WATERGY:

Energy and Water Efficiency in Municipal Water Supply and Wastewater Treatment

Cost-Effective Savings of Water and Energy

The Alliance to Save Energy

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ALLIANCE TO SAVE ENERGY
Creating an Energy-Efficient World

watergy
WATER & ENERGY EFFICIENCY

TABLE OF CONTENTS

ACRONYMS

AWWA	American Water Works Association
BEP	best efficiency point
ESCO	energy service company
GIS	geographical information system
HVAC	heating, ventilation and air conditioning
kWh	kilowatt hour
M&V	monitoring and verification
MTU	master terminal unit
O&M	operations and maintenance
RTU	remote terminal unit
SCADA	supervisory control and data acquisition

TABLES & FIGURES

EXECUTIVE SUMMARY

The term "Watergy" was coined by the Alliance to Save Energy to describe the strong link between water and energy in municipal water systems. The Watergy approach helps cities realize significant energy, water and monetary savings through technical and managerial improvements in water supply and wastewater treatment systems, creating efficiencies that provide consumers with quality service with a minimum of water and energy. Efficiency in the water sector involves both the *end use* of water—such as efficient toilets, low-flow showerheads and reducing peak demand—as well as efficiencies in the *supply* of water. This paper focuses on the water supply system itself since in many cities most of the inefficiencies occur before the water even reaches the end user.

Watergy principles have been applied in numerous cities around the world, demonstrating that water efficiency measures repay themselves quickly and yield many rewards: immediate improvements in water service, increased water delivery, reduced water and energy consumption, and more revenue for system upgrades and new customer connections. Opportunities abound throughout all stages of a water supply system. The most promising areas for intervention within water supply systems are:

- ❶ improving the pumping system,
- ❷ managing leaks,
- ❸ automating system operations, and
- ❹ regular monitoring (preferably with rigorous metering of end use).

These improvements often pay for themselves in months, most do so within a year, and almost all recover their costs within three years.

The *pumping system* is all important, since every liter of water that passes through the system represents a significant energy cost, a cost that is magnified by every liter lost to leaks. Pumping improvements range from lower cost measures like soft starters for motors, trimming impellers (when pumps are over-sized) and re-winding motors, to higher cost measures like replacing inefficient pumps with efficient ones and installing variable speed drives. *System automation* saves water, energy and operation costs, improves service, and lengthens equipment life. Automation handles operational functions in real time in response to changing situations. Examples are optimizing pressure in the network, triggering alarms in case of emergency, and turning off pumps. *Regular monitoring* of the system components, operations, and performance is essential in order to track performance and evaluate it against a set of benchmarks and targets. Incorporated as part of the larger O&M protocol, monitoring is a no- or low-cost efficiency enhancement within reach of all utility budgets. Effective *management of leaks* can save enormous quantities of water and energy. Leakage rates can be lowered dramatically with automated controls that reduce pressure in the network, especially at night. Pressure management is generally more cost-effective than expensive repairs to numerous leaks in buried pipes.

This paper provides a comprehensive overview—suitable to all technical levels—to introduce the reader to the approaches and benefits of Watergy. It is intended for a wide audience ranging from municipal and water utility decision makers, to funding organizations, to technical utility staff who want a solid understanding of what a water efficiency program entails without a high level of technical detail.

I. INTRODUCTION: CHALLENGES AND OPPORTUNITIES

The term "**Watergy**" was coined by the Alliance to Save Energy to describe the strong link between water and energy in municipal water distribution systems. Watergy helps cities realize significant energy, water and monetary savings through technical and managerial interventions in water and wastewater systems, providing consumers with quality water while using a minimum of water and energy. In areas where either resource is constrained, Watergy is a valuable resource waiting to be tapped, so cost-effective that the time it takes for improvements to pay themselves generally ranges from a few months to three years. The resulting savings leave more funds for critical public services. For those bearing the financial responsibility for local public services, efficiency in the provision of energy and water is one of the few cost-effective options available for meeting growing demands for vital services such as electricity, water and wastewater treatment. In addition to direct savings in energy and water, efficiency improvements in municipal water utilities generate impressive reductions in operating costs and often improve service.

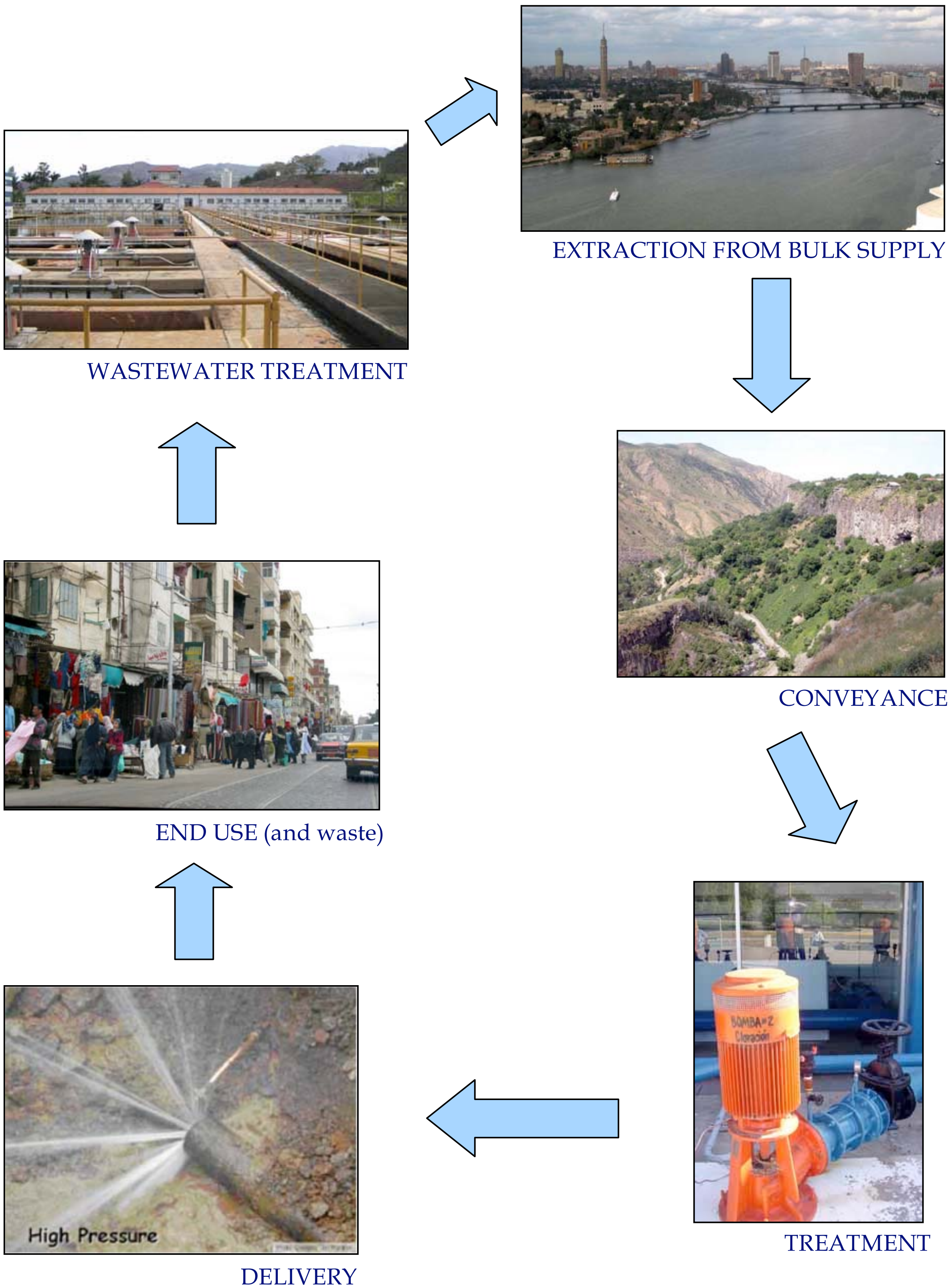
> Watergy makes the best use of two valuable, limited resources: water and energy.

The integral relationship between water and energy is not widely understood or sufficiently exploited through coordinated, holistic efficiency approaches. The water-energy relationship is based on the reality that treating water for human consumption and moving treated water to the consumer is an extremely energy intensive undertaking. Every liter of water that passes through a system represents a significant energy cost. **Figure 1** illustrates the major steps involved with providing municipal citizens with clean water and treating wastewater for safe discharge, each of which requires a significant and quantifiable amount of energy. The relative energy importance of the different steps depends on factors like the topography between the water source and its destination (especially elevation change), distance from the bulk water supply, and the integrity of the primary mains (supply pipes) and secondary mains (distribution pipes). Globally, energy is among the top three cost items to water utilities, often coming second after labor costs. In developing countries, energy is usually the highest cost associated with water supply.

Water supply and wastewater treatment are also infrastructure-intensive, requiring expensive pumping, treatment, and conveyance systems. Water access can be expanded much more quickly and inexpensively through efficiency than new infrastructure, deferring the need for additional infrastructure investment. Also, water and wastewater investment decisions that neglect energy efficiency have a domino effect that increase investments in other sectors, such as power plants, investments to extract and transport the additional fuel, and the environmental costs associated with air emissions and declining water and hydrocarbon reserves. A development agenda that maximizes the capacity of existing infrastructure through efficiency before encouraging new construction is the most cost-effective and sustainable way to meet the growing need for clean water. By incorporating efficiency into existing and planned infrastructure systems, costs can be controlled, service delivery can be improved and access expanded without necessarily adding to the cost of the service.

Part of what makes water supply such an energy intensive process, as well as one that squanders precious fresh water, is that so many distribution systems around the world are leaky. Even many cities in fully industrialized countries have high leakage rates due to aging

Figure 1. Lifecycle of Water Supply



Common Barriers to Energy and Water Efficiency

For some, the case for efficiency seems sufficiently compelling that its universal adoption should simply be a matter of course. In reality there are serious obstacles to the widespread adoption of more efficient practices and technologies, which can be grouped into five main categories:

1. *Lack of Awareness.* People will not make changes towards efficiency unless they are aware of the cost-benefit arguments for doing so. This is especially true in the case of applying energy efficiency to water supply, since those who operate day to day in the water sector are not accustomed to focusing on energy.
2. *Aversion to Risk.* Deviating from the usual routine is associated with risk, real or perceived, such as added burden on staff or financial risk. Fear of change has a rational basis and breaking through it requires that the fears be addressed and that the benefits of change clearly outweigh risks.
3. *Change May Imply a Problem with the Status Quo.* It is not uncommon for staff to be resistant to new ideas and procedures due to a feeling that suggestions for change imply criticism of their performance and ability.
4. *Subsidies.* Although subsidies have a role in providing essential services to the poor, when they are poorly planned or implemented they often greatly reduce the cost incentives inherent in efficiency. Some subsidies are unofficial, such as the tacit approval by the authorities of water or electricity theft.
5. *Financing Efficiency.* Quite a few Watergy measures cost little if anything. For those that do require capital outlays, performance contracting approaches pay for project costs from the cost savings on water and energy. Those contemplating efficiency improvements often lack an understanding of performance contracting mechanisms, especially the awareness that they can be applied to the water sector. In some countries, financing issues are compounded by an insufficient supply of service providers capable of performance contracting, or the suppliers exist but the industry is so nascent that confidence in them is lacking. This lack of confidence usually translates into an inability of these firms to provide the project financing, since their unproven creditworthiness either denies them access to loans altogether, or the terms are poor. On the flip side, in some countries municipal governments do not have a good track record of sound financial management or honoring contracts, making efficiency service providers reluctant to enter into contracts with municipalities.

infrastructure. Whenever water is lost to leaks, also lost are the energy and cost of energy embodied in that water, from pumping, treating and conveying the water. When water is lost before it reaches the end user—which is where the majority of losses occur in many countries—the associated water production costs cannot be recovered.

In developing countries, typically one-third to one-half of the volume of water produced is lost to leaks and system inefficiencies. In Latin America, for example, one-third of the water that enters distribution systems in Mexico is lost before it reaches the consumer; the losses average 44%in Brazil. Indian cities lose about half of their water to leakage on average, with the figure being about 40% in large metropolitan cities but more in the range of 50% to 60% in smaller cities. In South Africa most big cities also average about 40% loss. Watergy can produce the dramatic reductions in such losses needed to bridge the growing gap between the need for water and the capacity to provide it. For example, the water currently lost to leaks in Mexico would cover the growth in demand expected there for the next six years, meeting future needs and diminishing current shortfalls so that investments in infrastructure could be postponed, and stretching limited water and energy resources.

Table 1. Water and Wastewater Utility Systems that Use Energy

STAGE	OPERATION	ENERGY-USING SYSTEMS
EXTRACTION	Deep well extraction	Submersible or shaft turbine deep well pumping systems
	Extraction from a surface source	Horizontal or vertical centrifugal pumping systems
TREATMENT	Chemical (disinfection and clarification)	Piston-type dosing pumps
	Physical (e.g. filtration and sedimentation)	Pumping systems, fans, agitators, centrifugal blowers
PIPING BETWEEN SOURCE AND DISTRIBUTION NETWORK	Sending the drinking water to the distribution grid	Submersible or shaft turbine deep well pumping systems; horizontal or vertical centrifugal pumping systems
	Booster pumping	Horizontal or vertical centrifugal pumping systems used to increase pressure of water going into the distribution system or to pump water to a higher elevation.
DISTRIBUTION	Distribution to end users	Horizontal or vertical centrifugal pumping systems
STORM AND SANITARY SEWER SYSTEMS	Piping of sewage and/or rainwater	Horizontal or vertical centrifugal pumping systems
	Wastewater treatment and disposal	Pumping systems, fans, agitators, centrifugal blowers
SUPPORT SYSTEMS	Support functions associated with the utility building(s)	Lighting systems, HVAC (Heating, Ventilation and Air Conditioning), etc.

II. TECHNICAL AND MANAGERIAL APPROACHES TO WATERGY

To the extent that municipalities and water utilities think about efficiency in the water sector, it is most often limited to demand side management or conservation *after* the water arrives at end user properties. While there are tremendous efficiency gains to be made downstream of the water meter, as demonstrated by South African case studies presented in Section IV, there are numerous fruitful efficiency opportunities in the various stages preceding the arrival of the water at its end use destination. **Table 1** summarizes the many components involved in supplying water and treating wastewater that use energy, apart from end use.

In the experience of the Alliance to Save Energy, which has helped over 40 water utilities implement Watergy programs, no two Watergy projects are alike. The specific form that a Watergy project will take depends on a myriad of local factors such as water scarcity, geography, tariff structures for water and electricity, culture, and the way that water supply is governed and administrated. However, over the years the Alliance has used its practical experience facilitating Watergy projects around the world to forge a general approach to creating lasting water efficiency improvements. This approach is illustrated in **Figure 2** and the three steps in the process—generating political will, technical management and analysis, and implementing efficiency measures—are described in this section. Financing the measures is addressed in Section III.

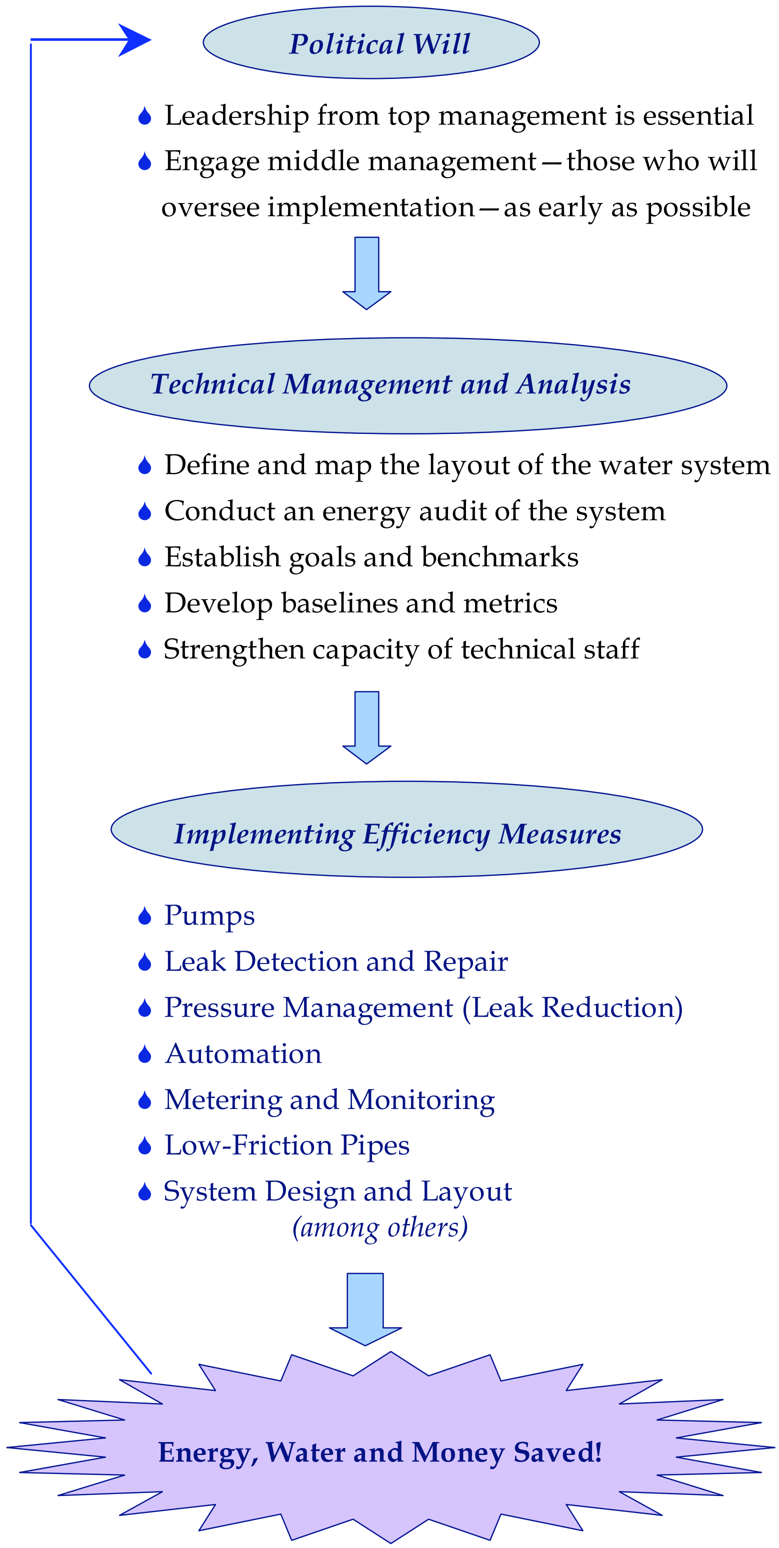
A. Generating Political Will

Lasting change in any institution requires political will at the senior management level. In the context of end use efficiency of water, a public good, the will of the community can also be critical to the success or failure of an attempt to improve efficiency of water supply or wastewater treatment. This is especially true when consumers will be asked to take on additional costs or responsibilities as a result of an intervention, though this will generally not be the case for improvements focused o the water supply system itself.

In the manufacturing sector, energy is largely viewed as a manageable cost, and one that can lead to reduced production costs and an improved bottom line through investments in technology and staff capacity. These companies have come to understand that, using technologies that are readily available, energy efficiency investments have rapid payback periods. In the water sector, the greatest obstacle to large-scale implementation of efficiency stems from the lack of expertise both at the management and technician level. The water sector languishes in a climate where few efficiency examples serve as models for implementing these initiatives on any meaningful scale, although Watergy is rapidly changing that as more and more successes are achieved.

Management understands all the concepts embodied in Watergy: efficiency, productivity, reliability, minimizing operating costs, and generating revenue. Managers will generally become believers in water and wastewater system efficiency if the opportunities are presented in these terms, accompanied by examples where other utilities have been successful. A cost-benefit analysis is needed in order for decision-makers to know how long it will take for improvements to pay for themselves. Payback periods for Watergy measures, summarized in **Table 2**, are often less than two years and very seldom exceed three years. Another key component to an overall cost-benefit analysis is understanding life cycle costs. This is especially critical in the case of pumps since pumping systems account for most of the energy usage in

Figure 2. Stages of the Watergy Approach



water supply and wastewater treatment systems. Over the lifetime a typical pump, when all costs to operate and maintain the pump are considered, 3% of the total cost is for purchase and 74% is for energy! A more efficient pump also has lower maintenance & downtime costs. **Figure 3** illustrates the tremendous cost advantage of buying energy efficient pumps: even though the purchase price of an efficient pump can be significantly higher than an inefficient one, the energy savings make. The efficient pump less expensive even in the first year when the purchase was made. In subsequent years the lower operating costs go right to the bottom line, almost $50,000 per pump in this example, year after year.

Table 2. Measures to Improve Efficiency in Water Supply and Wastewater Treatment and Illustrative Payback Periods

Area	Function	Typical Payback Period (years)
Electricity Rates	Reduce demand during periods of peak electricity rates	0 – 2 depending on storage capacity
Electric installations	Power factor optimization with capacitors	0.8 – 1.5
	Reduction in voltage imbalance	1 – 1.5
Operations and maintenance	Routine pump maintenance	2
	Deep well maintenance and rehabilitation	1 – 2
Production and Distribution	Use automation (such as telemetry, SCADA, and electronic controllers on modulating valves), for example to control pressure and output in the networks, and to optimize the operation of pumping equipment	0 – 5
	New efficient pump	1 – 2
	New efficient motor	2 – 3
	Replace Impeller	0.5
	Optimize the distribution network (e.g., by removing unnecessary valves, sectoring, and installing variable speed drives and regulating valves)	0.5 – 3
End Use	Incentive program for the use of efficiency technologies	1 – 3
	Effective metering of consumption	1 – 2

It is best to engage middle management in the discussions as early in the process as possible. Once middle management receives word from the top to proceed, they will be the ones overseeing the Watergy program. The program will run much more smoothly if they are convinced of its merits and if their expert opinions have been incorporated into the planning process.

A preliminary "walk-through" audit is often necessary to get commitment from management because it generates a list of the kinds of interventions that can be made and at least a rough estimate of the energy, water and monetary savings that will result. The cost for a preliminary audit will vary depending on the level of detail, but they are generally easily affordable

B. Technical Management and Analysis

The first technical step towards an efficient system is to ensure that the physical layout of the water distribution or wastewater treatment system is accurately captured in both graphic form (sore form of schematic layout) and descriptively. Ideally the system layout will be entered into a Geographical Information System (GIS), and linked to the engineering database and the database of billing information for the system. This level of sophistication will not be possible in all locations, but in any case a system cannot be managed effectively unless its boundaries are defined and the technical parameters and location of all of its components are described. If the system has not been well defined, or an existing schematic layout has not been updated recently, this can be done as part of the detailed efficiency audit on the system.

The next step is to have a qualified efficiency service provider perform an investment grade audit on the system to determine what measures can be taken to improve energy and water efficiency, and their payback periods. The main purpose of this step is to translate technical findings into the financial terms needed by decision makers. In cases where external financing is sought, banks need this financial information to assess whether the project is a bankable one capable of servicing a loan.

The audit begins with discussions between the auditor and key personnel from both the managerial and technical levels of the system. The purpose of these meetings is two-fold. One is to ensure that the decision makers thoroughly understand and are on board with the process. The other is to ensure that relevant facility staff have an adequate understanding of the process since they will be providing the auditor with data and specifications about the facility essential to the audit. Next the auditor will visit all facilities involved in the project to ascertain the availability of data and system complexity, formulate a data collection strategy, and identify the proper personnel at different facilities with whom to coordinate on the audit.

Examples of measurements made in an audit on water supply or wastewater treatment systems

Pumping Systems

- Total head (water pressure in the system)
- Pumping system efficiency

Electrical Systems

- Power factor
- Losses in transformers and cables
- Analyzing electricity bills
- Peak and off-peak operating loads

Electrical Motors

- Motor losses and loads
- Potential savings from improvements like

The audit provides the basis for deciding which efficiency measures to implement by providing:

- a description and inventory of all relevant systems and facilities covered by the audit;

- the results of the energy performance and system optimization evaluation of all facilities targeted for improvements, including efficiency tests on the major energy consuming equipment and energy consumption details;
- a description of the methodology followed in establishing the baseline parameters and the criteria to be followed in adjusting it as needed over time;
- the various types of data collected and their sources;
- system maps and the methodology followed for mapping the system (if not already available);
- a list of all efficiency measures identified—including any suggestions for improving operating and maintenance practices—prioritized according to the highest rate of return on investment; and
- a suggested monitoring and verification plan to track progress during implementation.

In addition, the following three steps are critical to maximizing the savings and system improvements that are made:

- establishing performance targets and benchmarks against which to evaluate progress;
- developing metrics relative to the baseline, as well as a monitoring system to measure them; and
- strengthening the capacity of technical staff in new procedures and technologies.

C. Implementing Efficiency Measures

This paper focuses on the four most fruitful areas of intervention for water and wastewater efficiency improvements:

- Pumping
- Leak Management
- System Automation
- Metering and Monitoring

The intention is to provide an overview of the most common interventions, rather than to delve into operational details on implementing them. **Figure 4** provides a snapshot of some typical Watergy measures.

> ***Buy pumps based on efficiency, not purchase price***
>
> Over the lifetime of an inefficient pump, the purchase price accounts for only about 3% of total costs, while energy to run the pump accounts for about three-quarters of the costs. An inefficient pump also has higher costs for maintenance and downtime.

1. Pumping Systems

One of the most critical elements to improving water or wastewater system efficiency is to optimize energy consumption by the pumping systems. Optimizing the system includes improvements such as matching the pump to requirements, optimizing the distribution piping, eliminating unnecessary valves, controlling pump speed where appropriate, and institutionalizing improved O&M practices. For example, according to a study by the U.S. Department of Energy[1], matching pumps to the

[1]United States Industrial Motor Systems Market Opportunities Assessment, December 1998, www1.eere.energy.gov/industry/bestpractices/pdfs/mtrmkt.pdf

Figure 4. Some Typical Watergy Interventions

Improve Pump System Efficiency

- Replace inefficient (and often over-sized) pumps with efficient, properly sized ones.
- Install variable speed drives
- Regular preventative inspection and maintenance, including cleaning or replacing impellers and checking lubrication of bearings.
- Re-wind pump motors (when insufficient funds to replace them)
- Trim impellers where pumps too large for the application but otherwise suitable.

Leak Management

- Leak detection and repair
- Pressure management within the network
- Measure minimum night flow to gauge leakiness of system

System Automation

Automate the system; various levels of complexity depending on needs and resources:

- Stand alone devices – perform actions only where placed.
- Telemetry – transmits information from remote devices to a central station.
- Supervisory Control and Data Acquisition (SCADA) – remotely controls components such as pumps and provides operational information in real time.

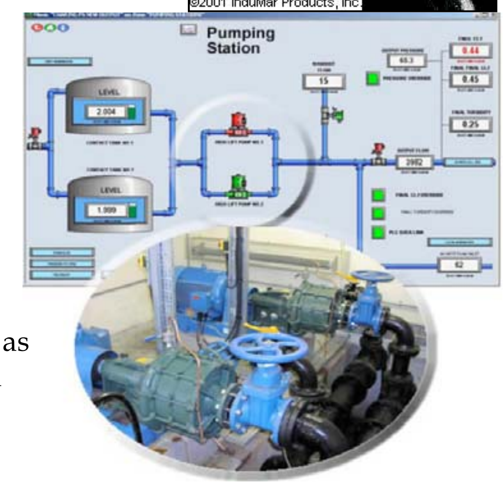


Photo: Mid Kent Water

Metering and Monitoring

- Create a system for regular monitoring of system components and performance
- Install and maintain water meters; replace on a regular basis (about every 10 years).
- Develop metrics to track system performance and compare performance to appropriate benchmarks and targets.
- Monitor the pump system (such as valves, flow, pressure, rotating speed, energy used, volume pumped, and velocity in the main headers).

system requirements so no more flow and pressure are pumped than needed generally saves between 10 and 30 percent, while the appropriate use of variable speed drives[2] to adjust pump speeds saves on average 10.5%. Pump system optimization can readily result in 20% energy savings, with savings of 30 to 40% often feasible.

The pumping system should be analyzed to identify the opportunities for improvements. Software is available for this purpose, for example the Pumping System Assessment Tool provided free of charge on the U.S. Department of Energy web site.[3] Such analysis can identify inefficiencies such as equipment that runs when it doesn't need to, and unnecessary restrictions such as valves. A common problem in water supply and wastewater treatment pumping systems is for pumps to be too large for the needs of the system. All pumps have a best efficiency point (BEP)—the flow rate at which the pump operates with the lowest energy intensity (volume moved per kWh)—and a pump operating at a flow rate significantly lower than its BEP is wasting a lot of energy and wearing out more quickly. Besides switching to a smaller pump other possible approaches are to trim the impeller[4] (that is, to reduce the length of the blades that move the water), install a smaller impeller, reduce pump speed, and—for a multi-stage pump—remove one or more stages.

Aside from an initial set of efficiency measures, it is critical to institute improvements in the routine operations and maintenance protocol. Managers should develop a facility layout showing the location of all critical pumps and use it as a road map for the maintenance technicians to follow for troubleshooting, preventive inspection, cleaning, and minor adjustments. Some routine operations and maintenance procedures that increase the life of equipment as well as efficiency are to:

- Monitor the electrical system, including motors (such as motor operating parameters, power factors, peak and off-peak loads, and electricity consumption).
- Optimize pump variables (pressure, flow, peak load, and motor starting and stopping).
- Clean the impellers and replace as needed.
- Periodically run the manufacturer's field test on the pumps and check the packing and lubrication of the bearings.
- Check pumps for excessive heat, leaks, vibration and noise.
- Maintain uniform flow profiles at pump inlets and outlet

2. Leak Management

The phrase leak management is used here to embrace two basic activities, apart from repairing leaks, aimed at reducing water losses from a water supply or wastewater treatment system: leak

[2] Electronic variable speed drives adjust the speed of the motors they control by varying the voltage and frequency of the electric power supplied to the motor. They sense the load required of the motor and change its power and speed accordingly. VSDs save energy because pumps often do not need to operate at their maximum load, so the motor driving the pump can run with less power whenever the application requires less than a full load.

[3] www1.eere.energy.gov/industry/bestpractices/software.html

[4] The impeller is basically a propeller inside the pump, powered by the shaft upon which it is mounted. The torque power of the engine is translated from the shaft to the blades of the impeller to move water.

reduction through pressure management, and leak detection. This section addresses only physical, or "real" losses (i.e., leaks), and not "apparent losses". The American Water Works Association (AWWA, www.awwa.org) defines real and apparent losses as follows:

> **Real losses** are the physical losses of water from the distribution system, including leakage and storage overflows.
>
> **Apparent losses** are the paper losses that occur in utility operations due to customer meter inaccuracies, billing system data errors and unauthorized consumption. In other words, this is water that is consumed but is not properly measured, accounted or paid for.

This paper is generally silent on apparent losses other than a brief discussion relating to end use metering in Section II.C.4. It should be noted, however, that in addition to many other advantages of end use meters, they are also an essential element in leak management because a higher than normal meter reading can be a sign of a leak on the property.

ANALYZING LEAKAGE

Before leaks can be managed, the network must be analyzed to determine the extent of leakage and the sources. There is a variety of software available to assist with this, but all require basic data on the system such as water supply, billed and metered consumption, and average operating pressure. Water audit software is available free of charge from AWWA (http://www.awwa.org/WaterWiser/waterloss/Docs/WaterAuditSoftware.cfm). This software is not intended to replace a full audit, and it does not address energy, but is a good place to start a leak management program because it uses data entered by the user to calculate various types of real and apparent water losses, as well as performance indicators.

Another way to gauge the extent of leakage from the system is to measure *minimum night flow*, meaning the volume of water supplied per hour to the network when there is little demand, generally between about 1 and 4 a.m. In a section of a network where leaks are well controlled, the minimum night flow won't be much above zero, as shown in **Figure 5**. The higher the minimum night flow, the leakier the system. One extreme example of this was in Emfuleni, South Africa (the case study which is given in Section IV), where minimum night flows were measured as high as a staggering 2800 m^3/hr (or 12,300 gal/min) because 80% of the water being supplied to this residential area was lost through leaking household plumbing fixtures (mainly toilets).

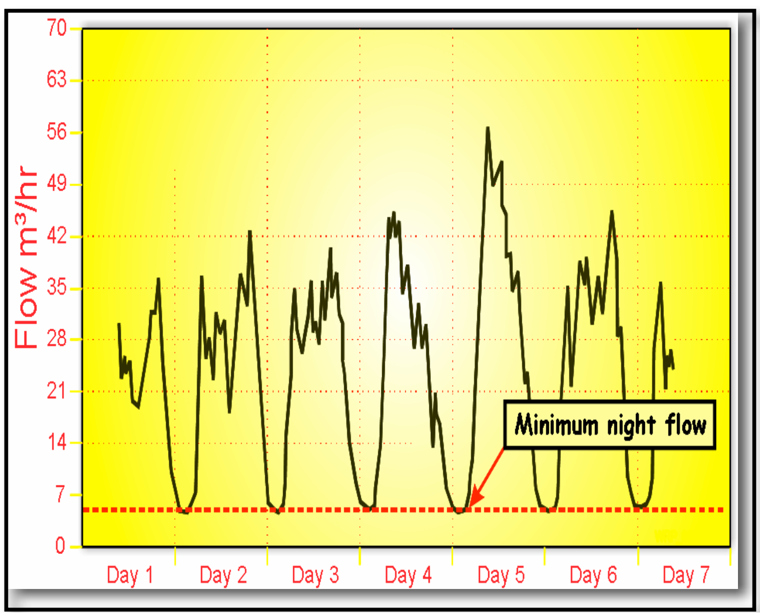


Figure 5: Minimum Night Flow Where Leaks are Well Managed *(courtesy of Ronnie McKenzie, WRP, Ltd.)*

Leak Detection

Once a preliminary analysis provides an overview of leakage in the distribution system as the whole, the most cost effective approach is to identify and address the largest 20% of the leaks, since a rule of thumb is that they account for 80% of the losses. A *zoned distribution system* allows for isolating the worst leaks to a particular zone which can then be more accurately assessed using appropriate leak detection equipment. Strategically installed flow meters divide the network into a set of defined sections or zones that can be analyzing individually. A leak is suspected if the flow measured at the downstream end of a zone is lower than that measured at the entrance of the zone. To further narrow down the location of leaks the *step test* is used, in which sections of pipe are progressively isolated by closing line valves located within a zone. The isolation can be done either by beginning at the pipes farthest away from the meter and ending at the pipe nearest the meter, or by halving the zone with the centrally located meter and then sequentially halving sub-zones until the leaking section of pipe is located. Ideally the step test is performed at night when demand is most stable and disruption to consumers is minimized.

Figure 6. Acoustic Loggers and Digital Ground Microphone for Leak Detection
(Photos: Gutermann International, www.gutermann-uk.com)

Leak detection equipment spans the range from basic to sophisticated, several of which will be discussed here to illustrate the types of technology used. The simplest device is the ground microphone, which is simply a microphone held over the ground to amplify the sound made by the leak. A significant step above that is the digital leak noise correlator. Two sensors are attached on pipe fittings or connected to hydrants on either side of the suspected leak. Noise made by the water as it escapes through the leak is conducted along the pipe, both in the form of vibrations in the pipe and as a pressure wave through the water column. Since the signals from the leak travel at the same speed in both directions, the first sensor to detect the noise is the one closest to the leak. The correlator calculates the leak position based on the difference between the arrival times at the two sensors, combined with data on the pipe type and length. Depending on conditions, the leak can be located to within centimeters.

Two more sophisticated devices are the acoustic logger and digital ground microphone (shown in **Figure 6,** left and right respectively). Acoustic loggers are placed on surface fittings such as fire hydrants or valves, and can be either permanently installed or used as needed for short periods of about two days. Loggers in different locations record noise from the pipes, including the sound of any water rushing through leaks, and software correlates the noise amplitudes and different locations of the loggers to locate the leak. The advantage of the digital ground microphone is that it detects actual leak noise—without ambient interference—rather than an indirect signal. In addition to measurement of the exact digital value in real time, the noise level is also delivered graphically and through headphones. By recording noise levels for a number of locations the position of leak can be located with high precision.

PRESSURE MANAGEMENT

The principle behind pressure management is simply that decreasing water pressure in the network decreases the volume of water escaping through any existing hole or leak in the pipe, as demonstrated by the photographs in **Figure 7**. It is also beneficial because it allows the utility to equalize pressure within the network, allowing a greater number of people to be served with little or no increase in water input. Ideally the pressure reduction valves and associated equipment will be automated so that pressure can be automatically adjusted to account for fluctuations such as changing incoming pressure, and pressure can be reduced even further at night when demand is low. In situations where the buried pipes of the network have numerous leaks, pressure management is likely the most cost-effective way of reducing leakage, aside from major leaks that must be repaired. A case study in Section IV, for Emfuleni in South Africa, describes a pressure management project with a payback period of less than three months that is saving 14 million kWh of electricity and 8 million kL of water (over 2 *billion* gallons) every year.

Figure 7. Burst water main at high and low pressure
(photos: Ronnie McKenzie, WRP, Ltd.)

3. Automation

Automation in a water supply or wastewater treatment system monitors—and if sophisticated enough, also controls—various system components for optimal system performance and efficiency. Automation varies in complexity but it always has at its core *sensors* that measure system parameters such as pressure, water level, and flow rates. The most basic and inexpensive form of automation consists of stand alone devices that act on the information from the sensor to perform simple actions only at the site where they are placed, such as an automatic shut-off valve responding to water level indicator. Next in line of complexity is telemetry, which automatically measures and transmits measurements from sensing devices located throughout the network to a central receiving station. (The word telemetry is derived from the Greek "meter" (to measure) and "tele" (from a distance).) Data acquired by the devices can be transmitted via radio, fiber optics or phone lines, and it is not uncommon for more than one form of communication to be used in a single system.

In the absence of control devices, telemetry requires an operator to analyze the input and act upon it. A control system not only monitors variables in the water distribution or wastewater treatment system, but it automatically maintains them at a desired range of values. A set of controlled devices, such as control valves, motors, pumps and fans, act in response to a set of controllers, such as an automatic power factor controller. For example, a motor is a controlled device that responds to a variable speed drive, a controller. One of the major benefits offered by control systems is the ability to adjust the scheduling and operation of component devices to changing demand and conditions, allowing the performance of various system functions to be continually and automatically optimized.

The most common type of control automation used in water and wastewater systems is the Supervisory Control & Data Acquisition (SCADA) system. SCADA can remotely monitor and control *in real time* a large array of components spread over large geographic areas, while also providing performance information on individual sites. The basic SCADA system consists of one central computer (the master terminal unit, MTU) that communicates with and controls a number of remote terminal units (RTUs) at key control points such as pumping and metering stations, plus the equipment to communicate between the MTU and RTUs. The RTU serves two functions: it uses information from those sensors connected to it to control system components such as pumps and valves, and it enables the user to access performance information on the site.

A properly designed SCADA system for water pumping saves time and money while improving service. Some of the many benefits include:

- Complete information on pumping operation provided in real time
- Pump operation adjusted automatically as needed to ensure reliable water supply
- The need for service personnel to visit sites for inspection, data collection or adjustments greatly reduced
- Alarms sent to the central control location in case of emergency
- Optimal pressure maintained in the water supply network, minimizing service interruptions and eliminating water hammers
- Electricity consumption reduced and pump productivity increased
- Troubleshooting facilitated
- Equipment life increased
- Reports generated automatically

Although the exact numbers will vary greatly depending on conditions, the following are typical saving ranges from a control system:

- water savings: about 10%
- electricity savings: 12-30%
- reduced downtime: up to 30%
- reduced maintenance and personnel costs: 15-30%

Examples of ways to use a control system in a water supply system

- Regulate the use of pumps based on the water level in storage tanks.
- Use frequency converters to control pumps according to changes in demand and to control daytime and nighttime pressure in the network, saving energy when demand is lower.
- Use variable speed drives and automated pressure controls to stabilize water pressure in the system and reduces downtime.
- Save energy costs by scheduling reservoir filling to coincide with low electricity rates and low demand).

4. Metering and Monitoring

There is a longstanding saying in business that "you can't manage what you don't measure". In water systems around the world, only about 35% of consumption and 50% of supply is metered, making it difficult to improve system performance. Any Watergy approach must include the establishment of a system to regularly monitor the various components and locations within the water or wastewater system. The basic steps for putting in place a successful monitoring and metering system are to:

- Create a system for water metering and monitoring if there is none, or expand and upgrade the existing system.
- Develop baselines and metrics for regular monitoring.
- Create targets and gauge success towards achieving them against baselines and benchmarks.
- Procure the proper measurement instrumentation.

Experience shows that it is cost effective to have a program to regularly replace water meters. This is because the working parts in a meter wear out over time, causing the meter to slow down and lose accuracy. In addition, older meters generally do not register water passing through the meter resulting from a leak on the property and resulting water loss becomes the liability of the municipality. A ten year replacement cycle is typical because—assuming that water is priced to fully recover the cost of providing it—meters older than 10 years are losing the utility more money than it costs to replace them.

The lists below summarizes the parameters typically monitored in a regular monitoring protocol. In order to isolate problem areas within the system, measurements should be made on discrete system components such as specific equipment and areas of facility buildings.

PUMP SYSTEM

- **Valve**s – inspect for leaks, clogs, or an open or closed stationary position.
- **Flow** – compare water flow rates in different parts of the system to help pinpoint leaks and other problem areas needing attention.
- **Pressure** – monitor working head and suction and delivery pressure (meter/kg-cm^2), not only to identify leaks but to indicate whether there is excessive pumping, enabling pressure, and therefore service, to be kept constant. Monitor network pressure at the critical point in the distribution zone to ensure sufficient supply pressure.
- **Rotating Speed** – measure pump speed with a strobe light to determine whether a motor is operating at optimal efficiency.
- **Power Consumption** – an increase indicates a loss of pump efficiency
- **Volume of Water** – pumped per day

ELECTRICAL SYSTEMS

- **Motors** – under different flow conditions, measure operating parameters such as input power (to indicate whether motor operating at optimal efficiency), the current upon start-up and while running, frequency, and speed.
- **Power Factors**
- **Operating Loads** – peak and off-peak
- **Energy Consumption** – track and analyze electricity bills.

III. FINANCING WATERGY WITH PERFORMANCE CONTRACTING

While there are many ways to finance energy efficiency projects, in the case of public entities or those that serve the public interest, performance contracting has became popular in many countries because the goods and services associated with the project are paid from the savings accrued from it. This allows a municipality to finance improvements without necessarily incurring any upfront costs. Performance contracts are different from traditional contracts because the contracted firm is compensated based on the actual savings resulting from project implementation (energy and water in the case of Watergy), instead of a fixed contract price (see **Figure 8**). Performance contracts are inherently flexible and can be structured to best fit the needs of the parties involved, for example with regard to the repayment schedule and compensation for the service provider, be it an Energy Service Company (ESCO) or other type of firm. In the case of water efficiency, the service provider might be a water engineering firm rather than an ESCO.

Typical services provided by ESCOs are energy audits, calculating baseline energy consumption, determining water and energy saving measures, designing efficiency projects, installing and maintaining the new energy efficient equipment, training the facility's technical personnel, and monitoring the realized energy savings. However, it is important that an ESCO not only provide the technical services needed to optimally design and implement an energy efficiency project, but to also generate from their analysis the specific types of information needed by financial institutions to evaluate the project's financial viability.

Sometimes ESCOs are able to finance the improvements internally, offering a full complement of services under one roof. In developing countries, however, it is more common for an ESCO to arrange for third party financing from a bank or other financial institution. (See the box on the next page for more discussion about special issues in developing countries.) Yet another option is for the municipality to secure the financing itself, which may be the desired route where government agencies offer discounted rates and relaxed lending criteria to municipalities.

A. The Audit

The first step in using performance contracting to finance Watergy improvements is the investment grade audit. The final audit report from an ESCO or like service provider is not only the foundation for the performance contract but is the key document used by financial institutions to assess the financial viability of the project. The report contains:

- ✓ background about the municipality and project,
- ✓ a description of the facilities covered,
- ✓ a list of the data collected, including energy consumption details of all facilities included in the audit and their energy sources;

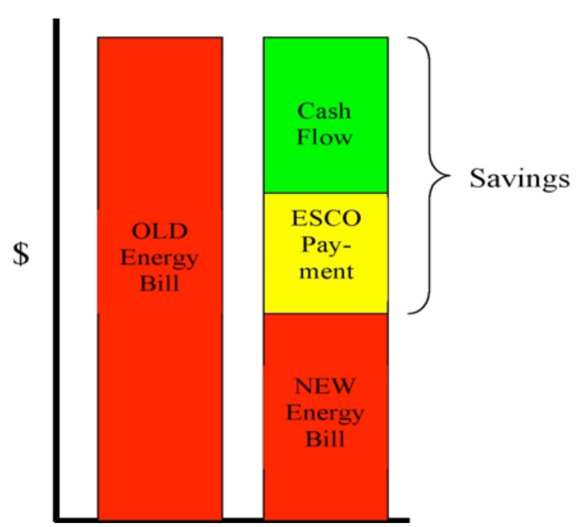


Figure 8. Performance Contracting Pays for the Project From the Reduced Energy Costs

- ✓ a list of all identified measures with estimates of the savings and payback periods on investments; and
- ✓ details on each recommended project, including:
  - the proposed retrofits and modifications necessary for achieving the savings and the cost-benefit analysis associated with each of them;
  - the baseline parameters for each project and any adjustments that might be required over the course of the project, for example due to a change in demand;
  - a monitoring and verification plan for each project; and
  - possible risks in implementing the project and suggested risk mitigation measures.
  - If relevant based on discussions with engineers and other relevant staff, the report should include a proposal for short- and-long term training that the ESCO will conduct for facility personnel.

B. Types of Performance Contracts

There are two main types of performance contract: *shared savings* where the financial risk lies with the ESCO and the savings are shared between the ESCO and water utility for a negotiated period of time; and *guaranteed savings* where the ESCO guarantees a certain percentage of savings. There can be numerous variations and combinations of these two main types. The essence of a performance contract, common to all types, is that the investment costs are paid from the savings generated.

1. Guaranteed Savings

- The ESCO guarantees that savings will be sufficient to cover the investment cost, and if they are not the ESCO pays the difference between the realized savings and project payments. The guarantee can be either a one-time payment or on-going.
- If external financing is needed, the municipality takes on the third party financing from a lender, putting the loan on the municipality's balance sheet.
- Excess savings can be shared between the municipality and ESCO.

In this scenario the municipality assumes no risk even though they may have the financing because the guarantee covers the financing cost, a known and quantifiable amount. However, a guarantee puts more of the risk onto the ESCO, which trickles through as added cost to the project in the form of a higher percentage of the savings being taken by the ESCO. When a contract includes some form of guarantee, a contractor might take out insurance against that guarantee. Such insurance is generally expensive since insurance companies cannot adequately quantify these types of risks unless the contract is for a simple type of project with a long track record, like changing light bulbs, where there are few unknowns in the equation. The cost of the insurance policy is added, with associated mark-ups, to the cost of the contract. In summary, guarantees made by the ESCO cause them to negotiate a higher—often significantly higher—percentage of the savings to ensure an adequate profit margin to cover the added risk they assume.

Barriers to the Use of Performance Contracting in Developing and Transition Countries

In many developing countries, as well as former Soviet Union countries with transition economies, performance contracting is still a new idea. Aside from the usual barriers to energy efficiency itself, there are many barriers to the use of performance contracting and the development of a robust ESCO industry, especially when applied to municipal services. These barriers will vary depending on the country, but some of the more common ones are listed below, in no particular order.

- Fear on the part of ESCOs that they will not paid by the municipality.
- Existing contract laws and conditions in a country might not be favorable to support the contractual underpinning of performance contracts. Laws sometimes contain loopholes that allow parties not to repay their debts.
- State or central agencies sometimes control municipal budgets, complicating contractual arrangements that pay for municipal efficiency projects with savings.
- Lack of a mature ESCO industry. New ESCOs are usually very small and lack adequate credit histories and financial track records, leading both potential clients and banks to regard them as high risk.
- In a nascent ESCO industry, many if not most of the technical consultants and ESCOs marketing their services are not guided by standard principles. For example, it is not uncommon for an audit to lack some of the financial information needed by financial institutions, or for one ESCO to not consider usable the audit results of another ESCO.
- ESCOs are often not familiar with how to adapt their trade from the industrial to the municipal sector. This lack of familiarity can also make the profits appear too low relative to the perceived risks.
- Financial institutions, unfamiliar with energy efficiency projects, often view them as high risk even when financial indicators are favorable.
- Municipalities and utilities often are not well versed in the project development and finance procedures needed to procure and finance efficiency services, including performance contracting, or they lack the necessary staff time.
- Inadequate metering prevents the determination of an accurate baseline against which to measure savings.

These barriers will be lowered by advances that promote energy and water efficiency in general, such as reduced subsidies for energy and water, but most will also require a critical mass of positive examples that speak to the fears and lack of awareness of all concerned: the municipalities, utilities, service providers, and financial institutions. Steps that increase trust in ESCOs will help, such as regulations that certify ESCOs and the adoption of standardized audit procedures. In situations where municipalities have a poor history with regard to honoring contractual obligations, a special escrow account can be used to pay ESCOs, with the municipality depositing savings from the project into the account. Another mechanism to protect savings from political pressure or turnover is a Trust and Retention Account, in which the municipality uses saving revenue from electricity and/or water bills to make payments to an Escrow account in accordance with the payment schedule of the loan.

There are circumstances where a municipality is willing to sacrifice some of the savings accrued from the project in order to have a guarantee that brings a high degree of certainty. In emerging markets the guaranteed savings type of performance contract is often more widespread than the shared savings type due to the lower risk for the municipality combined with the fact that many ESCOs in such countries are small and new with inadequate credit histories and financial track records. Also, municipalities in some countries have access to lower financing costs that make the guaranteed savings arrangement more attractive.

2. Shared Savings

- The savings are shared between the municipality and ESCO with the contract stipulating that the municipality will receive a certain *percentage* of the savings, but it does not guarantee the *magnitude* of those savings.
- All risk lies with the ESCO. The ESCO takes on the risk of any third party financing from a lender, putting the loan on the ESCO's balance sheet.

In this scenario, the ESCO is still carrying the cost of the project but without the additional cost of the guarantee. Therefore the client (municipality) is not carrying any risk, although it also is not assured of a set amount of savings. The most likely outcome from a shared savings performance contract—should circumstances allow for this type of contract—is that the municipality will accrue significantly greater financial rewards from the project than if a guaranteed savings contract had been used. The details of the sharing can vary depending on the specifics of the contract. For example, the split can vary over time, or it can be done as a "first out" arrangement where either the customer gets the first savings up to a negotiated threshold (which can be defined in terms of money, kWh or time), then the ESCO gets the rest, or the other way around.

There are any number of other options that take advantage of the principles of performance contracting. For example, the services or salary of a technical consultant—sometimes called a Resource Conservation Manager—can be paid on the basis of savings generated. Operations and maintenance (O&M) for services such as water supply or HVAC can be outsourced to the ESCO, which assumes all the risk for delivering O&M. This arrangement often requires significant capital investments, though, making the terms long, such as 15 years. Other arrangements can be made directly with equipment manufacturers or suppliers, who finance the sale of the equipment, including design and commissioning, with the client making payments from the savings until all payments are made and they assume ownership.

The text box on the following page lays out the general process for a municipality or utility to contract with an ESCO (or like service provider) to get an efficiency project implemented. The general steps hold regardless of which party is handling the financing.

STEPS FOR A MUNICIPALITY OR UTILITY TO DEVELOP AN ENERGY EFFICIENCY PROJECT USING PERFORMANCE CONTRACTING

1) **Develop and Issue a Request for Expressions of Interest (EOI)** for conducting an Investment Grade Energy Audit and implementing an efficiency project in the sector(s) to be targeted (such as water, wastewater, street lighting and municipal buildings). The EOI contains a brief description of the scope of work and basic information on the municipal installations to be audited, and requests information on the technical and financial capabilities of the firm including their work force, audit instrumentation, and relevant experience.

2) **Issue a Request for Proposal (RFP)** to all viable firms who submitted EOIs. The RFP describes the facility's energy use, equipment, operating schedule, maintenance problems, and planned equipment replacement or renovation plans, as well as the utility bill history for the past three years. It is recommended that a site visit be organized for interested ESCOs to tour the facility and interview facility staff before they submit their responses to the RFP.

3) **Evaluate the Proposals** according to the terms of the RFP.

4) **Finalize ESCO Selection** based on expertise and relevant experience, being sure to match the skills of the ESCO with the needs of the municipality.

5) **Award the Investment Grade Audit Contract**, an agreement with the ESCO to develop a project concept and perform the investment grade audit (IGA). The IGA report forms the basis for the energy performance contract between the municipality and ESCO, identifying all feasible short- medium- and long-term energy saving measures and their payback periods, and providing the baseline data to be used during monitoring and verification.

6) **Project Packaged for Third Party Financing** if needed for the project. The party taking on the financing (be it the municipality or ESCO) puts together a package of information on the project, including the IGA report, for review by financial institutions. The financially relevant information contained in the IGA report is critical at this stage for convincing a financial institution to provide a loan.

7) **Enter into the Performance Contract –** The contract dictates the terms and conditions by which the ESCO implements the energy efficiency measures. It details the responsibilities of the ESCO and municipality and how savings are divided between them, the compensation schedule for the ESCO, financing conditions, maintenance, personnel training, monitoring and verification procedures, risks and a risk mitigation plan, and the definition of the baseline and possible adjustments to it.

8) **Monitoring and Verification** (M&V) of results performed according to the procedures in the performance contract. M&V determines the actual savings over the period of the contract and ensures that all parties are getting full value from the energy performance contract, including compensation for the ESCO. It includes approval of equipment installation based on the contract specifications, and involves regular communication with the ESCO and utility. A third party often handles M&V.

IV. WATERGY CASE STUDIES

A. South Africa: Emfuleni

1. Background

Sebokeng and Evaton are two previously disadvantaged, sprawling residential areas located in the Emfuleni Local Municipality, which is serviced by Metsi-a-Lekoa, the water and sanitation business unit of the municipality. These areas support a population of 420,000 and consist of approximately 65,000 freestanding housing units.

Key Results

- Performance contracting applied to water supply
- Payback period less than 3 months
- Annual cost savings: US$ 3.8 million
- Annual energy savings: 14 million kWh
- Annual water savings: 8 million kL
- Annual GHG emissions avoided: 12,000 tonnes
- Pressure management technology reduced water losses by over 30%

As a result of relatively high pressures in the water network, many on-property plumbing fixtures fail prematurely resulting in leakage and water wastage. Due to various socio-political and socio-economic factors, most failed fixtures remain in a state of disrepair and continue to waste water over lengthy periods of time, sometimes even years.

The overall effect is high levels of water wastage as measured in terms of Minimum Night Flow

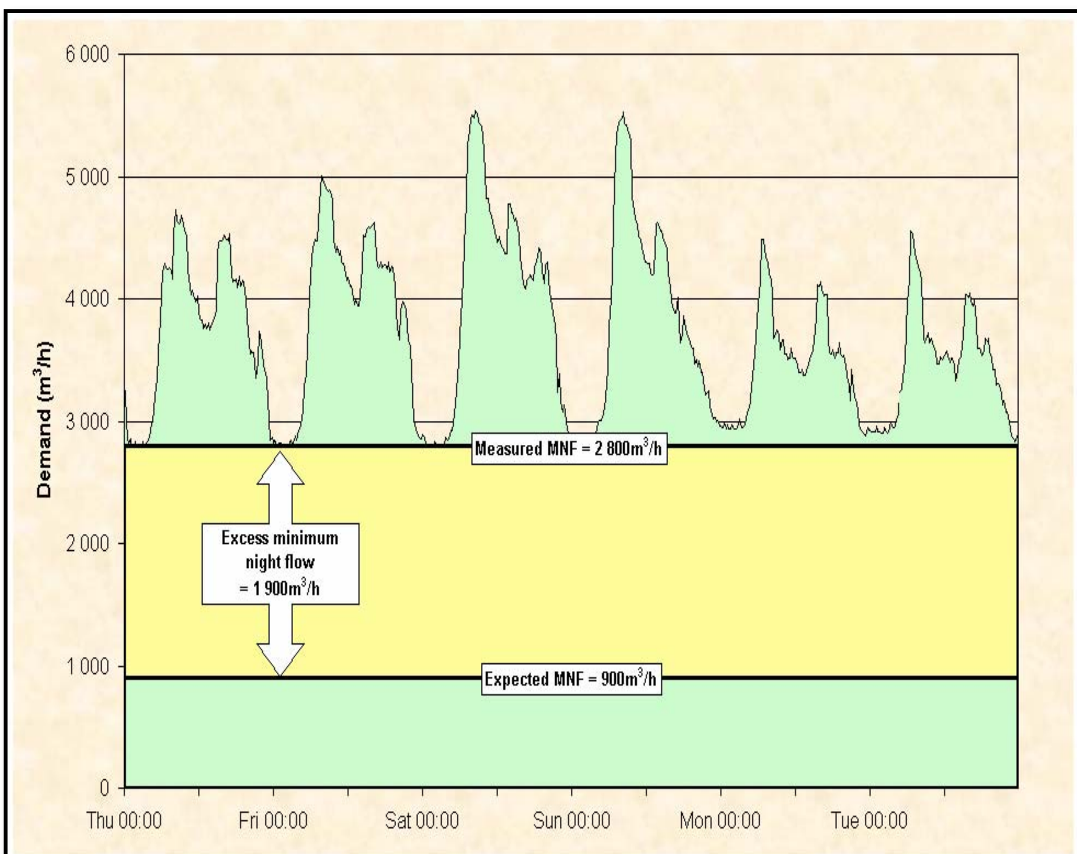


Figure 9: Minimum Night Flow for Sebokeng/Evaton

(or MNF, the best indicator of the level of water leakage and wastage for a particular area). For Sebokeng/Evaton, MNF amounted to 2800 m³/hour, enough water to fill two Olympic sized swimming pools every hour! This is the highest recorded night flow on record for almost a dozen countries. Of all water flowing into these homes, 80% was lost through leaking plumbing fixtures.

Figure 9 shows the logging results of the MNF for Sebokeng/Evaton, as logged on the two dedicated bulk water supply lines into the area. From the graph it can be seen that the MNF is 70% of the average peak daily demand flow rate. By comparison, **Figure 10** illustrates what the MNF should be for an area where leaks are managed both on properties and within the network. Furthermore it has been established that the bulk of the leakage in Sebokeng and Evaton is occurring within homes, based on night time sewer flows of 2500m³/h entering the wastewater system, representing 80% of the volume of water flowing into these same areas.

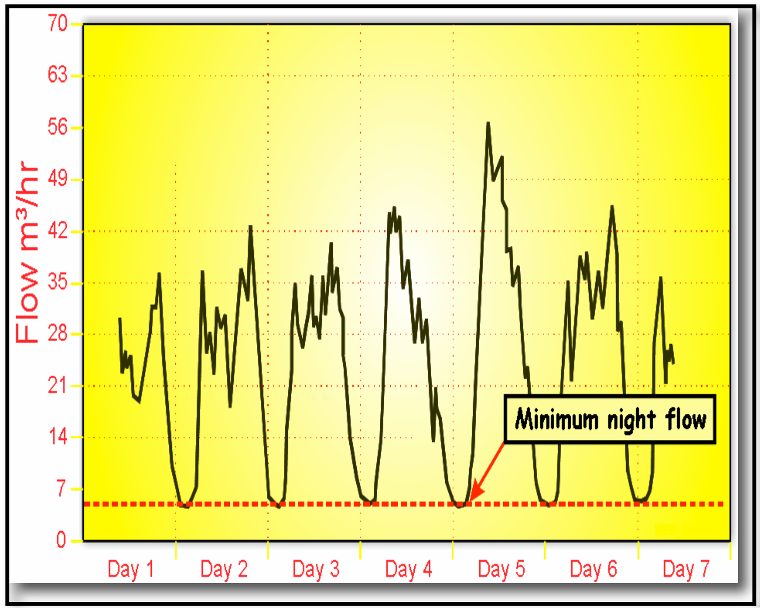


Figure 10: Minimum Night Flow Where Leaks are Well Managed *(courtesy of Ronnie McKenzie, WRP, Ltd.)*

2. The Technical Solution

Although theoretically it is possible to reduce wastage by repairing leaks on properties, it makes more technical and economic sense to first reduce higher operating pressures to prevent further damage to existing fixtures and potential damage to repaired and/or replaced plumbing equipment. This can be achieved through *advanced pressure management* which not only reduces and controls high pressures, but also allows pressures to be reduced even further at nighttimes when full operating pressures are unnecessary due to low demand and minimal usage.

Figure 11. Burst water main at high and low pressure

In theoretical and empirical terms, leakage is driven by pressure. When pressure is lowered, the water lost through a hole or leak is reduced. This holds true for all leaks, whether the leak is a typical burst pipe or simply a leaking tap, tap washer or toilet. The two photographs below in **Figure 11** graphically illustrate the difference in volumes of water lost under high pressure and under low pressure for the same burst pipe. It is also noted that over time higher pressures tend to exacerbate the damaged pipe or fixture, having a 'cutting' effect on the 'hole' and causing the 'hole' to increase in size over time.

Advanced pressure management is also very cost effective. This is especially true in the case of Sebokeng/Evaton where municipal water is supplied from a single point through two co-located and parallel spur-feed pipelines. The construction consists of a single large above-and-below ground chamber to house all of the required equipment. The installation of inlet and outlet manifolds allows for possible crossover and hence greater flexibility in supply, as shown in **Figure 12**. Construction of the chamber (shown on the next page) was completed in September 2005. The total estimated capital cost of the pressure management installation is R5 million ($800,000) with anticipated savings in water supplied of R25 million per year.

Assistance provided by the Alliance to Save Energy included conceptualization, planning, procurement, contracting and legal arrangements, negotiations, contract management and the statistical determination of future water supply projections (the baseline). Currently the Alliance is playing the role of independent Technical Auditor for the verification of monthly savings and related payment to the contractor.

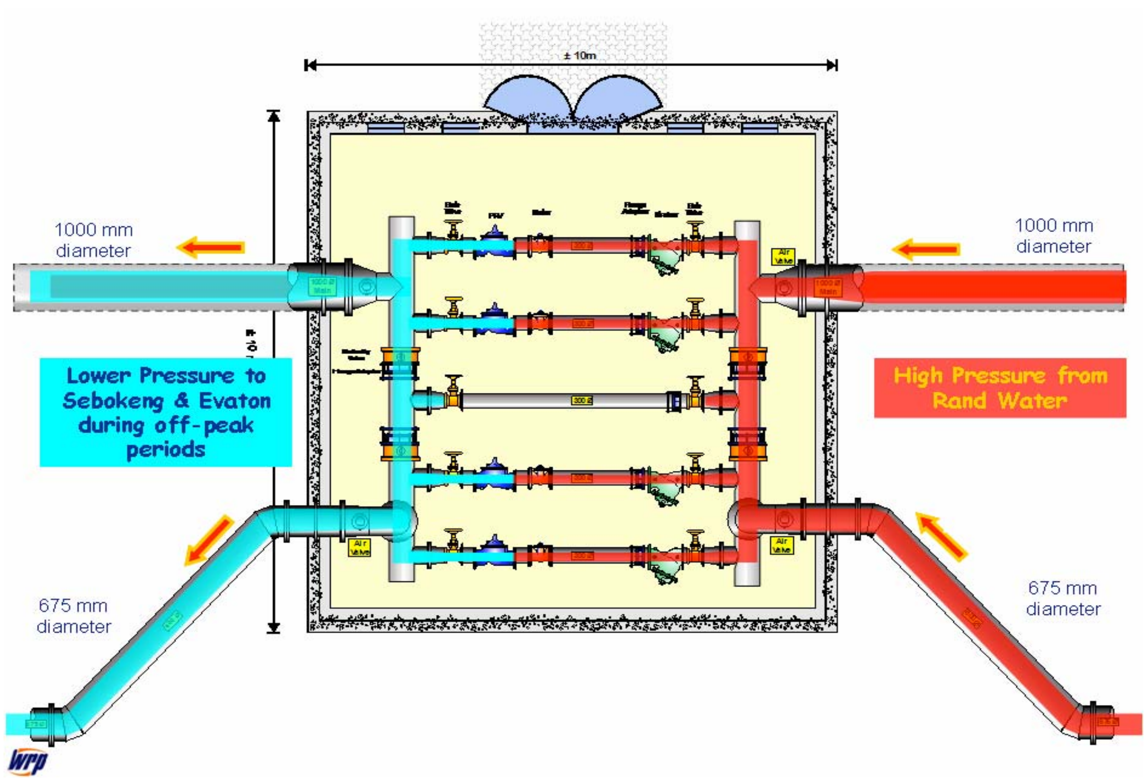


Figure 12. Schematic Representation of the Pressure Management Installation

3. The Financial Solution

This project lends itself to performance contracting and the application of a Build-Own-Operate-Transfer (BOOT) type arrangement. This contracting mechanism was deemed to be the best approach in light of the municipality's limited ability to access capital and its lack of technical capacity with regard to pressure management. The original Request For Proposals therefore called upon bidders to not only implement efficiency measures but to also provide funding for the project, with remuneration paid through the resulting savings in water purchases from the bulk supplier of water to the municipality. This shared savings approach is common in the electricity industry.

The savings in water are so significant that both the municipality and contractor gain, with 80% of the savings accruing to the municipality and the remaining 20% used as remuneration to the contractor for services provided over a five year period. The contractor is required to provide a basket of services including financing of capital, design, implementation, commissioning, operation and maintenance over the contract period as well as training of municipal staff in operations prior to handover. As the installed infrastructure is permanent in nature and has a design life of at least 20 years, the municipality will continue to achieve savings well beyond the initial five year period.


4. Results

This project reduced water losses by over 30%, saving about 8 million kL per year with an equivalent financial value of around $3.5 million. Because of the water-energy nexus and the energy required to pump water, these water savings also translate into energy savings of around 14,250,000 kWh per annum. This corresponds to a reduction of about 12,000 metric tonnes of greenhouse gas emissions every year. The Sebokeng/Evaton pressure management project is reportedly the largest installation of its type in the world. It represents innovation in many respects and although the project may not necessarily be replicable as a whole, many of its technical, financial and contractual components will find application elsewhere, not only in South Africa but around the world.

All photos and figures for the Emfuleni case study are courtesy of Ronnie McKenzie of WRP (Pty), Ltd.

B. South Africa: Soweto

1. Challenges

The supply of water to Soweto is characterized by unsustainably high wastage. Water pumped to the region averages around 67 kilolitres (kL) per property per month which—prior to the implementation of the intervention project described in this case study—was increasing at a rate of 4% per annum. Where the project has been implemented, consumptions average only 10 kL per property per month. This scenario is repeated throughout South Africa and is not sustainable either environmentally—since South Africa is water scarce—or financially, since most service delivery costs incurred by the municipality are not reimbursed due to non-payment.

Key Results

- Estimated Savings (when all phases completed):
  - ✓ Energy: 175 million kWh/year
  - ✓ Cost: US$ 45 million/year
  - ✓ Water : 97 million kL/year
- Ownership of consumption transferred to the consumer, creating awareness of the true value of water
- Reduction in operating and maintenance costs due to water network upgrade
- Creation of over 1500 temporary jobs in the communities where project being implemented

This state of affairs can be attributed to a number of factors including the 'deemed consumption' billing method for water services rather than consumption-based, a lack of maintenance of private plumbing fixtures by property owners, as well as the poor condition of the water network. (Deemed consumption billing where water and sanitation is billed on a set volume that one is "deemed" to have used rather than actual use.) These issues are historical in nature and can be traced back to previous unworkable political policies.

Gcin' amanzi
because every drop matters

For the most part therefore, customers do not take ownership of consumption, nor of private plumbing fixtures located on their properties, causing high levels of water waste. The result is that Non-Revenue Water (the difference between the volume of water supplied and the volume billed) is about 200% for Soweto. In addition, customers do not in reality receive the benefit of Free Basic Water. Even those customers who are poor or use water sparingly receive no real free water benefit and are required to pay the same amount for water as customers using water excessively or irresponsibly.

The Alliance to Save Energy has been playing an ongoing advisory role for Johannesburg Water (Pty) Ltd. in the implementation of **Operation Gcin'amanzi** (Operation Save Water), aimed at addressing a host of problems plaguing Soweto. Johannesburg Water is the authorized provider of water and sanitation services to the City of Johannesburg, including the greater Soweto region.

2. Objectives

The objective of Operation Gcin'amanzi is to create an efficient water supply system and achieve significant savings in total water supplied to the area by reducing excessive consumption and wastage. Once completed, the project is expected to reduce by at least 20%

the water consumed by the city as a whole. Operation Gcin'amanzi was designed to add social and economic value to the community through:

- improved water service delivery and customer interface,
- rehabilitated municipal infrastructure,
- rehabilitated private plumbing fixtures,
- temporary and permanent employment for unskilled and semi-skilled labor,
- empowering the customer to take ownership of water consumption,
- reduced cost of water to the end user,
- Free Basic Water dispensed to all residents, and
- reduced municipal service arrears due to prepayment metering.

4. Approach

Johannesburg Water initiated Operation Gcin'amanzi in Soweto as a multi-faceted intervention project focusing on the rehabilitation of the water network and private plumbing fixtures. A cornerstone of the project is the installation of a prepayment metering device on each property, eliminating the deemed consumption approach to water accounting. The prepayment metering system dispenses 6000 liters of Free Basic Water to each property every month, thereafter dispensing any water according to the availability of credit on the meter. The project was launched in June 2003 after a lengthy consultative, awareness and approval process with communities, councilors, ward committees, and trade unions. Operation Gcin'amanzi is estimated to cost 500 million Rand when completed.

5. Results

The results achieved in all areas where the project has been implemented are spectacular, with the average water supply dropping from pre-intervention levels around 67 kL per residential property per month to post-intervention levels that so far average about 10 kL per property per month. So far, in the first 14 months of the project, these reductions have saved Johannesburg Water (JW) US$6.8 million, and once all phases are completed JW will save almost 270 million Rand (US$45 million) per year in bulk water purchases alone. The effective payback period of the project is less than 3 years. This does not include savings from reduced energy use.

Although Operation Gcin'amanzi initially received negative publicity–based mostly on misinformation and opposing political ideologies–the project is now supported by 96% of participating residents. The project ensures that the true value of water is recognized while at the same empowering customers to take ownership of consumption, thus ensuring that the service of water remains sustainable and affordable. The issues of Soweto are occur in many urban areas in South Africa and abroad. Operation Gcin'amanzi shows the tremendous value of creating water efficiencies at the municipal service delivery level, and it illustrates that significant public opposition can be replaced by the willingness of people to pay for reliable, clean water—once they experience the benefits of their ownership.

C. South Africa: Mogale City

1. Challenges

> **Key Results**
>
> - Successful application of conventional and pre-payment metering where prior strong public opposition to payment for water had existed.
> - Payment rates rose from 10% to 95%
> - Annual cost savings: US$ 3.5 million
> - Annual energy savings: 15.4 million kWh
> - Annual water savings: 6 million kL
> - Annual GHG emissions avoided: 13,700 metric tonnes of CO_2

The Kagiso township is a previously disadvantaged, low income area located in Mogale City. This area consists of approximately 20,000 properties with primarily low income housing. The Kagiso area has witnessed rapid population growth over the past decade without a corresponding increase in sound water service delivery or staff expertise in water management. Various socio-political and socio-economic factors coupled with poor infrastructure have resulted in a lack of metering and inadequate accounting of water services provided. Another consequence of these factors is the entrenched culture and mindset among Kagiso residents of not paying for water. Payment levels were recorded at 10%, by 1996 when an earlier metering project was conducted, total unpaid dues to the municipality had reached R1.5 million (about $250,000).

2. The Solution

The Kagiso solution is two-pronged, with a technical approach that established an effective water demand management program with improved infrastructure and staffing capabilities, coupled with a focus on instilling responsibility among residents to pay for the water they consume and to maintain their meters and connections. The Alliance to Save Energy has been providing key technical support since 1999, including planning, creating financial models to assess project feasibility, training on the use of equipment, and drafting documentation. Project management support was provided to the municipality's water services department.

CONVENTIONAL METERING

The first step in the project was to establish a metering system to monitor all existing water connections and realistically account for the amount of water supplied to the residents. Conventional meters were installed and pressured yard connections were fixed on each property in the township. Select leak repairs were also conducted on households. Additional staff was hired to monitor billing and individual

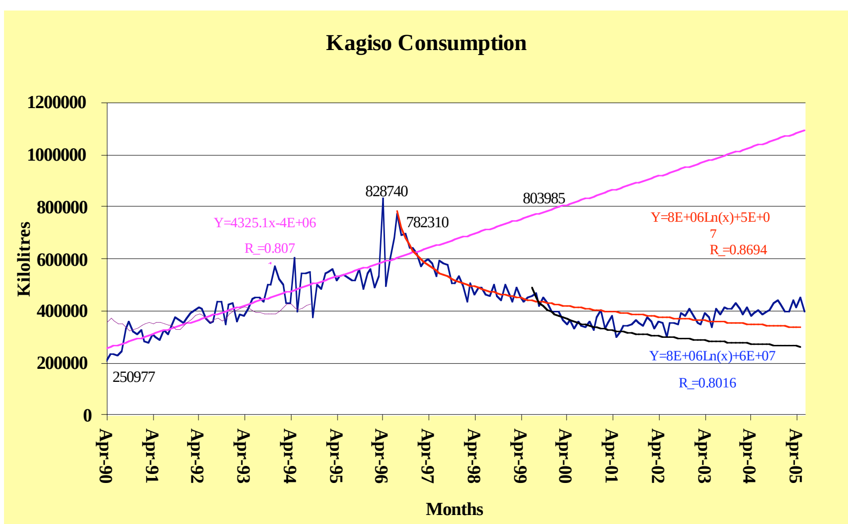


Figure 13. Kagiso Water Consumption over 15 years

property accounts and to maintain the new systems. **Figure 13** illustrates the impact of water demand management efforts in Kagiso. Actual water consumption is shown by the blue line, with the pink line extrapolating the consumption trend in the absence of interventions. The initial sharp drop in consumption in the center of the graph is the result of an earlier project at the end of 1996 and beginning of 1997, including metering and select leak repairs. The black line on the right half of the graph shows the dramatic drop in water consumption as a result of prepayment metering. The resulting savings in water costs paid for the conventional meters.

Pre-payment Metering

The limitation of conventional meters is that they do not ensure that residents pay for water consumed, resulting in difficulties in establishing a credit control system that holds customers responsible for water payment. There are several types of interventions a municipality could implement. For example, a policy could institute limits on the level of water residents may consume. In Kagiso, inability to pay for water resulted in the termination of thousands of water connections, which was not only a significant burden on the affected households, but was a cost-intensive process for the municipality.

Key Policy Decision for Prepayment Metering

1. All new standard sized water connections (15 mm) will automatically receive a prepayment meter without requiring owner consent.
2. Any existing customer can apply for a prepayment water meter. Except for new connections, no existing consumer will be forced into prepayment.
3. Retrofitting will be free of charge. Customers with new connections will pay the normal fee.
4. Meters are installed inside the property to encourage ownership.
5. Prepayment customers will not pay a premium for water. The same tariff structure will be used for both prepayment and conventional meters.
6. Capital cost of prepayment water will be subsidized by the Council.

Pre-payment metering was introduced to resolve these issues by allowing customers to pay the municipality a subsidized fee in advance for the consumption of a specific amount of water over and above their "Free Basic Water" allocation of 6000 L per month. Waste is avoiding because customers use only that quantity of water for which they have paid. The "pay before you use" paradigm was a shift from the entrenched culture that advocated the free use of water with no limitations. To overcome this, the municipality carefully marketed the pre-payment concept through several key policy decisions, outlined in the box above. Kagiso began installing prepayment meters in 1999 and the system was rapidly accepted by most residents. By 2001 13,500 yard connections had been established and payment levels rose from 10% to 95%.

3. Results

The installation of both conventional and prepayment metering has resulted in significant savings. Total water savings from both projects is approximately 6 million kL every year, with an associated annual cost savings of US$3.5 million and energy savings of 15.4 million kWh. This project demonstrated that metering is essential to the cost effective supply of water, allowing less monitoring and management and increased credit control. The Kagiso metering project serves as successful model that can be replicated in other municipalities, not only in South Africa but around the world wherever there is a need to ensure sustainable and affordable delivery for under-served communities.

D. India: Pune

1. Background

Key Results

- Energy Savings: 3.8 million kWh/year
- Cost Savings: US$336,000/year
- Water pumped: 10% more water delivered to the community with no additional new capacity
- CO_2 Emissions Avoided: 38,000 tonnes/year

Indian municipalities continue to face the challenges of a growing population, urban expansion, increasing power tariffs and acute water shortages. At present only about two-thirds of the urban population has direct access to clean, affordable, reliable drinking water service. At the same time, municipal water utilities in India spend upwards of 60 percent of their budget on energy for water pumping. The Alliance to Save Energy has found that savings of at least 20% are typically available from no- and low-cost efficiency measures made in municipal water utilities, with much more possible with higher cost measures.

Pune lies in western Maharashtra, the second largest city in the state after Mumbai with a population of over 3.5 million. The Alliance began its Watergy Program in India by partnering with Pune Municipal Corporation (PMC) in 1997. The Alliance conducted an energy audit on the Cantonment Water Works, and PMC implemented the suggested low-cost measures in 2000. The savings totaled 4,230,000 kWh with an average payback of 16 months. However, the project came to a standstill due to various reasons in 2000 and resumed after 2004 when PMC came under new administration and rekindled its partnership with the Alliance. This case study describes only the second phase of the Pune water efficiency effort, implemented in 2005 and 2006.

2. Objective

The main objective of the Alliance partnership with PMC was to demonstrate that harnessing efficiencies at the nexus between municipal water and energy can greatly help municipalities in India and other developing countries address their urban water and energy challenges. The Alliance to Save Energy Watergy program helps cities take advantage of untapped energy and water efficiency opportunities in their water systems, yielding significant energy, water and monetary savings that provide consumers with quality service using a minimum of water and energy.

3. Project

In January 2005, the Alliance conducted energy audits on PMC's bulk water supply systems. Coupled with the audit process, in order to build technical and managerial capacity at PMC, the Alliance also conducted hands-on training for 45 PMC engineers that involved ten days of classroom and field work. Also participating in the training were the state institutional partner, the Maharashtra Energy Development Agency (MEDA), and engineers from Nagpur Municipal Corporation, a city of two million people in the northeastern corner of the state. The draft audit report was discussed with PMC officials and once the municipal engineers agreed upon on the measures to be implemented, the report was finalized. The Energy Audit report suggested that PMC could accrue energy cost savings of Rs. 146 lakhs ($332,000) with an investment of Rs. 87 lakhs ($198,000). Nearly 70% of the suggested measures had payback periods of less than one year. PMC contributed a total of US$189,000 (Rs. 8.5 million) to implement a series of capital-intensive efficiency measures.

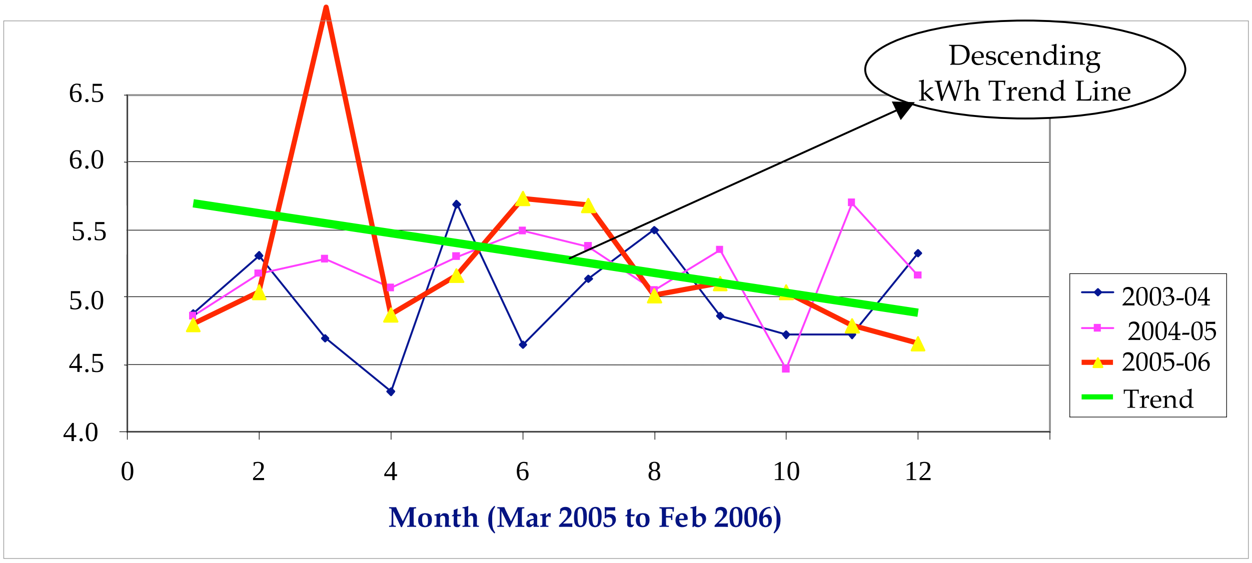


Figure 14: Results from Parvati Water Works – Pune Municipal Corp.
(in millions of kWh per month)

4. Results
As a result of these measures, PMC is experiencing annual energy savings of 3.78 million kWh and annual cost savings of over $336,000 (148 lakhs Rupees). The savings achieved at PMC are higher than projected in the energy audit report since the PMC municipal engineers implemented additional low and no cost energy efficiency measures at the pumping stations including distribution pumping stations. This is a direct result of the training provided to the municipal engineers by the Alliance to Save Energy. The implementation of EE measures also resulted in 10% additional delivery of water to community without adding any new capacity. In addition to direct reductions in energy costs, the utility also saved money by qualifying for a rebate program offered by the Maharashtra State Electricity Board to facilities maintaining a good power factor and reducing usage during peak hours. The efficient operation of the largest pumping station, Parvati Water Works, reduced the energy intensity of water supply by 6%, from 375 kWh/million liters of water to 352, and increased its rebate by almost 8% since fiscal year 2003-04, from $110,000 (48.57 lakhs Rupees) to $196,000 (86.27 lakhs Rupees).

The success of the PMC energy efficiency program has encouraged PMC to sustain its energy efficiency activities. The Municipality is currently discussing with consultants an extension of energy audits to other pumping stations in the network.

E. India: Vishakhapatnam

1. Challenges

Indian municipalities are facing the challenges of rapid urban expansion, increasing power tariffs, and acute water shortages. At present only about two-thirds of the urban population has direct access to clean, affordable and reliable drinking water services. At the same time, municipal water utilities in India spend upwards of 60 percent of their budgets on energy used for water pumping. Municipal officials are often aware of the opportunities for making bulk water supply and street lighting systems more efficient, however for the most part they lack the means to take advantage of these opportunities.

Key Results

- Energy saved: 1.4 million kWh/year
- Cost Savings: $60,400 per year from an investment of $24,500

2. Background

Vishakhapatnam, with a population of 1.2 million, is the second largest city in the southern Indian state of Andhra Pradesh. The city has a severe shortage of water: 213 million liters per day (MLD) are required by the city, which in turn requires 340 MLD to be pumped from the source, due to waste that occurs at various points in the system. However, only 190 MLD was being supplied to the city, and in some areas drinking water is supplied only once every two days.

Vishakhapatnam Municipal Corporation (VMC) is working to augment the water supply by bringing water from a reservoir of the River Godavari from a distance of nearly 200 km. The distance from the river to the reservoir is another 56 km. VMC is spending US$ 94 million to lay the transmission pipeline from the river to the reservoir, and another US$ 23 million to integrate the new water received into the existing supply system. VMC has also allocated US$ 3.4 million for reduction of water losses, energy efficiency and other measures. When VMC learned about the successful efforts of the Watergy Program, it asked to partner with the Alliance to make its existing bulk water supply system water and energy efficient. The Alliance began providing technical assistance in energy efficiency best practices to VMC in 2003.

3. Objectives

The main objectives of the VMC Watergy Efficiency program were to:

- Coordinate a water and energy audit study of VMC's bulk water supply system.
- Build in-house technical and managerial capacity of VMC to oversee energy audits and implement energy savings measures.
- Assist VMC in incorporating energy efficiency measures in the design stage of its new Godavari water works.

3. Approach

In response to the urban water and energy challenges faced by municipalities in developing countries, the Alliance has developed sustainable 'Watergy' solutions, which emphasize the important nexus between municipal water supply and energy use. By taking advantage of untapped energy and water efficiency opportunities in their water systems, municipalities can optimize energy use and reduce water wastage, reduce costs and ultimately improve water services.

As a first step, the Alliance coordinated a detailed energy audit of the bulk water supply systems at VMC. VMC bore 50 percent of the cost of the audit and committed to the implementation of the 20 suggested energy efficiency measures, six of which were no-cost. The Alliance also helped VMC incorporate energy efficiency measures at the design stage of the new pumping station for delivering water from River Godavari, by reviewing tender documents and redefining the technical specifications of pumps and motors.

4. Results

VMC implemented all energy efficiency measures suggested by Alliance with an investment of only US$24,500 from its Operations and Maintenance funds. The measures included retrofitting pumps and motors, optimizing the use of contracted demand, segregating low tension and high tension, and trimming impellers. As a result of these measures, VMC is accruing an annual energy savings of 1.4 million kWh and an annual financial savings of approximately US$ 60,400. This has reduced VMC's annual energy bill for pumping water by about 5.4 percent, and has reduced CO_2 emissions by about 2,400 metric tonnes. The simultaneous reductions in municipal water waste, through more effective supply and distribution, will allow the municipality to deliver water to more homes.

In addition, all the suggestions provided by the Alliance during the design stage of the River Godavari water augmentation project have been included in the tender documents to ensure the quality procurement of pumps and motors, along with post-installation verification terms and conditions. Based on this assistance, VMC floated a tender and has awarded the contract to one of the leading pumps and motors manufacturing companies in India.

F. Brazil: Fortaleza

1. Challenges

Key Results

- Energy saved: 88 million kWh over 4 years
- Households newly connected to water while water consumption remained constant: 88,000
- $2.5 million saved per year with an investment of $1.1 million.
- Operational procedures improved and standardized.
- Automated system control devices provide the ability to act in real time.

The design of water distribution systems in Brazil—as in many countries—are based on population projections from statistical and historical data that is projected over a 20 or 30 year planning horizon. Because of this, many systems are over-designed in the sizing of storage, treatment and distribution. This over-design carries with it energy consumption levels that are much greater than necessary to provide for adequate demand, especially for booster stations. Design criteria affect not only pumping stations, but also the sizing of pipes, capacity of reservoirs, and the construction of treatment facilities and booster stations. Water systems need to be able to expand to satisfy increasing demand, but not while sacrificing efficient use of energy.

2. Objectives

The Alliance to Save Energy worked alongside the Companhia de Água e Esgoto do Ceara (CAGECE) in the Northeast of Brazil starting in 2001 to develop and implement measures to improve the distribution of water and the access to sanitation services, while reducing operational costs and environmental impacts.

In the process of doing this, another objective was to provide CAGECE with the tools and know-how to produce on their own initiatives that save energy and clean water.

3. Approach

Actions included:

- Establishing a baseline of energy consumed and water distributed by CAGECE.
- Implementing efficiency measures that led to reduced operational energy consumption.
- Creating an operations procedures manual to serve as a reference for daily performance to operations crews and CAGECE management.
- Developing a financing proposal with the Government of Brazil Fight Against Electricity Waste Program (PROCEL) in order to implement energy efficiency projects with CAGECE's operations crew.
- The development of energy efficiency projects, cost/benefit analysis, and specifications for equipment that could be financed. These projects included automation of operations, rewinding and replacing motors, maximizing existing pump systems efficiency, and increasing storage capacity to allow pumps to be shutdown during peak electricity rate hours.

Automation at CAGECE

An automation system in water distribution systems allows operators to obtain strategic data to control equipment in real time, including the correction of deficiencies in the system in real time. To automate the water supply system in the Fortaleza Metropolitan Region, the Alliance helped CAGECE establish an Operational Control Center for the water supply system that:

- Optimizes operations to reduce energy costs;
- Improved system management by centralizing control;
- Speeds up recognition of and response times to maintenance needs using sensors and by acting through controlling devices; and
- Generates system diagnostics using historical records of operational data.

4. Results

Over the course of four years, CAGECE saved 88 GWh of energy, improving efficiency each year. Before CAGECE instituted their energy efficiency program, they provided access to 442,400 households. Four years later, the utility provided 88,000 new connections over the original baseline, while decreasing total energy consumption and costs and maintaining water consumption levels. Four years of official data show savings of over US$2.5 million with an initial investment by CAGECE of only US $1.1 million (R$3 million).

G. Mexico: Veracruz

1. Challenges

Key Results

- Energy Savings: 24 million kWh/year, a 24% reduction
- Cost Saving: US$ 394,000/year
- Improved Energy Intensity: 19%
- Improved reliability in water & sanitation service
- Elimination of service complaints
- Substantial reduction in losses of water due to pressure control

The Metropolitan System of Water and Sanitation at Veracruz (SAS), the water utility in Veracruz, Mexico, was motivated to undertake significant steps to become more energy efficient for two reasons: one is that energy costs ranked second in total operating costs, and the other is that their service was sporadic with severe interruptions a common occurrence. The system serves 628,000 users, and provides water and sanitation in the municipalities of Veracruz, Boca del Rió and Medellín in the state of Veracruz.

Before the project, parts of the system experienced severe interruption of service lasting up to five hours at a time. The project goal was to increase the energy efficiency of the operating system, improve the conditions of operation, and provide better service to the customer. The Alliance to Save Energy assisted in developing a plan to save energy based on its energy and water saving concept, Watergy. The plan helps to improve energy and water supply efficiency, at the same time improving water service. This case study describes a pilot project conducted in the Volcanes sector of the Veracruz system, with a population of 25,000.

2. Approach

The following analysis was conducted to determine the specific actions needed:

- An energy diagnostic using production statistics and electricity bills (e.g., **Figure 15**).
- A feasibility analysis of energy saving measures such as demand management and power factor optimization.
- An analysis of cost saving measures including load shifting to off-peak hours.
- Collection and analysis of data using specialized equipment for analyzing electrical networks and the electromechanical efficiency of pumping systems.
- Installation of high efficiency pumping equipment.
- Analysis of physical conditions of deep wells to evaluate their condition and determine rehabilitation and maintenance options.
- Hydraulic modeling to optimize pressure and flow sectors in the system.
- Sectorization (the process of isolating a section of a distribution system using valves) to develop hydraulic models of the system; GIS mapping; and conducting maintenance programs such as unidirectional flushing, ultrasonic leak detection, and valve exercising.

The analysis found that water supply was being inefficiently delivered with three principal effects:

- Excessive operational energy use for the pumping system and interrupted service when the pumps were operating at maximum capacity.
- Loss of water to the supply zones bordering the Volcanes sector and excessive operating pressure in the sector itself, which increased leakage.
- Low level of service to the local population, reflected in consistent complaints averaging 100 per month.

In response, the project optimized electromechanical efficiency, installed an automation system, detected and repaired leaks, and conserved water. Hydraulic modeling tools and sectorization optimized pressure and flow range in the Volcanes sector. Once that was done, isolation valves were installed so that the sector could be cut off from the rest of the system and supplied solely from the pumping system at the Volcanes well. The well itself was rehabilitated and a high efficiency submersible pump was installed. Also, to avoid excessive energy consumption and to eliminate the necessity of constructing a storage tank, an automatic control mechanism was installed that includes a variable frequency drive. Controlled at constant pressure, the drive reduces the pump's energy consumption by 30% compared to when the pump operates without the drive. The variable speed drive allows the Volcanes pump system to save energy during hours of low demand. The variable speed drive improved the electromechanical efficiency from 45% to 72%.

3. Results

The continuous monitoring by the Supervisory Control and Data Acquisition System, together with an aggressive program of maintenance and leak repair, has permitted SAS to reduce water losses to a minimum.

- The leak management and water conservation resulting in savings of 35,500 kWh/month.
- Optimization of electromechanical efficiency reduced energy use by 24%, saving 153,254 kWh per month with a payback period of 1.7 years.
- Over the course of the program, the energy intensity was reduced 19% (from 0.48 kWh/m^3 to 0.39 kWh/m^3), saving the utility US$394,000.
- The number of monthly complaints in this sector has decreased to almost zero. This improvement has allowed SAS to leverage user confidence to raise their income from previously unpaid monthly service bills.
- Due to pressure control, water losses have been substantially reduced. Combined with a leak and loss recovery program, energy use will be reduced further.

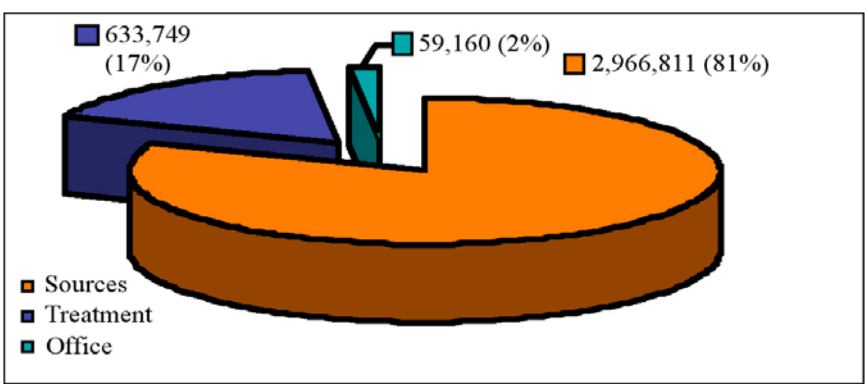


Figure 15: Energy Use by Veracruz Water Utility

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