectiveness of Save Water Campaigns and Sustained Publicity Program

In 1996 PUB conducted a survey to gather feedback from the public. More than 90 percent of the people interviewed were aware of the need to save water. Such sur veys serve as a useful channel for feedback ascertaining the effectiveness of the cam paigns and helping to determine the focus of subsequent campaigns. Based on infor mation gathered in the 1996 survey, the focus of the Save Water Campaign held in 1998 shifted from creating awareness about the need to save water to effecting behav ioral change in water use. The results of a follow-up survey carried out in 1999 showed that 93 percent of the people sur veyed have to various degrees been encour aged to conserve water. In addition, 84 percent of the people surveyed had actually made an effort to conserve water. The cam paigns and publicity programs carried out have proved successful in both creating awareness of the need to save water and effecting behavioral change.[111]

Reducing demand for water is as important as developing new sources of supply. Provided Singaporeans conserve water, these long-term measures will ensure that we will always have enough water for our essential needs.[112]

IX. ACCRA, GHANA: SUPPLY-SIDE MANAGEMENT

Key Topics
- Energy survey
- Energy efficient equipment upgrades
- Metering and monitoring

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Key Results
- Set up metering and monitoring system to analyze data for energy-saving projects
- Installed capacitors to improve power factor and saved more than $25,000 with less than a 2-year payback

Goal

Access to clean, affordable water is a basic need for Ghana's population and a central goal of Ghana's development plans.

Background

The Ghana Water Company (GWC) is a publicly held company responsible for water distribution throughout Ghana. GWC maintains and operates more than 103 headworks (see glossary) and pumping stations in Ghana's ten regions; most of the stations serve urban populations in the southern part of the country. Monthly vol ume through all stations ranges from 14.7 to 16.3 million m^3; more than half (7.7 to 9.6 million m^3) of that volume serves the Greater Accra Metropolitan Area. The Government of Ghana has announced plans to partially privatize the water distri bution utility; GWC would remain as a holding company and overseer of the water delivery system. Private sector firms will be awarded franchises with an obligation to serve particular districts of the country. Water pumping accounts for a significant portion of the total energy demand in Ghana at a time when Ghana is facing power shortages brought on by periodic and prolonged drought. Much of the coun try remains unserved by piped water.

Motivation

In 1997 the chief executive officer of GWC, faced with high and rising costs of energy, commissioned an energy survey to establish usage and load requirements. Extending service to larger sections of the country will require a massive infrastructure investment. In addition, the price of electricity, includ ing demand charges, power factor penalties, and other tariff elements, drives the cost of providing service to those already connect ed to GWC lines. Reducing the cost of pro duction frees up financial resources within GWC to extend or improve existing service. It also frees up power on the national grid for other productive purposes.

Methodology

GWC's energy program, although still somewhat informal, uses its staff engineers to analyze operations reports from the field. GWC has also relied on consultants and NGOs for assistance and guidance, including the Ghana Energy Foundation.

About the Program

Overview

Pumping is the primary cost driver for GWC, so data analysis has focused on total energy consumption, hours of operation, and electric utility bills. Project implementa tion decisions are currently made on a case-by-case basis; one exception is for purchase of efficient capacitors for power factor correction at several large headworks. Procurement is directed at the most cost-effective, efficient technology available to replace obsolete or faulty equipment. Procurement remains at the discretion of the CEO, contingent on the availability of funds and minimization of payback periods. Any new projects are required to take effi ciency into account in the planning stage.

The GWC Energy Efficiency Program is currently using in-house staff as needed to collect data, analyze opportunities, and implement projects. Current data collec tion includes kilowatt-hour (kWh) usage, kilovolt-ampere (kVA)* demand, motor/ pump efficiency, downtime/lost operation hours, and energy bills. GWC has recently begun to track the kWh/m^3 for each of its pumping stations, as was suggested during a meeting with the Ghana Energy Foundation.

Observations

The results of the initial survey in 1997 and a follow-up survey to look at power factors at selected headworks showed significant opportunities for efficiency improvements. GWC was paying high penalties for low power factors caused by inefficient capaci tors as well as oversized and fixed speed motors and drives. Much of the equipment was old, and controls were inadequate. Monitoring of individual pieces of equip ment was also inadequate. In one station, for example, part of the load was discov ered to come from a useless, unidentified pump submerged in the reservoir.

Results to Date

Based on the power factor survey of its headworks, GWC initiated installation of efficient capacitors at 13 stations. The largest station in the GWC system, Kpong, had an existing demand of 12,000 kVA with a power factor of 0.89. In a typical month, Kpong pumps more than 5 million m^3 into homes and businesses in Accra. The installation of two 300 kVAR† capaci tors reduced the maximum demand to 11,736 kVA and improved the power factor to 0.91, avoiding any power factor penalty. The capacitors cost approximately US$7,000, but will save more than US$5,000/year with a payback period of about 1.37 years.

Overall, the capacitor installations will save more than US$25,000 per year and the investment will pay off in less than 2 years.

The efficiency of each pumping station varies dramatically: from as low as 4 kWh/m^3 to around 1 kWh/m^3 for the largest station at Kpong and to as high as 0.5 kWh/m^3 for many of the small- and medium-sized stations. Average efficiency appears to be around 0.8 kWh/m^3 for the whole country, with only a slight seasonal variation.

GWC is examining the feasibility of installing additional capacitors, as well as resizing motors and installing variable speed drives on their pumps. Management has taken note of the considerable savings to be generated from efficiency gains and is directing resources toward improving system efficiency.

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* This measure (kVA) equals one thousand volt-amperes and is used to measure total power—active power, which does work (watts), and reactive power, which creates an electromagnetic field (VAR) ($kVA^2 = kwatts^2 + kVAR^2$). Capacitors can help reduce the total power required by supplying magnetic requirements on sight.

† One VAR is equal to one volt-ampere of reactive power. A kVAR is one thousand VARs.

X. AHMEDABAD, INDIA: SUPPLY-SIDE MANAGEMENT

Key Topics
- Team building
- Energy-efficient equipment upgrades

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Goal

The city has set a goal of establishing an energy management cell within the Ahmedabad Municipal Corporation (AMC) and develop a comprehensive energy man agement plan that will enable the city to save energy used in pumping water.

Motivation

Ahmedabad is a major commercial center located in the western Indian state of Gujarat with limited water resources. About 75 percent of the Ahmedabad Municipal Corporation's electricity con sumption is used for pumping water, main ly because the city's water-pumping system is antiquated and inefficient. Also, because Ahmedabad is located close to a desert, much of its water must be pumped from underground wells, an extremely energy-intensive process. AMC has developed a comprehensive energy management system to reduce energy waste, improve environ mental quality, and save money that could be used for other urban improvements.

In Ahmedabad, overharvesting of groundwater has caused the city's water table to drop an average of 7 ft per year in the past 20 years. The local power compa ny estimates that it requires an additional 0.04723 W/gal to pump water to the sur face with every 7 ft drop in the water table. This translates into an additional 1 million kWh every year to bring the same amount of water to the surface at an added annual cost of more than US$60,000.[113]

Key Results
- Created water efficiency team
- Replaced pipes in jack-wells to reduce friction losses
- Installed capacitors saving $62,000

Methodology

To institutionalize the energy management process in the city, AMC has created an energy management cell. This cell provides in-house capability for monitoring and eval uating energy management initiatives. The energy management cell brings together staff from various other divisions, such as water, drainage, and electricity, to imple ment specific energy efficiency investments.

About the Program

Overview

As with all Indian municipalities, AMC has several functions, including pumping and distributing water, collecting and disposing of solid waste, and maintaining city infra structure such as roads; however, because the costs of pumping and distributing water are so high, they make up most of the city's energy bill.

AMC collects water from two sources: surface (or river) water and groundwater. It draws the river water from the nearby Sabarmati River from shallow wells called Jack or French wells. The groundwater is usually drawn from deeper wells, called bore wells, which are located in many places around the city.

The water pumping authorities collect water from both of these sources in underground reservoirs, called *sumps*, and distrib ute it using two types of water pumps: intake pumps that collect water and supply pumps that distribute water. Although the intake pumps run continuously 24 hours a day, the quantity of water they collect is not sufficient to meet the demand for water. As a result, AMC restricts water supply to two or three hours a day, creating a peak demand for water ranging from 35 MW to 40 MW in the early morning and evening hours. During the rest of the time, the power used for pumping water is only about 15 MW.

Due to the inefficient and costly use of power to operate the city's pumps, AMC focused on improving the efficiency of the water-pumping infrastructure. In the first 2 years, these water-utility efficiency inter ventions saved about US$209,000 in reduced energy bills. If AMC follows these recommendations, it can expect to have continued annual savings of US$430,000. Examples of savings are detailed in the following categories:

- **Energy demand management.** AMC used to operate its intake pumps 24 hours a day, a practice that consumed an enormous amount of energy. To save energy, AMC shut off these intake pumps during peak electricity demand hours, which occurred in the early morning and evening. To meet con sumer demand for water during these times, water was stored in nearby reser voirs or sumps. AMC found out it could only use this strategy to meet morning water demand. These meas ures, if continued, will lead to approxi mate annual savings of US$38,000.
- **Loss reduction from water pumps.** Many water pumps consume electricity very inefficiently; this problem can be solved by installing a device called a capacitor. AMC has installed several capacitors on its bore wells and drain ing pumps and estimates annual power savings of 1.07 million kWh, which is worth US$62,000. AMC also installed additional capacitors on water and drainage pumps and on transformers. The annual savings from this new measure are estimated at US$75,000.
- **New pipes in water-pumping stations.** AMC replaced the steel piping in some of its French wells with a wider, durable plastic pipe to prevent friction loss. Due to the excellent results seen in the first few French wells, AMC management decided to replace pipes in the remain ing French wells, saving an estimated US$102,000 each year.
- **Transformers.** AMC replaced oversized and inefficient transformers in several locations, saving an estimated US$25,000.

AMC's energy management plan has been a tremendous success. As mentioned earlier, if AMC continues to implement energy efficiency initiatives, it could save up to US$430,000 per year.

Long-Term Impact

Long-term institutional changes, such as establishing the energy management cell, have also been successful. AMC has drawn Ahmedabad's other stakeholders in energy management, such as the local utility as well as various NGOs, into a united dia logue on how to help the city save energy. In addition, the city's pioneering energy management work has served as a model for municipalities all around India. Several cities, including Vadodara, Pune, Faridabad, and Indore, are now embarking on their own energy management programs.

XI. BULAWAYO, ZIMBABWE: SUPPLY-SIDE MANAGEMENT

Key Topics
- Water leak detection division
- Water metering and monitoring
- Water supply audit

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Background

Bulawayo is a city of approximately one million people in Southwest Zimbabwe. Rainfall has historically been erratic, and stringent rationing has been in force for most of the past two decades. Losses from the system have amounted to an estimated 22 million liters per day, about 25 percent of the ration-restricted supply. The losses have significantly affected energy use, which currently accounts for about 50 percent of total delivery costs.

Goal

The city set a goal of reducing system water losses to 6–7.5 million liters/day (about 8 percent of rationed supply).

Motivation

Water utility efficiency efforts in Bulawayo began in 1998 at the height of a serious drought.

Methodology

To prevent leaks and improve efficiency of the water distribution system, the city has focused on improved operations and maintenance.

Key Results
- Established leak detection team
- Installed metering systems
- Improved pressure management

About the Program

The Plan's Development Process

A water management study for Bulawayo, funded by the Government of the United Kingdom in 1992, provided the basis for the city's actions. Later, the Bulawayo City Council approached the Norwegian Embassy for assistance in relieving pressure on water resources. Norwegian government assistance supported the design of a water management system through technical assistance that increased the capacity of the city to set up systems for water loss control.

Technical assistance began in June 1999, with significant work mapping the water and sewer utility using computer-assisted drafting, because the previously available maps were very inaccurate and out of date. Calibration of a water network computer model was also undertaken and awaits additional resources for completion.

Management and Development Team

The City Council is responsible for provid ing water and sewerage services. To meet the technical needs of leak and break repair, which was identified as the main system management bottleneck, the city established a Leak Detection Division within the Engineering Services Department. One goal has been to coordinate the iden tification of leaks and breaks better with the team of repair people to solve prob lems quickly.

Management Structure

For continuity and institutionalization of management efforts, project managers document their actions, submit project policy documents, and construct procedure manuals. To ensure that the City Council allocates adequate resources, project man agers who best understand water and sew erage needs and constraints are responsible for submitting operations and maintenance budget requests.

Monitoring and Verification of Savings

Recognizing the need to measure bulk water flow and distribution, the city has been divided into about 50 metered zones, equipped with management meters to be read monthly. As missing and faulty meters have created problems in measuring the bulk flow into the city, Bulawayo has also begun replacing meters. Recorded flow will be compared with predicted average flow and billed consumption. Minimum night-flow measurements will also be taken at least once a year.

The city government plans to undertake water supply audits at the city level in addi tion to the meter zone level. Introduction of 20 or so new pressure zones to control static pressures within the range of 30 to 60 meters will also control pressures more accurately.[114]

XII. COLUMBUS, UNITED STATES: SUPPLY-SIDE MANAGEMENT

Key Topics
- Energy metering and monitoring
- Energy team building
- Equipment upgrades

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Goal
The city set the goal of reducing operating costs by improving energy efficiency at the waterworks.

Motivation
Columbus Water Works is a municipally owned water and wastewater utility serving 186,000 people in Columbus, Georgia. In looking for initiatives that would save money, Columbus found that energy costs are the utility's largest single expenditure.

Methodology
The staff at Columbus makes recommen dations to upper management for efficiency-improvement projects, which weigh potential project savings against the available investment capital.

Key Results
- Completed automated system controls
- Installed automated motor operators, which saved $200,000

About the Program

Basic Theme
Create an energy management program to reduce operating costs.

Development Process
In the planning process, Columbus staff looked for initiatives that would save the utility money. It took the leadership of Columbus' president and senior vice president of operations to make the switch to an energy-efficient operation.

Management and Development Team
Similar to a private business, the utility operates with a five-member Board of Water Commissioners. Project proposals are first screened by the senior vice-president and then forwarded to the president for approval.

Management Structure

Operators, team leaders, or any other staff member can propose changes in the plants to increase efficiency. Staff members are encouraged to present their ideas, and managers and team leaders have biannual seminars on energy efficiency. The utility has also reorganized its management struc ture to take advantage of additional oppor tunities to lower its energy expenditures.

Efficiency Activities

Columbus has:

- Reengineered its wastewater treatment and drinking water treatment plants to be fully automated
- Retrofitted older equipment
- Automated aeration blowers
- Installed adjustable speed drive motors and automated controls for chemical feed pumps.

Most of the new equipment invest ments Columbus has made have focused on replacing old motors with more energy-efficient upgrades. For example, automated motor operators installed on four com pressed air blowers saved the utility US$250,000 by reducing energy costs by 25 percent. This project had less than a 1-year payback period and was awarded the Governor of Georgia's Award for Pollution Prevention.

In addition, Columbus has hired an energy consultant to perform quarterly reviews of the facility's energy use. In a 5-year period, the utility has saved more than US$1 million by changing its rate structure, optimizing processes, and adding efficient technologies to blowers, motors, and pumps at wastewater treatment plants.

Columbus has been experiencing addi tional gains through a pilot project being developed in concert with their power provider. This project provides the utility a direct tie-in between demand metering and the utility's SCADA system, allowing them to set benchmark points beyond which additional kW load cannot be added without a manual override of the system. This system has resulted in signifi cant kilowatt-hour savings during summer months.

XIII. FAIRFIELD, UNITED STATES: SUPPLY-SIDE MANAGEMENT

Key Topics
- Team building
- Real-time energy rate pricing and energy payback schemes
- Energy metering and monitoring

Fairfield Wastewater Treatment Facility
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Motivation

Fairfield Wastewater Treatment Facility in Ohio covers a region of approximately 45,000 people. In 1986 a new superintend ent decided to investigate options to reduce peak electrical demand and prevent costly power factor penalties. After assessing the potential opportunities, the utility decided to move to an automated system and update its operational equipment. The results covered in this case study focus on one plant and did not include system wide efforts.

Methodology

Weekly operations meetings serve as a forum to discuss new technologies and energy efficiency ideas for the plant. Potential projects discussed at these meetings can then be sent to the super intendent for funding authorization.

Key Results
- Fund projects under $15,000 with less than a 5-year payback
- Defer 35–40 percent peak load to off-peak periods through automated operations system

About the Program

Development and Management Team

Fairfield's efficiency actions began with motivation and support from top-level managers. In addition, 21 operations staff members on an ad hoc team regularly dis cuss new technology and energy efficiency ideas. In addition to the ad hoc team's input, Fairfield Wastewater also conducts weekly operations meetings, at which anyone on staff may discuss new technology and energy efficiency ideas.

Management Structure

Fairfield's superintendent makes the ultimate decision to invest in efficiency projects, using a general set of guidelines for making funding decisions. Fairfield Wastewater uses a 3- to 5-year payback for project investments. A policy project is authorized if it falls within this range and the overall costs are less than US$15,000. This process gives project managers more flexibility to plan their budgets with less micromanage ment from company executives.

Automated Data System

In 1999 the Wastewater Division began utilizing a real-time rate-pricing program being offered by its energy provider, Cinergy. This program calculates an energy usage baseline from the previous year's usage pattern. Usage above or below this predetermined baseline, which varies daily, results in the buying or selling back of power at daily market rates. When electric ity prices peak, the facility can use its automated system to shut down for three to four hours and save money. With Fairfield's automated operations system and an ability to postpone energy loads, 35–40 percent of peak loads was deferred to off-peak periods; this has resulted in energy bill reductions of up to 17 percent.

Monitoring and Evaluation of Savings

Computer spreadsheets are used to help monitor trends of monthly cost, total usage (kWh), maximum/minimum power (kW), power factor, and so on to see if operating trends fall within a reasonable band of operation. Initial equipment tests determine reasonable operating condi tions. When operating trends fall outside of expected performance or cannot be justified (for example, aeration systems are down for repairs), staff conducts fur ther investigations to maintain optimal performance.

XIV. FORTALEZA, BRAZIL: SUPPLY-SIDE MANAGEMENT

Key Topics
- Energy metering and monitoring
- Team building
- Educational campaigns

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Background

Fortaleza, capital of the northeastern Brazilian state of Ceará, is a city of more than two million inhabitants. CAGECE, the state of Ceará's water and wastewater company, is the third largest energy user in the state. Ceará's water supply comprises mostly surface water that is stored and distributed by means of more than 8,000 reservoirs with a capacity of more than 10 million m^3. The reservoirs provide multiyear storage and about 90 percent of the state's water supply.

Key Results
- Established energy efficiency team
- Installed an automated metering and monitoring system
- Achieved a 7.9 percent energy reduction in the first year of the program
- Instituted water-use educational outreach campaign

Motivation

Due to an estimated 20 percent electric power shortfall in 2001, Fortaleza faced potential blackouts. In an effort to reduce the impact of the electricity shortage, the state identified CAGECE as a major potential source of electricity demand reductions.

Goal

CAGECE intends to reduce total energy costs by 15 percent between 2000 and 2001.

Methodology

CAGECE has developed a proactive training and efficiency program to improve operations and reduce costs. The program is designed with two purposes in mind: instructing employees on how to identify and implement savings opportunities and helping to implement approximately 50 companywide projects to improve efficiency. The projects focus on people and energy efficiency, which represent respectively the first and second major expenses of the company.

The electromechanical team provides the bulk of the day-to-day support for these projects. For example, the team manages a variety of tasks, such as developing electrical and automation projects, checking electromechanical equipment, and training staff.

CAGECE is also implementing a water waste reduction outreach campaign focused on educating school-aged children. The program uses two water efficiency mascots, Pingo and Gota d'Agua, to convey to even the youngest school children the benefits of using water efficiently. Lesson plans, colorful posters, coloring books, and T-shirts highlighting these two water drop–shaped, energy-saving heroes are made available to schools. As part of this effort, CAGECE personnel participate regularly in community

events, speaking about ways the public can become more efficient in their daily water use. Some of the specific groups included in this outreach are industry, hotels, private firms, housing complexes, and so on. Given CAGECE's statewide focus, this message is taken well beyond Fortaleza, reaching CAGECE customers throughout the state of Ceará. These ongoing public education programs help CAGECE to increase general awareness on the need to become more efficient in daily water and energy use.

About the Program

Monitoring

An automated energy management system gathers all necessary electricity billing information for identifying energy efficien cy opportunities. This system receives technical and commercial data directly from the main database of the Electrical Company of Ceará. Analyzing these data garners useful facts and figures that can be immensely helpful to managers in deci sions on energy efficiency investments. The information is monitored and compared, based on the efficiency index of kWh/m^3.

From this automated data collection system, CAGECE developed a data bank with historical information on several parameters, which it is currently integrat ing with its electromechanical management system. The electromechanical manage ment system monitors CAGECE's major equipment and incorporates real-time data (e.g., pressure, flow, system demand, and energy consumption), which are processed through the Operational Control Center.

Innovation

After studying the energy management systems in other water companies in Brazil, CAGECE concluded that no Brazilian model exists for comprehensively address ing energy efficiency in municipal water utilities. Most water companies had few if any controls or procedures in place to track and minimize energy costs. Energy was not used as a criterion in making tech nical decisions or taking actions to modify the pumping operational system. As a result, old and inefficient equipment had become the norm.

CAGECE is undertaking several meas ures as part of the energy efficiency project, such as:

- Disseminating critical energy data throughout its internal network
- Creating a manual focused on energy saving in motor and pump startup to highlight the potential benefits of technologies such as variable speed drives and capacitors
- Developing specifications for efficient equipment that meet reasonable pay-back period requirements
- Establishing procurement practices to promote uniformity in equipment specifications
- Conducting studies on the use of cogeneration to reduce peak purchases of electricity.

Team

In the past, little cross-fertilization occurred among different departments, especially those based in different loca tions. CAGECE employed an energy efficiency manager who promoted several significant programs. The manager con tributed substantially to promoting and establishing a goal for energy efficiency in the municipal authority's strategic plan for improvement; however, he had to battle numerous obstacles while trying to achieve his goals. This led CAGECE to move toward a "water utility efficiency team" approach. The managers of each department—with considerable leadership from engineering staff, who are knowl edgeable on energy efficiency—work together to provide new procedures for the company. For example, some of the parameters used in identifying energy efficiency projects have come from the financial department, which now analyzes the energy cost for water production. In addition, CAGECE's training efforts are targeted to reach staff outside of the capital of Fortaleza.

Outcomes

Through system redesigns and equipment upgrades, CAGECE has already reduced its total energy use by 7.9 percent from 2000 levels and saved 90,000 Brazilian Reais (US$45,000) per month.

XV. INDORE, INDIA: SUPPLY-SIDE MANAGEMENT

Key Topics

- Team building
- Energy equipment upgrades
- Energy and water metering and monitoring

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Background

Indore is a town of almost two million peo ple in the state of Madhya Pradesh. It has about 110,000 residential connections, 750 commercial connections, and 1,100 indus trial connections. It spends about 70 percent of its budget on electricity; labor and general maintenance split the remaining 30 percent. Indore currently averages a water supply of about 210 million liters per day in a normal season.

Motivation

The city of Indore is currently facing a severe water shortage. In the late 1970s, a water plan was developed for the region based on projected population growth; consequently, a major water main more than 70 km long with almost a 700 m head was constructed to provide water service to meet the growing demand.

Key Results

- Revealed through a data collection analysis system a consistent overcharge by the electrical utility
- Identified and implemented more than $35,000 in saving for no-cost operational improvements

Population growth, however, has far exceeded expectations for this region. Existing water resources are proving inade quate to meet the current population's needs. In addition, costs are far outweigh ing revenues, creating many financial and other maintenance burdens for the municipal corporation.

The Indore Municipal Corporation (IMC) is understandably eager to defer investment in new water lines, reduce current costs, and improve services. To do so, IMC partnered with the Alliance to Save Energy and

USAID through the Sustainable Cities Program to develop and implement a com prehensive water efficiency plan. To date, savings of more than 1.6 million rupees (US$35,000) through systems optimization for no investment cost have been identified. Additionally, improvements in monitoring and tracking of energy usage allowed IMC to identify more than 3.1 million rupees (US$70,000) in additional savings due to overbilling from the electricity company.

Methodology

The Indore Municipal Corporation has focused on three major areas in its efforts to improve water efficiency. With the help of the Alliance to Save Energy, IMC has begun an analysis of its basic operation to identify immediate opportunities for savings by minimizing water and energy waste, thereby giving the entire effort momentum and credibility. The second part of IMC's work has focused on developing a well-funded and -staffed water efficiency management team within the structure of the corpora tion. The third area of activity has been development of an energy and water meter ing and monitoring infrastructure.

About the Program

Management and Development Team

The initial work in Indore concentrated on building the physical infrastructure and personnel of a management team to coor dinate all water utility efficiency activities for IMC. One of the first actions of the IMC's Commissioner was to dedicate office space, computers, and staff to the effort. Staff includes both senior and support per sonnel. During the initial planning process, it became clear that improving IMC's data collection system was the top priority for the newly formed team. Because some data existed, but were scattered in many differ ent places, the first step of the process was to develop a database system to collect and manage data. A data manager was one of the first full-time staff members assigned to the team.

Outcomes

The data's value became apparent immedi ately after collection and initial analyses by the team. It turned out that the power company had been charging the utility for many more hours of operation than were actually occurring. In just one water intake station, this overcharge amounted to more than 1.5 million rupees (US$33,000) per year for at least 2 years.

The data collection activity led to many more discoveries. For example, it became clear that a particular retrofit that was done to expand one water intake station had not been completed in an optimal way. In fact, the pumps that were chosen for this retro fit were not compatible with the existing system and, consequently, added no water pressure to the system. Simply by turning off these new pumps, IMC achieved sub stantial savings. With the appropriate sys tem data in hand, IMC is now redesigning this particular intake station to optimize efficiency.

XVI. LVIV, UKRAINE: SUPPLY-SIDE MANAGEMENT

Key Topics
- Water and energy equipment upgrades
- Energy metering and monitoring
- Team building

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Goal
Vodokanal, the City of Lviv's water utility, set a goal of reducing energy costs and replacing outdated plant infrastructure.

Motivation
Energy prices have gone up considerably in recent years. Vodokanal has limited finances and is often in debt to the energy company. Reducing energy use and water waste can significantly improve their finan cial situation.

Methodology
Vodokanal is in the process of gauging efficiency by gathering data on electricity used in pump stations to compare with the water pumped. It is using this information to prioritize projects for any available funding.

Key Results
- Secured $40 million to upgrade water system efficiency
- Developed a metering and monitoring system that will help prioritize upgrades

About the Plan

Development Process
After a 5-year development phase, Lviv will receive funding from international organizations to modernize its water supply system. The largest percentage of the US$40 million project will come from a US$24 million World Bank loan approved in June 2001. The remaining funds will come from a US$6 million grant from the Swedish International Development Agency and a US$10 million contribution from local authorities, once the Government of Ukraine has approved the World Bank credit agreement.

A large portion of the World Bank proj ect will focus on promoting energy savings by replacing inappropriate pumps, building pressure zones for stability, and repairing water lines that have high rates of leakage.

Up-to-date management principles and a policy of adequate tariffs for water will also be introduced. In addition, Lviv has obtained equipment on a grant from USAID to upgrade pumps and motors.

Management and Development Team

Lviv's chief engineer manages the water utility efficiency of the system. Staff mem bers in charge of pump stations and well fields, along with the chief electrical engi neers, have primary responsibility for identifying projects and seeking funding opportunities. Because the pipelines are old, the maintenance staff frequently makes pipeline repairs. With the recently acquired funding, Lviv plans to correct the leak and pumping problems associated with old equipment.

Monitoring and Verification of Savings

Vodokanal has installed domestic customer meters to measure the amount of water they use with the goal of driving down water demand. Meter unreliability, and tampering and limited ability to penalize the customer for nonpayment, however, pose barriers to the utility's efforts. Vodokanal is in the process of quantifying the benefits of improvements. It is already clear that improvement actions have result ed in pump efficiency improvement at well fields in pump stations where Vodokanal incurs most of its major costs.

XVII. PUNE, INDIA: SUPPLY-SIDE MANAGEMENT

Key Topics

- Team building
- Energy and water metering and monitoring
- Energy and water audits
- Energy efficient equipment upgrades

Pune Municipal Corporation
Ashok Deshpande, Additional Commissioner
(+91) 20 553-4365
Ramesh Juvekar, Prima
(+91) 20 541-1208

Background

Pune is a town of 2.5 million people in the state of Maharashtra. It has about 1,000 km of water pipes in its distribution system. It consumes 105 MWh each year in electricity, costing about 450 million rupees (US$10 million). Water pumping and street lighting incur the vast majority of municipal electricity expenditures. The Alliance to Save Energy with support from the USAID and the U.S. Asian Environmental Partnership identified numerous energy saving opportunities worth approximately 7 million rupees (US$150,000) in the water plants of the Pune Municipal Corporation (PMC). Pune has already made system changes based on these recommendations, saving more than 1.5 million rupees (US$33,000) annually with no investment costs.

Motivation

PMC currently spends a huge proportion of its annual budget on electricity to pump water. The financial and environmental costs of both electricity and water continue to rise as water availability declines and demand increases.

Goal

PMC is currently in the process of establishing short-term and long-term goals to tap these savings.

Key Results

- Created an energy management team
- Identified more than US$150,000 in annual energy-saving opportunities
- Achieved savings of more than US$33,000 through system operation improvements

Methodology

The efforts of PMC are intended to achieve the following:

- Support and institutionalize energy management cells at PMC
- Establish and achieve short-term and long-term goals for energy and water savings based on systemwide energy audits
- Implement periodic systemwide energy audits of PMC systems
- Prioritize and implement system improvement projects and programs
- Test new energy-efficient technology (pilot projects)
- Develop and evaluate water and energy efficiency benchmarks for future expansions of facilities
- Study potential improvements in rate structures and collection mechanisms for water
- Design and implement a public awareness campaign to educate municipal water consumers about the costs to them and to society of water waste and how they can save water.

About the Program

Development Process

In collaboration with the Alliance to Save Energy, the PMC water and energy efficien cy team is working to identify energy- and water-saving opportunities. The team is analyzing system data, carrying out site trials and measurements, and conducting periodic energy and water audits to deter-mine where opportunities for improve ments exist. The team is tasked with identifying potential solutions to these problems and offering the most cost-effective solutions.

Management and Development Team

PMC is providing staff and budget for the operation of its water efficiency and energy management cell (EMC), which it created to help incorporate energy efficiency into the operations of the municipal corpora tion. The cell's current staff (including top managers, field experts, and a data manag er) has been valuable in gathering data and has already identified some additional energy- and water-saving opportunities.

Monitoring and Verification of Savings

Part of PMC's current process of gathering and verifying energy and water use data is determining baselines for consumption. Using these baselines as benchmarks, the EMC will set goals for energy efficiency and water loss reduction. It will be the EMC senior staff's and director's job to track progress toward these goals and create a strategy to attain them.

Automated Data System

The EMC has been tasked with the job of institutionalizing the collection and analy sis of energy and water use data. This auto-mated data system required the purchase of monitoring equipment and training for field staff on its use. The EMC manages and updates its database and reports regu larly to the Municipal Commissioner and others concerned.

Outcome

The anticipated results of these efforts include:

- Implementing almost 7 million rupees (US$150,000) worth of savings oppor tunities already identified a year (1.5 million rupees [US$33,000] in savings have already been implemented)
- Identifying additional opportunities to reduce energy and related expenditures associated with water pumping and other municipal services
- Increasing awareness of local con sumers about measures they can take to reduce water losses and waste and otherwise reduce their energy use
- Creating greater awareness in the local population about efforts PMC is taking to reduce costs and operate efficiently.

WATER RESOURCE MANAGEMENT

ACT Future Water Supply Strategy

Australian Capital Authority Energy and Water, June 1994. A strategic plan developed by the water authority of Canberra, Australia, in concert with the community to manage water resources sus tainably. It contains 137 tasks in education and awareness, water pricing, water conser vation practices and appliances, supply secu rity, alternative water supply sources, and efficient water supply system for integrated water management.

Key Topics Covered
- Drought strategy
- Environmental management
- Alternative sources
- Pricing models

Phone: (+61 2) 6248 3111/ 6209 6899
Website: <www.actewagl.com.au>
E-mail: advisory@actewagl.com.au

Commercial and Institutional End Uses of Water

Awwa Research Foundation (AwwaRF), Aquacraft, Inc., Planning and Management Consultants, and Water Resources Management. Summarizes and interprets the existing knowledge base on commercial and institutional uses of utility-supplied potable water in urban areas. Presents the results of field studies in a sample of 25 establishments in five urban areas. Provides a set of efficiency benchmarks for restaurants, hotels, motels, supermarkets, office buildings, and schools. Research partner: U.S. Bureau of Reclamation. Published in 2000.

Awwa Research Foundation
6666 West Quincy Avenue, Denver, CO 80235-3098 USA
Phone: (+1 303) 347 6100
Website: <www.awwarf.com/>

Community Co-Management of Urban Environmental Quality: Water, Sanitation, and Water Pollution Control

World Bank Urban Development Series, December 2000. A study designed to determine the best decision-making procedure for coordinating the municipal government, community, and private sector in designing water and sanitation, solid waste management, and water pollution control systems.

Phone: (+1 800) 645 7247
Website: <www.worldbank.org/resources>

Effective Energy Management Guide

United Kingdom Government Office for the South West and Energy Efficiency, Best Practice Programme, Bristol, United Kingdom.

Phone: (+01 17) 900 1800
Website: <www.oursouthwest.com/SusBus/susbus9/eemguide.htm>

Impacts of Demand Reduction on Water Utilities

Awwa Research Foundation (AwwaRF), Montgomery Watson. Provides utility managers with data to quantify accurately the impacts of reduced flows result ing from conservation measures and evaluate the impacts on operating costs. Also assists water planners in implementing a least-cost-facility expansion or upgrade policy and in integrating conservation measures during the master planning process. Published in 1996.

Awwa Research Foundation
6666 West Quincy Avenue, Denver, CO 80235-3098 USA
Phone: (+1 303) 347 6100
Website: <www.awwarf.com/>

Long-Term Effects of Conservation Rates

Awwa Research Foundation (AwwaRF), Wade Miller Associates, Inc. Provides guidance on an overview analysis of the long-term effects of conservation pricing strategies. Includes a computer-based spreadsheet-forecasting model for evaluating conservation rates. Published in 1997.

Awwa Research Foundation
6666 West Quincy Avenue, Denver, CO 80235-3098 USA
Phone: (+1 303) 347 6100
Website: <www.awwarf.com/>

Water Conservation and Peak Demand Management Plan

Town of Cary, North Carolina. The least-cost plan for water management in 2000–10 for the Town of Cary.

Phone: (+1 919) 469 4000
Website: <www.townofcary.org>
E-mail: jplatt@ci.cary.nc.us

Key Topics Covered
- Water-use analysis
- Reclaimed water system
- Benefit cost analysis
- Rate structure

WaterPlan 21

Sydney Water (1997). A vision of sustainable water use for the area around Sydney, Australia, including action items to improve water efficiency and attain sustainable water use.

Phone: (+61 2) 9350 6969
Website: <www.sydneywater.com.au>
E-mail: on.tap@sydneywater.com.au

Key Topics Covered
- Wastewater/storm water plan
- Biosolids management
- Overflow abatement
- Environment management

RESOURCES FOR AUDITS AND BENCHMARKS

General

Water Wiser: The Water Efficiency Clearinghouse

Provides a clearinghouse on water service companies, water efficiency references, and publications, such as *Water Audits and Leak Detection* and many others, for supply-side actions.

Phone: (+1 800) 559 9855
Website: <www.waterwiser.org>
E-mail: bewiser@waterwiser.org

American Water Works Association (AWWA) Conservation Division

Part of the conservation division mission is to develop urban water conserva tion measures, implementation strategies, and analysis procedures to help address water supply issues.

Phone: (+1 303) 794 7711
Website: <www.awwa.org>

Water Engineering and Management

Magazine that contains products, technology demonstration case studies, and system management tips.

Phone: (+1 847) 298 6622
Website: <www.waterinfocenter.com>

Key Topics Covered
- News, information, and products in water/waste-water industries
- System management

World Bank Web-Based Tool to Benchmark Utility Performance

Shows a compilation of water and wastewater performance indicators and analysis drawn from Baltic region utilities.

Website: <www.water.hut.fi/BUBI>
E-mail: ssoderstrom@worldbank.org

Key Topics Covered
- Benchmarking
- Performance indicators
- Water quality
- Environmental indicators

Publications

Water Efficiency: A Resource for Utility Managers, Community Planners, and Other Decision Makers

Resource Management Institute, 1991. Rocky Mountain Institute, The Water Program, Snowmass, CO. Suggests several options and considerations for systemwide planning and water management, including metering.

Phone: (+1 970) 927 3851
Website: <www.rmi.org>

Key Topics Covered
- Integrated resource planning
- Gray water use
- Rainwater collection systems
- Water banking
- Reclamation and reuse

Tap into Savings: How to Save Energy in Water and Wastewater Systems Manual
Iowa Association of Municipal Utilities, August 1998.
Phone: (+1 515) 289 1999
Website: <www.iamu.org>

Key Topics Covered
- Water energy audit
- Fine-bubble diffusers
- Variable speed pumps/drives
- High efficiency motors
- Load management

Energy Audit Manual for Water-Wastewater Facilities
Electric Power Research Institute, Report. CR-104300, 1994.
Phone: (+1 650) 855 2000
Website: <www.epri.com>

"Selecting Liquid Flowmeters"
Plant Engineering, Dec. 1999. Cahners, Inc.
Website: <www.plantengineering.com>
E-mail: planteng@cahners.com

Water Engineering and Management
March 2001. Issue focuses on controls systems.
Phone: (+1 847) 298 6622
Website: <www.waterinfocenter.com>

Pumping Systems Field Monitoring and Application of the Pumping System Assessment Tool
Don Casada, U.S. Department of Energy. Specifically for pumping system monitoring and measurement.
Phone: (+1 800) 862 2086
Website: <www.oit.doe.gov/bestpractices>

Key Topics Covered
- Pump efficiency
- Life cycle cost analysis
- Optimization
- Modernization

Water Pumping Optimization Tools

Cities Cut Water System Energy Costs
Website: <www.eren.doe.gov/cities_counties/watersy.html>

Water Resources Consulting Services, The Premiere Spot for Locating Hydrology and Hydraulics Modeling Tools
Website: <www.waterengr.com/>
Website: <www.derceto.com/projects.html>
Website: <www.ex.ac.uk/WaterSystems/about_us.html>

DATA ANALYSIS: KEY PLAYERS AND RESOURCES

Alliance to Save Energy

The Alliance to Save Energy regularly receives requests to provide information on energy efficiency financing tools, as well as advice on how to create loan funds for financing energy efficiency projects. In response to these requests, the Alliance is creating a database that documents debt/equity funds and partial guarantees.

Phone: (+1 202) 857 0666
Website: <www.ase.org>

American Water Works Association (AWWA)

AWWA has contacts for municipal and regional water companies around the world.

Phone: (+1 303) 794 7711
Website: <www.awwa.org>

Best Practices Study for Energy Management

Awwa Research Foundation (AwwaRF), EMA Services, Inc., Rose Enterprises, Inc., and Treefarm Center Consultants, Inc. Will develop a documented consor tium benchmarking process for water utility application. Will test application of the process in an energy management benchmarking study. Research partner: Irvine Ranch Water District (to be completed in 2002).

Awwa Research Foundation
6666 West Quincy Avenue, Denver, CO 80235-3098 USA
Phone: (+1 303) 347 6100
Website: <www.awwarf.com/>

Energy and Water Quality Management System

Awwa Research Foundation (AwwaRF), EMA Services, Inc., and East Bay Municipal Utility District (Oakland, Calif.). Based on a pilot project, provides a methodology and guidelines for evaluating various designs for energy manage ment systems that will be part of a utility SCADA system. Determines the bene fits of a water quality–constrained energy management system. Bases benefits on a variety of alternative future scenarios for energy management, including electric utility deregulation. Research partner: EPRI CEC. Published in 1997.

EPRI AMP Customer Assistance Center at 800-432-0267.
Awwa Research Foundation
6666 West Quincy Avenue, Denver, CO 80235-3098 USA
Phone: (+1 303) 347 6100
Website: <www.awwarf.com/>

Handbook of Energy Audits

Fourth Edition, Albert Thumann, 1995, Fairmont Press, Lilburn, Georgia, USA, 444 pp. Handbook describes the audit process and suggests improvements for a variety of systems.

Implementing a Prototype Energy and Water Quality Management System

Awwa Research Foundation (AwwaRF), EMA Services, Inc. Will quantify the projected benefits of an energy and water quality management system (EWQMS) at a major water utility. Will design, model, implement, measure results, and document the Operations Planner and Scheduler (OPS) function modeled in previous EWQMS phases. Will develop site-specific specifications of OPS software, with a requirement that the system can be made operational within six months and yield a positive return on investment within 1 year. Will document performance of OPS software following installation and start-up. Research partner: Colorado Springs Utilities. (To be completed in 2002)

Awwa Research Foundation
6666 West Quincy Avenue, Denver, CO 80235-3098 USA
Phone: (+1 303) 347 6100
Website: <www.awwarf.com/>

Ozone System Energy Optimization Handbook

Awwa Research Foundation (AwwaRF), Process Applications, Inc. Provides an energy efficiency protocol for ozone systems used in drinking water plants. Documents a series of one-week plant audits focused on the ozone system. Quantifies the improvements that were implemented. Research partner: EPRI CEC. Published in 1996. EPRIAMP Customer Assistance Center at 800-432-0267.

Awwa Research Foundation
6666 West Quincy Avenue, Denver, CO 80235-3098 USA
Phone: (+1 303) 347 6100
Website: <www.awwarf.com/>

Practical Energy Audit Manual: Pumping Systems

Indo-German Energy Efficiency Project, August 1999. Tata Energy Research Institute, Bangalore, INDIA, 95 pp. Provides some engineering equations and audit guidance.

Phone: (+91 11) 468 2100
Website: <www.teriin.org>

Quality Energy Efficiency Retrofits for Water Systems

Awwa Research Foundation (AwwaRF), HDR Engineering, Inc. Provides pragmatic information to increase the likelihood of high quality, reliable, and persistent energy management retrofits. Includes information on how to avoid common pitfalls and problems, suggestions for selecting contractors, and how to evaluate completed projects. Research partners: California Energy Commission and EPRI CEC. Published in 1997.

EPRIAMP Customer Assistance Center at 800-432-0267.
Awwa Research Foundation
6666 West Quincy Avenue, Denver, CO 80235-3098 USA
Phone: (+1 303) 347 6100
Website: <www.awwarf.com/>

A Total Energy and Water Quality Management System

Awwa Research Foundation (AwwaRF), Westin Engineering, Inc. Presents a generic model for an energy and water quality management software system for the water community. Based on the generic model, develops standard specifications for the software applications required to minimize energy costs within the constraints of water quality and operations goals. Research partner: EPRI CEC. Published in 1999.

Awwa Research Foundation
6666 West Quincy Avenue, Denver, CO 80235-3098 USA
Phone: (+1 303) 347 6100
Website: <www.awwarf.com/>

Water Conservation Plan Guidelines

The U.S. Environmental Protection Agency, August 1998, Document 832/D-98-001. This manual was put together by USEPA to help water utility system planners incorporate customer water efficiency into facility planning. It offers guidelines on water accounting, source metering, user metering, and water loss control worksheets and customer water use benchmarks.

Phone: (+1 202) 260 7786
Website: <www.epa.gov/owm>

ADDITIONAL RESOURCES FOR EQUIPMENT UPGRADES

Case Studies in Residual Use and Energy Conservation at Wastewater Treatment Plants

U.S. Environmental Protection Agency, June 1995. Includes actual projects to reduce energy use, and produce energy with biogas and biosolids.

Phone: (+1 202) 260 7786
Website: <www.epa.gov/owm>

Key Topics Covered

- Biogas generation
- Central power generation
- Waste heat recovery
- Dewatering/drying bed

Plant Engineers and Managers Guide to Energy Conservation

Albert Thumann, 1996. Association of Energy Engineers, Fairmont Press, Lilburn, Georgia, USA, 390 pp. Covers lighting, electrical, heat transfer, heat recovery, ventilation, and utility process systems, such as pumps.

The following technical resources are available to help specifically capture opportunities in pump and motor systems:

Practical Energy Audit Manual: Pumping Systems

Indo-German Energy Efficiency Project, August 1999. Tata Energy Research Institute, Bangalore, INDIA, 95 pp.

Phone: (+91 11) 468 2100
Website: <www.teriin.org>

Key Topics Covered

- Centrifugal pumps
- Positive displacement pumps
- Capacity regulation
- Series/parallel operation
- Energy management programs

Manual on Energy Efficiency in Pumping Systems

Confederation of Indian Industry Energy Management Cell, Energy Management Centre, Indian Ministry of Power, September 1998, 173 pp.

Phone: (+91 44) 466 0571
E-mail: emc@sr.cii.ernet.in

Key Topics Covered

- Equipment upgrades: pumps
- Impellers
- Capacity regulation
- Standards/design

Improving Pump System Performance: A Sourcebook for Industry

U.S. Department of Energy, Office of Industrial Technologies, January 1999.

Phone: (+1 800) 862 2086
Website: <www.oit.doe.gov/bestpractices>

Key Topics Covered

- Pump system components
- Pump system principles
- Piping configurations
- Types of pumps

Pump Life Cycle Costs: A Guide to LCC Analysis for Pumping Systems
Europump and Hydraulic Institute, Parsippany, New Jersey, Frenning, Lars and others, 2001. First edition.
Website: <www.pumps.org>.

Pumping System Assessment Tool
The Pumping System Assessment Tool (PSAT) is a software program offered by the U.S. Department of Energy. Given motor and pump data, PSAT calculates efficiencies, power factors, and estimated costs for the existing pump and an optimal pump. PSAT uses achievable pump performance data and motor per formance data to calculate potential energy and associated cost savings.
Phone: (+1 800) 862 2086
Website: <www.oit.doe.gov/bestpractices>

For Leak and Loss Reduction:

Water Wiser, American Water Works, Association:
- *Water Audits and Leak Detection*, 1999, 96 pp. Provides guidance on conducting systemwide water audits with worksheets
- *Leaks in Water Distribution Systems*, 1987, 48 pp. Specific guidance on leak detection and repair

Phone: (+1 800) 559 9855
Website: <www.waterwiser.org>
E-mail: bewiser@waterwiser.org

Key Topics Covered
- Products directory
- Service companies' directory
- Leak detection & repair
- Water management principles

Using Water Efficiently: Technological Options
Mei Xie, Ulrich Kuffner, and Guy LeMoigne, 1993, World Bank Technical Paper Number 205. Gives an overview of system losses and ways to improve system performance.

Water Conservation Plan Guidelines
August 1998, Document 832/D-98-001.
The U.S. Environmental Protection Agency put this manual together to help water utility system planners incorporate customer water efficiency into facility planning. It offers:
- Guidelines on water accounting
- Source metering, user metering, and water loss control worksheets

Phone: (+1 202) 260 7786
Website: <www.epa.gov/owm>

Key Topics Covered
- Flow reduction
- Accounting
- Metering
- Loss control
- System profiling

Information Resources on Industrial Pollution Prevention,
CD-ROM, Hagler Bailly Inc., Environmental Export Council USAID, Summer 2000 (Spanish and English).

This CD-ROM provides information on industrial pollution prevention and cleaner production approaches, methods, and technologies to government agencies, clean production centers, and other NGOs, industry and trade associations, individual enterprises, academic institutions, and con sultants in Latin America and the Caribbean.

Key Topics Covered

Industrial pollution prevention in:

- Food industry
- Metal finishing industry
- Leather tanning industry
- Other sectors

A Guidebook for Reducing Unaccounted-for Water

Texas Water Development Board, Revised August 1999. This guidebook provides practical information on how to set up a comprehensive water accounting system, including metering, billing, and leak detection.

Website: <www.twdb.state.tx.us/assistance/conservation/guidebook.htm>

Key Topics Covered

- Metering
- Leak detection
- Water accounting worksheet
- Unaccounted-for water checklist

Water Distribution Optimization Tools/ Hydraulic Analysis Software:

The following lists links to software tools and other organizations that offer information. These types of tools have helped municipal water managers to monitor their water distribution systems, optimize system performance and cut water system energy costs.

Derceto: Water Distribution Optimization Software for Windows

A software tool that works online and in real-time to optimize water distribu tion costs by setting pump schedules and selecting lowest-cost water sources.

Website: <www.derceto.com/projects.html>

Supervisory Control and Data Acquisition (SCADA) Systems

SCADA systems help municipalities to manage water treatment and distribution as well as wastewater collection and treatment.

Website: <www.eren.doe.gov/cities_counties/watersy.html>

For a list of additional hydrology software packages visit:

The University of Kassel Irrisoft Database:

Website: <www.wiz.uni-kassel.de/kww/irrisoft/pipe/pipe_i.html>

Centre for Water Systems at the University of Exeter

Website: <www.ex.ac.uk/WaterSystems/about_us.html>

Organizations:

U.S. Department of Energy, Best Practices

Best Practices offers several guides for motor and pump system optimization, including:

- Energy Management for Motor-Driven Systems Handbook
- Improving Pump Systems Sourcebook
- MotorMaster+ Software
- Pumping System Assessment Tool (PSAT) Software

Phone: (+1 800) 862 2086
Website: <www.oit.doe.gov/bestpractices>

Water Resources Consulting Services

This *consulting* group based in San Francisco, California, provides links to hydrology and hydraulics modeling tools on their website, including links to Corps of Engineers modeling systems.

Website: <www.waterengr.com/>

DSM/POLICY OPTIONS AND OTHER RESOURCES

Useful References from the American Water Works Association

- *Water Conservation Guidebook for Small and Medium-Sized Utilities,* Pacific Northwest Section, 1993. A report that includes chapters on how to esti mate water savings; examples of residential, commercial, and industrial conservation measures; how to estimate benefits and costs; and how to implement conservation programs.
- *A Guide to Water Utility Public Information Practices,* 1993
- *Public Involvement Strategies: A Manager's Handbook,* 1995
- *AWWA Journal*, November 1993. Includes information on public involvement and education
- "Conservation-Oriented Water Rates," *AWWA Journal,* November 1996.

AWWA has a conservation division and extensive resources for demand-side water management. It is a "must-see" resource for all water professionals.

Phone: (+1 303) 794 7711
Website: <www.awwa.org>

Key Topics Covered
- Integrated resources planning
- Conservation techniques
- AWWA water efficiency study
- System viability analysis

Water Conservation Plan Guidelines

U.S. Environmental Protection Agency (USEPA), August 1998, Document 832/D-98-001.

USEPA put this manual together to help water utility system planners incorporate customer water efficiency into facility planning. It offers:

- Guidelines on water accounting
- Source metering, user metering, and water loss control worksheets
- Customer water-use benchmarks.

Phone: (+1 202) 260 7786
Website: <www.epa.gov/owm>

Water Efficiency Manual for Commercial, Industrial, and Institutional Facilities

North Carolina Department of Environment and Natural Resources, August 1998. A man ual for large water utility customers to plan and manage water use comprehensively.

Phone: (+1 800) 763 0136
Website: <www.p2pays.org>

Key Topics Covered
- Principles of water management
- Industry-specific processes
- Efficiency compared with conservation
- Water balance
- Reuse

Facility Manager's Guide to Water Management

Arizona Municipal Water User's Association, August 2000. A manual for large water utili ty customers to plan and manage water use.

Phone: (+1 602) 248-8482
Website: <www.amwua.org>

Key Topics Covered
- Inventory
- Water balance analysis
- Monitoring

Water Efficiency: A Resource for Utility Managers, Community Planners, and Other Decision Makers

Resource Management Institute, 1991. Rocky Mountain Institute, The Water Program, Snowmass, CO. Suggests several options for demand-side water management.

Phone: (+1 970) 927 3851
Website: <www.rmi.org>

A Water Harvesting Manual for Urban Areas: Case Studies from Delhi

Center for Science and the Environment. The manual describes the concept and process involved in rainwater collection.

Website: <www.cseindia.org>

SAMPLE WATERGY FACT SHEETS

SAVING WATER AND ENERGY: INDUSTRY

Build a Water Efficiency Program

1. Create a water efficiency team and designate a water efficiency coordinator.
2. Identify and introduce a proper measurement system.
   - Develop a baseline and metrics
   - Benchmark progress internally and externally.
3. Carry out facility assessments.
   - Identify potential water-efficiency improvement at the target facility.
   - Calculate the expected water savings and the estimated costs associated with the implementation of water efficiency projects.
4. Establish a program of maintenance, inspection and evaluation of production practices.
5. Increase management and employee awareness of the need to use water efficiently. Involve employees in water efficiency efforts.
   - Develop best practices training.
   - Check with peers to verify technological results of similar projects and to get advice.

Optimize the Water Distribution System

1. Check for leaks.
   - Inspect for leaks in pipes, fittings, pumps and gauges in mechanical rooms and headers throughout the building. Repair will prevent collateral damage to wood surfaces and furnishings, ceiling tiles and electrical equipment. The savings will occur in the water bill and through a lower sewer disposal fees as well.
   - Leaks occurring in closed systems can be even more expensive. Water cir culating in the chiller, the condenser and the steam loops is usually chem ically treated for corrosion and high hardness. Here the total loss covers water as well as very costly chemicals and some of the energy needed to heat or cool the circulating fluid.
   - Inspect and repair damaged insulation systems. Sagging or missing sec tions of insulation indicate possible leaks.
2. Cooling systems and cooling towers
   - Meter and record water use.
   - Never use once-through water cooling. If there is no other choice, reuse the water elsewhere in the facility.
   - Use air cooling, as opposed to water cooling, where feasible.
   - Establish performance-based specifications when contracting with a cool ing tower vendor.

- Investigate side-stream treatment.
- Investigate the potential of wet-dry cooling towers.
- Reuse treated wastewater or other sources of water for cooling tower make-up.

3. Boilers and hot water
   - Insulate boilers, storage tank(s), and pipes.
   - Use instantaneous heaters at remote locations.
   - Establish performance-based specifications when contracting with a boiler vendor-operator.
   - Check stream traps regularly - faulty steam traps waste water and heat.
   - Reuse steam condensate water and boiler blow-down water where feasi ble.
   - Feed used water back into systems where possible.
   - Record water use and check for leaks.
4. Other water using equipment and operations
   - Use automatic valves that shut off the water when equipment is off.
   - Consider minimizing water use when purchasing new equipment.
   - Use mechanical/oil seals instead of water packing glands on pumps where possible.
   - Capture reject water from reverse osmosis units and reuse it where feasi ble.
   - Use automated computer control technology to regulate water use.
5. Reuse wastewater
   - Try to close the manufacturing loop by reusing water.
   - Treat used water only if necessary.
   - Identify discharges that can be reused and implement reuse practices.

SAVING WATER AND ENERGY AT HOME

For the average household, a 35 percent reduction or more in water use is feasi ble, just by following the steps outlined below. The bathroom is a key area on which to focus as nearly 65 percent of all indoor water use occurs there.

Saving Water Indoors

1. **Toilets:** *Toilets consume the most water inside the home.*
   - *Check for leaks.* Put a few drops of food coloring or leak identification tablets in your toilet tank. If the coloring appears within 30 minutes without flushing you have a leak that may waste up to 200,000 liters (52,800 gallons) a year. Often fixing a leak can be as simple as tightening loose connections, reconnecting joints after wrapping Teflon-Tape around the threads, or replacing a worn out float cup, rubber tank ball or flapper (which seals the opening between tank and toilet bowl).
   - *Flush toilets less often.* Do not use them as ashtrays or wastebaskets.
   - *Toilet dams/displacement devices.* Place plastic bottles filled with water in your toilet tank or use an inexpensive toilet dam to block part of the toilet tank. This can save 40 or more liters (11 gal) of water per day. Avoid bricks that can damage the tank.
   - *Ultra-low flush toilets.* Installing an ultra-low flush toilet can save more than 20 liters (5 gal) per flush.
2. **Use less water.**
   - Turn off faucets completely and reduce the amount of water used for hand washing, brushing teeth, shaving, and showering.
   - Replace old faucet aerators and showerheads. Newer models tend to use less water and provide more water pressure. Where possible, purchase inexpensive flow restrictors on showers and faucets
   - Water-saving shower heads, saving up to 20 liters (5 gal) a minute.
   - Faucet aerators saving between 12 and 65 liters (3 and 17 gal) per day.
   - When washing dishes by hand, don't leave the rinse water running.
   - Fully load your washing machine and dishwasher.
   - Purchase more efficient washing machines. Where possible, purchase Energy Star approved machines. Otherwise, front-loading washing machines tend to be more efficient. Comparing product specifications can also help to find the most efficient model.
3. **Check for leaks.**

   Check for leaks in pipes, hoses, faucets and couplings. Leaks can be costly. A leak of only one drop per second wastes about 10,000 (2,643 gal) liters of water per year. Read your water meter before and after a two- hour period when no water is being used. If the meter does not read exactly the same, there is a leak. Fixing leaks is usually less expensive than paying for wasted water (up to 75 liters or 20 gal a day per leak).

4. **Hot water heater.**
   •- Purchase an efficient water heater. (234 therms per year for a 152 liter or 40 gal gas water heater or 4,671 kWh per year for a 152 liter or 40 gal electric unit)
   •- Insulate hot water pipes and water heater using foam pipe insulation, water heater jackets, or other approved insulation materials.

5. **Reuse wastewater.**
   •- Never let water go down the drain when there may be another use for it such as watering a plant or cleaning. For example, when washing off fruit or vegetables, place a bucket under the faucet. Use the water collected in the bucket to water plants.

Saving Water Outdoors

1. **Cleaning.**
   •- Use a sweeper or broom to clean the garage, driveway, floors or sidewalk instead of a hose. Unnecessary use of a hose wastes 1000 liters (264 gal) of water per hour.
   •- When using a hose, outfit it with a shut-off nuzzle and when finished, "turn it off" at the faucet instead of at the nozzle to avoid leads.
   • Wash your car on the lawn with a bucket of water and a sponge.

2. **Garden.**
   •- Don't overwater your lawn, and plant low maintenance landscape with native species adapted to live in your climate conditions (xeriscaping).
   • Water the roots of plants, not the leaves.
   •- Water lawns early or late in the day when temperature and wind are the lowest to reduce losses from evaporation (early morning is usually recom mended to minimize mildew, etc.).
   • Adjust sprinklers to water lawns and not pavement.
   •- Use drip hoses where possible instead of sprinklers, which can lose water to evaporation and inaccurate targeting of water.
   •- Do not leave sprinklers or hoses unattended. Outdoor faucets can flow at rate of more than 1000 liters or 264 gal per hour.
   • Use irrigation timers.

3. **Capturing water.**
   - 1000 square feet of roof or pavement can collect 1500 liters (396 gal) of water from 1 inch of rain. A cistern or rain-barrels that capture and store rainwater can be used as a source for irrigation or washing. Also, connecting gutter downspouts to collection systems can also help supply the cistern.
4. **Installations.**
   - Avoid the installation of ornamental water features (such as fountains) unless the water is recycled.
   - If you have a swimming pool consider a new water-saving pool filter. Cover the pool when not in use; up to 200 liters (53 gal) of water per day can be lost because of evaporation. An average sized pool can lose more than 3,500 liters (925 gallons) per month through evaporation if left uncovered.

SAVING WATER AND ENERGY: MUNICIPALITIES AND WATER UTILITIES

Build the Infrastructure to Address Water Efficiency

Bring together the human and financial resources needed to address efficiency.

- Designate a water efficiency coordinator and build a water efficiency team. Set goals and develop a water-efficiency strategy.
- Educate and involve employees in water efficiency efforts.
- Create a targeted budget for water efficiency.

Analyze the Current System

Build the institutional capacity to analyze systems and locate efficiency opportunities.

- Create a metering and monitoring system.
- Develop a baseline of energy and water use.
- Benchmark progress internally and externally.

Encourage Demand-Side Reductions

Work with consumers to reduce waste and get more benefit from each liter of water used. Demand-side reductions can cost as little as one third the expendi ture for comparable new capacity.

Price

- Develop a price structure that reflects the true cost of water. Ensure that the utility rate structure encourages water efficiency, or at least does not encour age water waste.

Residential end-user

- Promote/distribute efficient water saving technologies, such as:
  - —Ultra low-flow toilets (6 liters per flush instead of up to 30 liters)
  - —Low-flow faucet aerators (reduce water flow by up to 50 percent while maintaining water pressure)
  - —High efficiency showerheads (using less than 10 liters a minute instead of 30 liters)
  - —Leak detection tablets (a leak of just one drop per second can waste 10,000 liters per year)
  - —Replacement valves.
- Offer rebates and installation programs to customers who buy high-efficiency products like low-flow showerheads, ultra low-flow toilets, clothes-washers, water heaters, etc.
- Educational outreach is essential. Include water tips in billing statements, provide water saving curriculum materials for schools, and so on.
- Enact and enforce water-efficiency building codes and equipment standards.
- Perform free water audits for customers, especially large users.

Industrial and business end-user

- Encourage industries to reduce water use by offering incentives.
- Promote wastewater reuse.
- Enact and enforce energy-efficiency building codes and equipment standards.
- Introduce tax breaks for major efficiency projects.
- Offer rebates for the installed cost of equipment that improves water efficiency such as retrofitting cooling towers, and replacing water-cooled with air-cooled equipment.
- Offer audits and surveys of water use.

Take Supply-Side Actions

- Improve operation and maintenance practices to increase efficiency.
- Implement a water-loss management program. Focus on pumps, pipe and valve leaks, and theft (water losses should be brought under 10 percent).
- Carry out facility assessments identifying water saving opportunities.
- Purchase appropriately sized energy-efficient equipment:
  - —Pumps
  - —Energy efficient motors
  - —Adjustable speed drives
  - —Impellers
  - —Lower friction pipes and coatings
  - —Valves
  - —Capacitors
- Introduce and enforce universal metering.
- Try reclaimed wastewater distribution for non-potable uses

Ad hoc management. A management approach in which no comprehensive effort is made to promote water efficiency. Efficiency actions that are implemented are likely to have been made without considering the effect on efficiencies in other parts of the system.

Adjustable speed drive (ASD). Devices that allow pumps and motors to adjust speeds to match varying load requirements.

Aeration control systems. Control systems that help optimize water treatment performance by controlling and adjusting the amount of air put into wastewater basins.

Air drying. The final stage in the primary treatment process of sludge in which digested sludge is placed on sand beds for air drying. Air drying requires dry, relatively warm weather for greatest efficiency; some plants have a greenhouse-like structure to shelter the sand beds.

Anaerobic digestion. An option of sludge processing that produces methane that can be burned as a fuel.

Aquifers. One or more geologic formations containing sufficient saturated porous and permeable material to transmit water at a rate sufficient to feed a spring or for economic extraction by a well.

Baseline. An analysis of the efficiency of a water utilities operation at a given point of time that can be used to compare with future efficiency.

Benchmark. Something that serves as a standard by which others may be measured or judged.

Bubble diffusers. In wastewater treatment, devices used to provide oxygen and agitation in biological treatment.

Bundling. Inclusion of many smaller projects together in a larger project.

Buyback. Offering industries money if they succeed in reducing certain levels of water everyday.

Bypass valve. Valve that allows flow to go around a system component by increasing or decreasing the flow resistance in a bypass line.

C-value. A factor of value used to indicate the smoothness of the interior of a pipe. The higher the c-value, the smoother the pipe, the greater the carrying capacity, and the smaller the friction or energy losses from water flowing in the pipe. To calculate the c-value, measure the flow, pipe diameter, distance between two pressure gauges, and the friction or energy loss of the water between them.

Capacitors. Devices that store electrical energy and are used to correct low power factor. Capacitors improve power factor and reduce the total power (kVA) that equipment consumes by supplying magnetic needs and locally reducing the reactive power (kVAR).

Centrifuge. A type of equipment used for dewatering. Centrifuge use rapid rotation of a fluid mixture inside a rigid vessel. The many designs of centrifuges include solid bowl, basket, and disc-stack.

Champion. A strong advocate for water efficiency in a water utility.

Chlorination. A major disinfection process for wastewater.

Climate change. A phenomenon caused by increased concentrations of CO_2, methane, and other greenhouse gases that has begun to affect municipalities adversely around the world through more extreme weather events, such as droughts, heat waves, floods, and storms.

Cogeneration. The production of electricity using waste heat (as in steam) from an industrial process or the use of steam from electric power generation as a source of heat.

Comminutor. Equipment that grinds up debris into finer particles.

Computerized control systems. Managing energy use by controlling pump operation, monitoring pump efficiencies, shifting loads to off-peak times, and controlling variable speed drives or pumps.

Cross-fertilization. In this report, the exchange of ideas and information among departments and people of different backgrounds.

Demand-side. Actions that reduce the amount of water consumed. This creates more system capacity, possibly avoiding investments in new facilities and equipment.

Dewatering. Sludge typically has a water content of greater than 90 percent, causing expensive recycling or disposal of pretreated sludge. Dewatering separates the liquids from the solids, thereby reducing recycling or disposal costs.

Digester gas. In *anaerobic* digestion, the sludge is fed into an air-free vessel. The digestion produces a gas, which is mostly a mixture of methane and carbon dioxide. The gas has a fuel value and can be burned to provide heat to the digester tank and even to run electric generators. This gas is called digester gas.

Digestion. A method of biological sludge treatment. Digestion can be either aerobic or anaerobic.

Disinfection. Destroying harmful microorganisms, thereby freeing from infection.

Efficiency kits. These contain inexpensive water-saving devices; supplied by municipalities to induce customers to conserve water.

Energy management system. A management structure designed to identify, implement, and verify savings from energy efficiency opportunities.

Energy performance contract (EPC). A way to finance and implement a capital improvement project by using a client's cost savings to cover project costs. An energy services company (ESCO) provides this service.

Energy services company (ESCO). A company that offers to reduce a client's energy costs, often splitting the cost savings with the client through an energy performance contract (EPC) or a shared savings agreement.

Facility assessment. A review of all equipment and devices involved with the processing, delivery, and treatment of water to identify efficiency opportunities. Also referred to as facility energy audits.

Filter press. A method of sludge dewatering.

Financial hurdle rate. A rate of return on investment that a proposed project must reach to be implemented.

Friction. The force that resists relative motion between two bodies in contact.

Frictional head. The head component attributable to friction.

Gray water. Processed wastewater not fit for drinking, but that can be used effectively in the industrial sector and for toilets or certain agricultural uses.

Grit removal. A wastewater treatment process to remove solids from wastewater.

Head. The measure of pressure indicating the height of a column of system fluid that has an equivalent amount of poten tial energy.

Headworks. A device or structure at the front or diversion point of a waterway to control the amount of water flowing.

Horizontal axis washing machine. A type of washing machine that spins clothes along a horizontal axis. They typically use less water than vertical axis machines.

Impeller. The spinning component in a centrifugal-type pump that pushes fluid through the system.

Incineration. A method of sludge treatment involving burning of the solid portion of the waste.

*Infiltration.*When water or other liquid per meates into a sealed pipe.

Kilovolt-ampere (kVA). A measurement of total power—active power, which does work (watts), and reactive power, which creates an electromagnetic field (VAR) ($kVA^2 = kW^2 + kVAR^2$). Capacitors can help reduce the total power required by supplying magnetic requirements (kVAR) on site.

Kilovolt-ampere reactive power (kVAR). One VAR is equal to a volt-ampere of reactive power; a kVAR is one thousand VARs. Reactive power does not do work like active power (kilowatts), but instead produces an electromagnetic field. Installing a capacitor can generate the required magnetic field on-site, reducing the total power (kilovolt-amperes) required to run a piece of equipment.

Load profile. A set of data often in graphic form portraying the significant features of energy consumption and demand of customers.

Metering. Measurement of water and elec tricity flow and consumption.

Methane. A colorless odorless flammable gaseous hydrocarbon (CH_4) produced by decomposition of organic matter and carbonization of coal and is used as a fuel and starting material in chemical synthesis.

Metrics. Measures of water efficiency. By creating a set of metrics to gauge improvements and identify inefficien cies, water efficiency management teams will be better able to prioritize opportu nities and assess their progress.

Monitoring. Tracking water efficiency programs. By developing comprehensive monitoring systems, many potential supply-side and demand-side savings opportunities can be identified, imple mented, and verified.

Nomograph. A graph consisting of three coplanar curves, each graduated for a different variable, so that a straight line cutting all three curves intersects the related values of each variable.

Organochlorine. A by-product of the chlo rine disinfection process for wastewater.

Outsourcing. The practice of subcontracting a function or most functions to outside companies. See also “energy service contracts.”

Overdesign. Systems designers occasionally overestimate the needed capacity to meet highest flow conditions. This can lead to operational problems and increases in costs.

Overharvesting. Removing more water from the ground, lakes, and rivers than is naturally replaced. This is an environ mentally threatening endeavor.

Oxidation ditch. A ditch that holds partially treated wastewater to allow algae, aquatic plants, and microorganisms in decom position process of the organic waste.

Ozonation. A disinfection process for wastewater using ozone.

Payback. The rate at which the savings from the project covers the initial costs of the project.

Pilot project. A small-scale version of a large project. Many utilities like to test ideas and potential actions on a small pilot level before they commit to a large investment.

Pipe relining. Recoating the interior of pipes with a low friction material to reduce friction losses.

Power factor. The ratio of active power (kW) to total power (kVA). A low power factor indicates a high level of reactive power (kVAR) that can waste electricity. Many utilities charge a penalty for low-power factors. Installing capacitors can correct low-power factors.

Pressure gauges. Instruments to measure pressure within a water system.

Price structure. A system that charges dif ferent prices for different customers and levels of consumption. To determine an appropriate price structure, utilities usu ally ascertain the price elasticity of water demand.

Primary treatment. The key method for pol lutant removal from sewage by means of sedimentation.

Programmable logic controls. Computerized control systems applied to electrically controlled equipment, such as pump variable frequency drives.

Proportional, integral, and derivative control (PID). Used to moderate wastewater flows rather than allow wastewater to surge and then stop.

Pump efficiency. A measure of the ability of a pump to transfer energy efficiently into pumping action.

Real-time rate pricing. The cost of buying or selling power based on the actual rates at specific times during the day.

Recalibration. Reformulating the set of graduations to indicate values or posi tions on a meter gauge.

Reclaimed water use. Water that has been used and would normally be disposed of, but is instead reused.

Renewable water. The amount of water that a watershed can replenish during a given timeframe. This is the amount of water that can safely be extracted with-out the danger of overharvesting.

Return on investment (ROI). A financial metric used to assess projects (ROI = profit/average capital*100).

Screening. A primary wastewater treatment process to remove solids.

Secondary treatment. Also known as biolog ical treatment, this process further reduces the amount of solids by helping bacteria and other microorganisms con sume the organic material in the sewage.

Sludge treatment. Stabilization or removal of hazardous waste constituents from a waste that is a mixture of both liquids and solids.

Stabilization. A sludge treatment process that chemically or physically immobi lizes the hazardous constituents in the waste by binding them into a solid mass. The resulting product has a low perme ability that resists leaching.

Static head. The head component attributa ble to the static pressure of the fluid.

Thickening. A sludge treatment process that removes as much water as possible before final dewatering of the sludge.

Throttle valves. A valve that regulates the supply of a fluid by increasing or decreasing the flow resistance across it.

Trickling filters. Used to reduce biological oxygen demand, pathogens, and nitro gen levels, trickling filters are composed of a bed of porous material (rocks, slag, plastic media, or any other medium with a high surface area and high per meability). Wastewater is first distrib uted over the surface of the media, where it flows downward as a thin film over the media surface for aerobic treatment and is then collected at the bottom through drain systems.

Trihalomethanes. Chlorinated by-products of wastewater disinfection processes.

Ultraviolet disinfection. A process using an ultraviolet (UV) light source, which is enclosed in a transparent protective sleeve. It is mounted so that water can pass through a flow chamber, and UV rays are admitted and absorbed into the stream. These rays destroy bacteria and deactivate many viruses.

Ultraviolet irradiation. UV irradiation is a physical disinfection process and, thus, different from a chemical disinfection process, such as chlorination. It has become the most common alternative to chlorination for wastewater disinfection in North America.

Unaccounted-for water. Loss in water supply and treatment due to leaks, unau thorized water usage, and poor water distribution and system maintenance.

Vacuum filter. A system of sludge dewater ing.

Variable frequency drives. Drives used to match motors and pumps to varying load requirements.

Water accounting. A system to account for water brought in from a source and delivered to end users, the customers. It should identify unmetered water, unauthorized water usage, leaks, losses, and so on.

Water audit. A methodical examination and review of a customer's water consump tion. Water audits can point out savings opportunities to the end user and, thus, act as a catalyst to induce implementa tion of efficiency measures.

Water subsidy. Charging a low water rate to consumers, even though the true cost of using water may be much higher. This has a distortionary effect and also encourages wasteful behavior.

Water-saving equipment. Equipment that helps conserve water, for example, low-flow faucets, ultralow flush toilets, effi cient washing machines, and so on.

Water-use categories. Different categories used to identify different types of water users, that is, residential, commercial, and so on. Targeting relevant efficiency programs at each category will be much more effective than having one generic program for all.

Watergy. Energy used in water systems.

Watergy efficiency. Optimizing energy use to cost effectively meet water needs.

Alliance to Save Energy. 2000. "The Impacts of Declining Water Tables in Ahmedabad." Unpublished report prepared with assistance from the Ahmedabad Energy Corporation. Washington, D.C.

American Gas Association. 2000. "Gaining Control Over Energy Costs." *Natural Gas Applications in Industry* Vol. 13, Issue 4 (Winter). Washington, D.C.

Arora, H. and M. LeChevallier. 1998. "Energy Management Opportunities." *AWWA Journal* (February).

Björlenius, Berndt. 2001. "Local Sewage Treatment Plant for Hammarby Sjöstad, Phase 1 Outline." City of Stockholm, Sweden. November.

Brown, Michael. 1999. "A Management System for Energy Proposed." *Energy Manager* (July/August).

Casada, Don. 1999. *Pumping Systems Field Monitoring and Application of the Pumping System Assessment Tool* (Oak Ridge, TN. U.S. Department of Energy).

CEGESTI, CACIA, and the Government of Costa Rica. 1995. *50 Sugerencias Para Una Mejor Eficiencia Ambiental en la Industria Alimentos*. Produced with the assistance of the Embassy of Canada in Costa Rica. San José, Costa Rica.

City of Austin. 2000. "Water and Wastewater Treatment Costs and the Potential of Conservation to Reduce These Costs." Austin Water Report. Austin, Texas.

City of Stockholm. 2000. "Welcome to Hammarby Sjöstad." Brochure. Hammarby Sjöstad Project, Real Estate, Streets, and Traffic Administration Stockholm, Sweden. December.

Confederation of Indian Industry (CII). 1998. *Manual on Energy Efficiency in Pumping Systems*. Energy Management Cell. New Delhi, India. September.

Gleick, Peter. 2001. "Making Every Drop Count." *Scientific American* (February).

Iowa Association of Municipal Utilities (IAMU). 1998. *Tap into Savings: How to Save Energy in Water and Wastewater Systems*. Ankeny, Iowa. <www.iamu.org/main/energy/water/waterport.htm> (accessed February 2001).

Jordão, E. P. 1995. "Tratamento de Esgotos Domésticos." Associação Brasileira de Engenharia Sanitária e Ambiental. Rio de Janeiro, Brazil.

Klein, Michael and Timothy Irwin. "Regulating Water Companies." In The World Bank Group, 1999, *The Private Sector in Water,* Washington, D.C.

Lau, Peter J. 1997. "Applying Disinfection Alternatives to Wastewater Treatment." *Pollution* Engineering. *September 1. <www.pollutionengineering.com/archives/1997/pol0901.97/09akc1f0.htm>.*

Loh, David. "Promotion of Public Information on Water Conservation in Singapore." Paper presented at the *Seminar on the Promotion of Public Information on Water Conservation,* organized by ESCAP in Bangkok, May 23–25, 2000.

Ng, K. H., C. S. Foo, and Y. K. Chan. 1997. "Unaccounted-For Water: Singapore's Experience." *Journal of Water Supply Research and Technology* Vol. 46, Number 5 (October).

Norland, Doug and Laura Lind. 2000. "Corporate Energy Management: A Survey of Large Manufacturing Companies." *22nd Industrial Energy Technology Conference Proceedings*. Houston, Texas, April 2000.

North Carolina Department of Environment and Natural Resources. 1998. *Water Efficiency Manual for Commercial, Industrial, and Institutional Facilities*. Raleigh, NC. August.

Obmascik, Mark. 1993. "Water Conservation: Dozens of Ways to Save Water, the Environment, and a Lot of Money." (Denver, Col.: American Water Works Association). August.

Oliver, Julia and Cynthia Putnam. 1997. "How to Avoid Taking a Bath on Energy Costs." *Opflow* (May).

Population Action International. 1990. *Water Stress Index, 1990: Sustaining Water: An Update*. Washington D.C.

Postel, Sandra. 2001. "Growing More Food with Less Water." *Scientific American* (March).

Rached, Eglal, Eva Rathgeber, and David B. Brooks, eds. 1996. "Water Supply and Management in Rural Ghana." Chapter 12 in International Development Research Center. *Water Management in Africa and the Middle East: Challenges and Opportunities*. Ottawa, Canada.

Rocky Mountain Institute. 1994. "Water Efficiency." Snowmass, CO. November.

Tata Energy Research Institute. 1999. *Practical Energy Audit Manual: Pumping Systems*. Indo-German Energy Efficiency Project. Bangalore, India. August.

USAID. 2000a. *Energy Savings Opportunities in Kolhapur City Water Supply*. Prepared by International Resource Group and Prima Techno-Commercial Services. Washington, D.C. June.

USAID. 2000b. *Water Practices in the Hotel Industry in Barbados*. prepared by Hagler Bailly Services Inc. Washington, D.C. March.

USAID. 2001. *Apaterm Water Distribution System, Galati, Romania*. Ecolinks Energy Efficiency Project. Prepared by The Cadmus Group Inc. and Apaterm, SA. Arlington, Virginia.

USAID, Hagler Bailly, and Environmental Export Council. 2000. "Prevencion de la contaminacion en una fabrica textil del Ecuador." (July 1998). *Information Resources on Industrial Pollution Prevention* (CD-Rom, Summer). Corporation for Technological and Scientific Management for the Urban Environment – OIKOS, Quito, Ecuador.

U.S. Department of Energy (DOE). 1996. "Reducing Power Factor Cost."DOE/GO-10096-286. Washington, D.C.

———. 1999. *Improving Pumping System Performance: A Sourcebook for Industry*. Office of Industrial Technologies. Washington, D.C. January.

———. 2000. *International Energy Annual 1999*. Energy Information Administration. <http://www.eia.doe.gov/pub/international/ieapdf/te_01.pdf> (accessed December 2000). Washington, D.C.

U.S. Environmental Protection Agency (USEPA). 1998. “Appendix A: Water Conservation Measures.” *Guidelines for Preparing Water Conservation Plans*. Washington, D.C. August.

Water Environment Federation. 1990. “Operation of Municipal Wastewater Municipal Plants.” MOP 11.

Wong, A. K., L. Owens-Viani, and P. Gleick., eds. 1999. *Sustainable Use of Water: California Success Stories* (Oakland, CA: Pacific Institute). January.

World Health Organization (WHO). 1989. *Health Guidelines for the Use of Wastewater in Agriculture and Aquaculture*. Geneva, Switzerland.

———. 2000. *Global Water Supply and Sanitation Assessment 2000 Report*. <www.who.int/water_sanitation_health/Globassessment/Global1.htm#1.1/> (accessed December 2001). Geneva, Switzerland.

Xie, Mei, Ulrich Kuffner, and Guy LeMoigne. 1993. *Using Water Efficiently: Technological Options*. World Bank. Technical Paper Number 205. Washington, D.C.

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[1] Based on the following data and assumptions:

1. *1000 cubic miles (or 4.2 quadrillion liters) of total annual world consumption* (Gleick 2001).
2. *6 kWh per 10,000 liters of water pumped* (estimated by Alliance to Save Energy).
3. *An estimated 30 percent of water is used by urban areas* (Postel 2001).
4. 381.9 Quads total annual world energy consumption (DOE 2000).
5. [(4.2 quadrillion liters × .0006 kWh/liter) × 10600 Btus/kWh] = 26.7 Quads and 26.7 Quads/381.9 Quads = 7%.

[2] CII 1998. In addition the Alliance to Save Energy estimated a *30 percent savings potential for municipal water utilities,* based on average unaccounted-for water levels, estimates of pump efficiency improvement opportunities, and other demand-side reduction technology.

[3] Based on the following data and assumptions:

1. *An estimated 30 percent of water is used by urban areas* (Postel 2001).
2. *30 percent savings potential for municipal water utilities* (estimated by the Alliance to Save Energy, based on average unaccounted-for water levels, estimates of pump efficiency improvement opportunities, and other demand-side reduction technology).
3. Thailand 2.47 Quads in 1999 (DOE 2000).

[4] United Nations (UN), "World Urbanization Prospects: The 1999 Revision," <http://www.un.org/esa/population/publications/wup1999/urbanization.pdf> (accessed on January 2002).

[5] Based on the following data and assumptions:

1. *1000 cubic miles of total world consumption* (Gleick 2001).
2. *6 kWh per 10,000 liters of water pumped* (estimated by Alliance to Save Energy).
3. *Japan 21.71 Quads and Taiwan 3.25 Quads in 1999* (DOE 2000).

[6] Oliver and Putnam 1997.

[7] Based on an analysis done by Laura Lind of the Alliance to Save Energy, using Model Energy Code Links (MECS), 1991. See also Arora and LeChevallier 1998.

[8] "Section 2: The Water Crisis: Where We Are Today and How We Got There," (<watervision.cdinet.com/pdfs/commission/cchpt2.pdf>), "Human Appropriation of the World's Fresh Water Supply," (<www.sprl.umich.edu/GCL/Notes-1999-Winter/freshwater.html>) in report by the World Commission on Water, <watervision.cdinet.com/commreport.htm> (accessed December 2001).

[9] WRI, "Table FW.1," <www.wri.org/wr-00-01/pdf/fw1n_2000.pdf> (accessed December 2001).

[10] Population Action International 1990.

[11] UN Habitat, "Global Urban Indicators," <http://www.unchs.org/guo/gui/index.html> (accessed January 2002). An average of the over 230 cities documented in this study.

[12] WHO, "Global Water Supply," Section 5.2. <www.who.int/water_sanitation_health/Globassessment/Global5-2.htm> (accessed December 2001).

[13] World Health Organization (WHO), "Global Water Supply and Sanitation Assessment 2000 Report," <www.who.int/water_sanitation_health/Globassessment/Global1.htm#1.1> (accessed December 2001).

[14] Klein and Irwin 1999.

[15] US Department of Energy, International Total Primary Energy Consumption (Demand) Forecasts <http://www.eia.doe.gov/oiaf/ieo/pdf/append_a.pdf> (accessed January 2002)

[16] Mukami Kariuki, "WSS Services for the Urban Poor," <www.wsscc.org/vision21/docs/doc16.html> (accessed December 2001).

[17] Based on an analysis done by Laura Lind of the Alliance to Save Energy, using Model Energy Code Links (MECS), 1991. See also Arora and LeChevallier 1998.

[18] WRI, October 27, 2000, "Water Quantity, Conditions, and Trends" and "Water: Critical Shortages Ahead?" <www.wri.org/trends/water.html> (accessed December 2001).

[19] WRI, "Freshwater Systems, Water Quantity," <www.wri.org/trends/water.html> (accessed December 2001).

[20] Based on the following data and assump tions:

4. *An estimated 30 percent of water is used by urban areas* (Postel 2001).
5. *30 percent savings potential for municipal water utilities* (estimated by the Alliance to Save Energy, based on average unaccounted-for water levels, esti mates of pump efficiency improvement opportunities, and other demand-side reduction technology).
6. Thailand 2.47 Quads in 1999 (DOE 2000).

[21] Water Supply and Sanitation Collabora tive Council, "Water Demand Management and Conservation," <www.wsscc.org/activities/vision21/docs/doc26.html> and <www.who.int/water_sanitation_health/wss/sustoptim.html> (accessed December 2001).

[22] WRI, "Table FW.1, <www.wri.org/wr-00-01/pdf/fw1n_2000.pdf> (accessed December 2001).

[23] Population Action International 1990.

[24] Kariuki, "WSS Services," <www.wsscc.org/vision21/docs/doc16.html> (accessed December 2001).

[25] CII 1998.

[26] UNICEF, <www.unicef.org/pon97/water4.htm> (accessed December 2001).

[27] United States Department of Energy, "Tomorrow's Energy Today for Cities and Counties," <www.eren.doe.gov/cities_counties/watersy.html> (accessed December 2001).

[28] Personal communications with Mr. Joe Boccia, Mr. Roman Kaszczij, and Ms. Tracy Korovesi of the Toronto Water Utility.

[29] United States Department of Energy, <www.eren.doe.gov/cities_counties/watersy.html> (accessed December 2001).

[30] Based on an analysis done by the Alliance to Save Energy in conjunction with the Indore Municipal Corporation's Energy Management Cell.

[31] Norland Lind 2000, pp. 220–27.

[32] American Gas Association, 2000, pp. A10–A11.

[33] Brown 1999.

[34] Norland and Lind 2000, pp. 220–27.

[35] Tata Energy Research Institute 1999.

[36] IAMU 1998.

[37] Tata Energy Research Institute 1999.

[38] Casada 1999.

[39] Casada 1999.

[40] CII 1998.

[41] Tata Energy Research Institute 1999.

[42] Personal communication with Amarquaye Armar, Principal Energy Specialist, World Bank, February 26, 2001.

[43] Helsinki University of Technology, Water Utility Benchmarking, <www.water.hut.fi/BUBI/> (accessed December 2001).

[44] USEPA 1998.

[45] IAMU 1998.

[46] USEPA 1998.

[47] Xie, Kuffner, and LeMoigne 1993, p.25.

[48] Adapted from Xie, Kuffner, and LeMoigne 1993.

[49] IAMU 1998.

[50] USEPA 1998.

[51] Xie, Kuffner, and LeMoigne 1993, p.19.

[52] Texas Water Development Board, August 1999, "A Guidebook for Reducing Unaccounted-for Water," <www.twdb.state.tx.us/assistance/conservation/guidebook.htm> (accessed December 2001).

[53] USAID 2001.

[54] CII 1998, pp.55–58.

[55] CII 1998, pp. 56–57.

[56] CII 1998, pp. 57 and 99.

[57] DOE 1999, pp.1–8.

[58] DOE 1999, pp. F10–3.

[59] CII 1998.

[60] DOE 1999, pp.1–7.

[61] DOE 1996.

[62] DOE 1999.

[63] USAID 2000a.

[64] IAMU 1998.

[65] Water Environment Federation 1990.

[66] IAMU 1998.

[67] IAMU 1998.

[68] IAMU 1998.

[69] Jordão 1995.

[70] Lau 1997, <www.pollutionengineering .com/archives/1997/pol0901.97/09akc1f0 .htm> (accessed December 2001).

[71] Soroushian, Fred, senior project manager and technology lead for UV disinfection at CH2MHill, e-mail: FSoroush@CH2M.com

[72] IAMU 1998.

[73] IAMU 1998.

[74] Xie, Kuffner, and LeMoigne 1993), p.25.

[75] Gleick 2001.

[76] WHO 1989.

[77] National Association of Energy Service Companies, "Trade Missions to Mexico, Japan/Thailand, and Brazil," <www.naesco.org> (accessed December 2001).

[78] Alliance to Save Energy 2000.

[79] Sydney Water, 2000, "Using Water: Encouraging Efficient Use of Water by the Community," <www.sydneywater.com.au/ html/AER2000> (accessed December 2001).

[80] Gleick 2001.

[81] Reuters, "Major Chinese Lake Disappearing in Water Crisis," <asia.cnn.com/2000/NATURE/12/20/ china.lake.reut/>. Posted: 2:33 PM EST (1933 GMT) December 20, 2000.

[82] Alliance to Save Energy 2000.

[83] USAID 2000b.

[84] Obmascik 1993.

[85] Rocky Mountain Institute 1994.

[86] Obmascik 1993, table 4–2.

[87] Obmascik 1993, table 4–3.

[88] Singapore Public Utility Board Website, <www.pub.gov.sg/ce.html> (accessed December 2001).

[89] Rand Water Homepage, <www.waterwise.co.za>.

[90] USAID, Hagler Bailly, and Environmental Export Council 2000.

[91] North Carolina Department of Environment and Natural Resources 1998, 120 pp.

[92] CEGESTI, CACIA, and the Government of Costa Rica 1995.

[93] North Carolina Department of Environment and Natural Resources 1998.

[94] Wong, Owens-Viani, and Gleick 1999.

[95] Rached, Rathgeber, and Brooks 1996.

[96] Kariuki, "WSS Services," <www.wsscc.org/vision21/docs/doc16.html> (accessed December 2001).

[97] WHO, "Global Water Supply," <www.who.int/water_sanitation_health/ Globassessment/Global3.4.htm.>

[98] Water Supply and Sanitation Collaborative Council, "Water Demand Management and Conservation," <www.wsscc.org/activities/vision21/docs/ doc26.html> and <www.who.int/ water_sanitation_health/wss/ sustoptim.html> (accessed December 2001).

[99] City of Austin 2000.

[100] City of Stockholm 2000.

[101] City of Stockholm 2000.

[102] Björlenius 2001.

[103] Personal communication with Berndt Björlenius, project leader for the Local Sewage Treatment Plant for Hammarby Sjöstad, July 2001.

[104] Sydney Water Corporation, WaterPlan21, (<www.sydneywater.com.au/html/ Environment/waterplan21.cfm>) and *2000–05 Environmental Plan* (<http://www.sydneywater.com.au/html/ Environment/enviro_plan_2000.cfm>) (both accessed January 2002).

[105] Sydney Water Corporation, *Sydney Water Annual Report 2001* (<www.sydneywater.com.au/html/about_us /report_2001/index.html>) and *Sydney Water Towards Sustainability* (<www .sydneywater.com.au/html/tsr/about/about .html >) (both accessed January 2002).

[106] Personal communication with Juan Carlos Herrera Arciniegas, EEPPM planning specialist, March 2001.

[107] Rand Water Homepage, <www.waterwise .co.za> (accessed December 2001).

[108] City of San Diego Website, October 2001, "News," <www.sannet.gov/mwwd/ news/index.shtml> (accessed December 2001).

[109] Ng, Foo, and Chan 1997.

[110] Ng, Foo, and Chan 1997.

[111]Loh 2000.
[112]As seen on the Singapore Public Utility Board Web page (<www.pub.gov.sg/ce.html>) on May 2001.
[113]Alliance to Save Energy 2000.
[114]Personal communication with Jeff Broome, Project Coordinator of the Bulawayo Water Conservation and Sector Services Upgrading Project, February 2001.

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