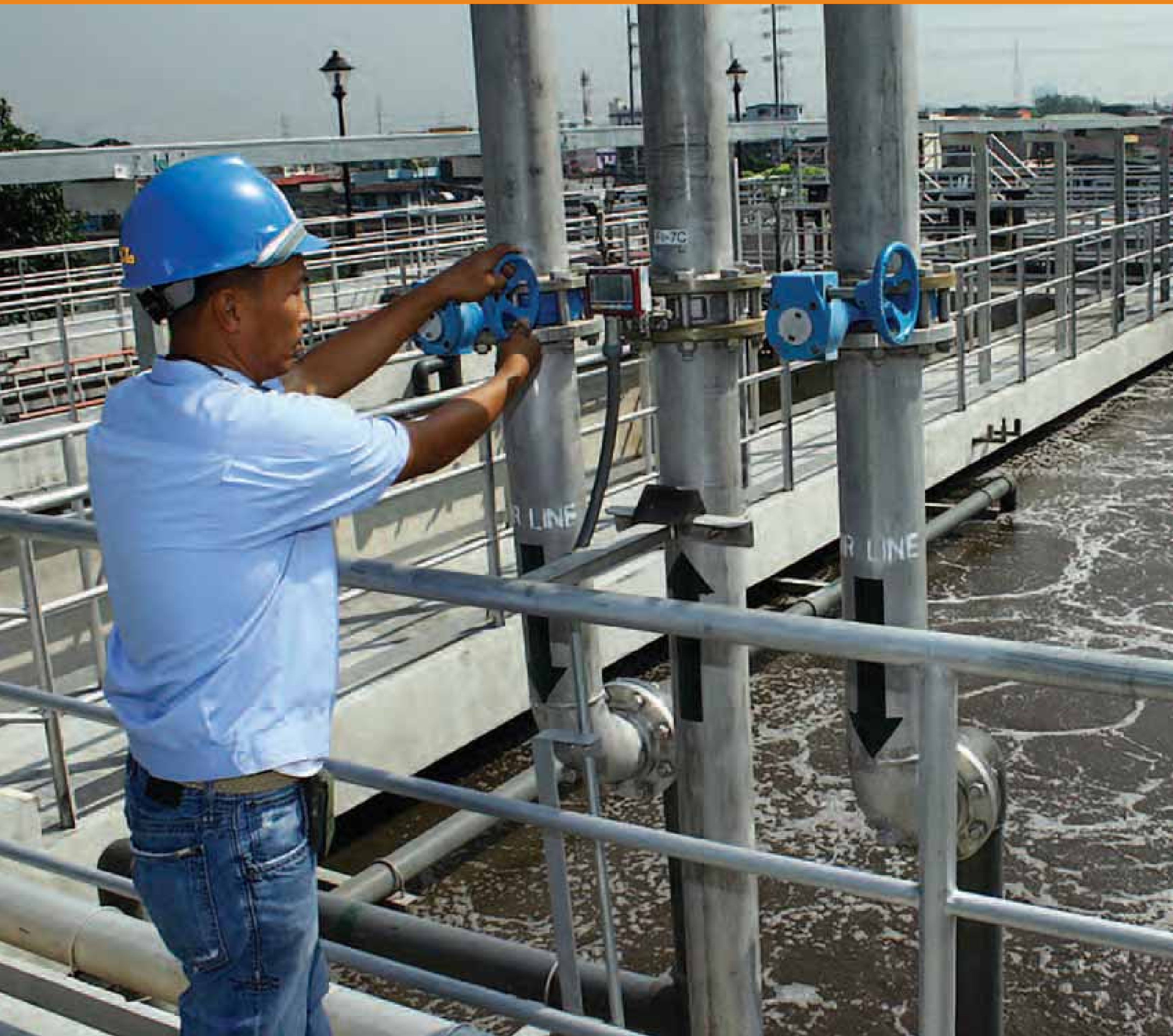
ESMAP

Energy Sector Management Assistance Program

TECHNICAL REPORT 001/12

A PRIMER ON ENERGY EFFICIENCY FOR MUNICIPAL WATER AND WASTEWATER UTILITIES



ESMAP MISSION

The Energy Sector Management Assistance Program (ESMAP) is a global knowledge and technical assistance program administered by the World Bank. It provides analytical and advisory services to low- and middle-income countries to increase their know-how and institutional capacity to achieve environmentally sustainable energy solutions for poverty reduction and economic growth. ESMAP is funded by Australia, Austria, Denmark, Finland, France, Germany, Iceland, Lithuania, the Netherlands, Norway, Sweden, and the United Kingdom, as well as the World Bank.

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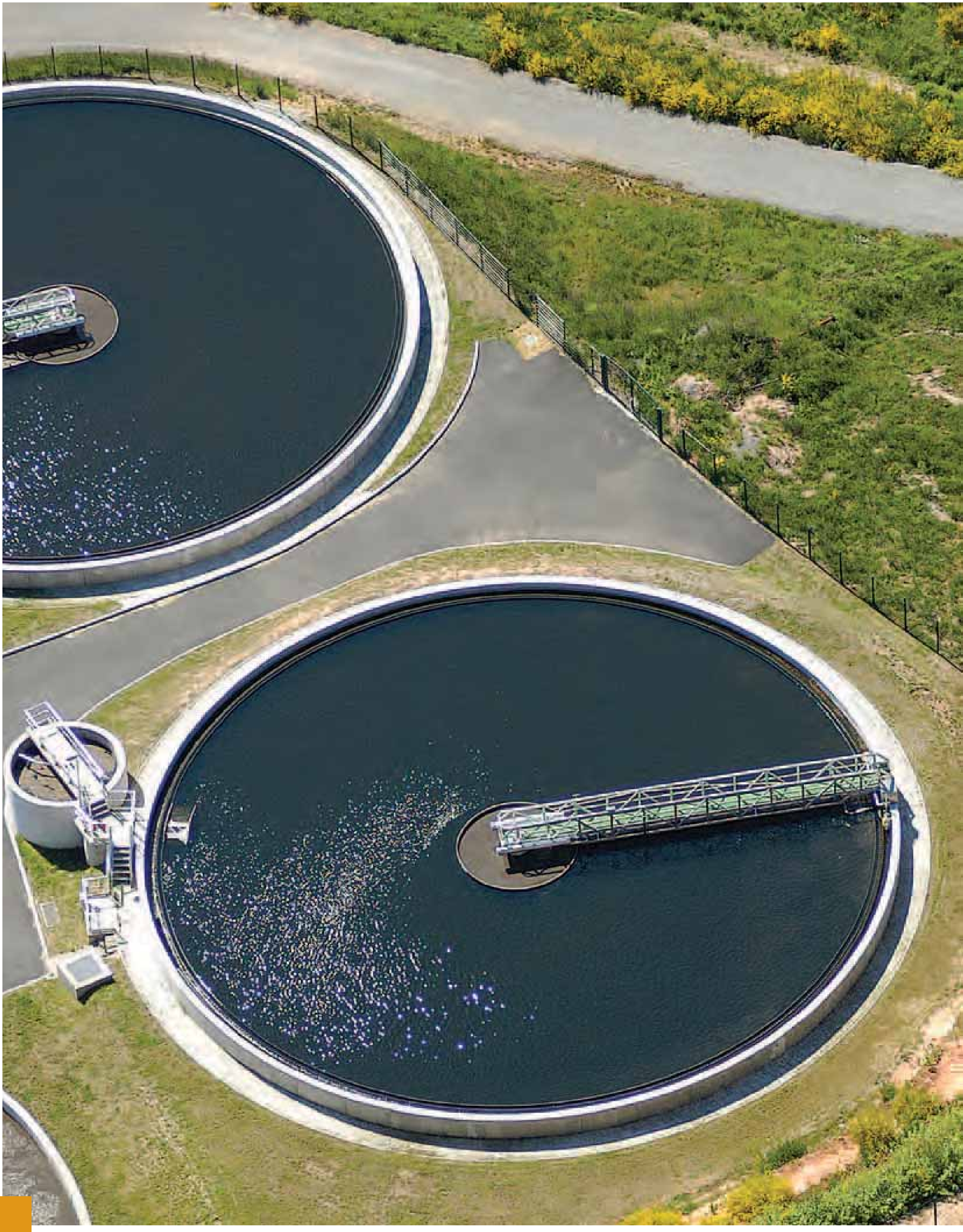
Energy Sector Management Assistance Program | The World Bank



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FOREWORD

This primer is concerned with energy use and efficiency of *network-based* water supply and wastewater treatment in urban areas. It focuses on the supply side of the municipal water cycle, including the extraction, treatment, and distribution of water, and collection and treatment of wastewater—activities which are directly managed by water and wastewater utilities (WWUs). Demand-side issues of the municipal water cycle, including water-use efficiency and water conservation, are referred to where linkages to energy efficiency (EE) are critical, but are not discussed in detail.

Electricity costs are usually between 5 to 30 percent of total operating costs among WWUs. The share is usually higher in developing countries and can go up to 40 percent or more in some countries. Such energy costs often contribute to high and unsustainable operating costs that directly affect the financial health of WWUs.

Improving EE is at the core of measures to reduce operational cost at WWUs. Since energy represents the largest controllable operational expenditure of most WWUs, and many EE measures have a payback period of less than five years, investing in EE supports quicker and greater expansion of clean water access for the poor by making the system cheaper to operate.

For cash-strapped cities, improving the EE of WWUs helps alleviate government fiscal constraints while also lessening the upward pressure on water and wastewater tariffs. On a national or global level, improving EE of WWUs reduces the pressure of adding new power generation capacity and reduces the emissions of local and global pollutants.

Based on the review of existing literature, most of the commonly applied technical measures to address EE issues at WWUs generate 10 to 30 percent energy savings per measure and have 1- to 5-year payback periods. Financially viable energy savings depend on the vintage and conditions of facilities, technologies used, effective energy prices, and other factors affecting the technical and financial performances of individual WWUs. Despite these challenges, there is evidence that significant energy savings at WWUs in developing countries can be attained cost effectively.

Adopting efficiency measures, such as those described in this primer, could see global energy saving potential of the sector at its current level of operation in the range of 34 to 168 terawatt hours (TWh) per year. The upper bound is roughly the annual generation of 23 large thermal power plants, or more than the annual electricity production of Indonesia in 2008.

The main challenges to scaling up EE in municipal water and wastewater services stem from sector governance issues, knowledge gaps, and financing hurdles. Utility governance affects the overall performance of individual WWUs and influences decision making, incentives and actions for energy management. This is likely the most significant barrier to WWU EE in many developing countries. Addressing knowledge gaps requires efforts to systematize data collection, training, and capacity building at utilities, supported by local and national governments. Financing hurdles can be reduced by introducing dedicated EE funds to address large but disaggregated investment needs and by promoting third-party financing through energy/water savings performance contracts.

The Energy Efficient Cities Initiative (EECI) of ESMAP was launched in 2008 to support municipal EE scale-up in World Bank (WB) operations and WB client countries. This primer is part of EECI's knowledge clearinghouse function to inform WB staff working in urban water supply and wastewater management, as well as in energy, about the opportunities and good practices for improving EE and reducing energy cost in municipal WWUs.

ACRONYMS AND ABBREVIATIONS

ACEEE	American Council for an Energy-Efficient Economy
AFR	Africa (World Bank region)
ANEEL	Agência Nacional de Energia Elétrica
ASE	Alliance to Save Energy
AWWA	American Water Works Association
CAESB	Companhia de Saneamento Ambiental do Distrito Federal
CBOD	carbonaceous biochemical oxygen demand
CDM	Clean Development Mechanism
CEC	California Energy Commission
CHP	combined heat and power
CO_2e	carbon dioxide equivalent
CONAGUA	Comisión Nacional del Agua
DAF	dissolved air flotation
DO	dissolved oxygen
DSM	demand-side management
EAP	East Asia and Pacific (World Bank region)
ECA	Europe and Central Asia (World Bank region)
EE	energy efficiency or energy efficient
EECI	Energy Efficient Cities Initiative
EEI	energy efficiency indicators
EPRI	Electric Power Research Institute
ESCO	energy service company
ESMAP	Energy Sector Management Assistance Program
ESPC	energy savings performance contract
FY	fiscal year
IBNET	International Benchmark Network for Water and Sanitation Utilities
IBRD	International Bank for Reconstruction and Development
IDA	International Development Association
IDB	Inter-American Development Bank
IFC	International Finance Corporation
ISO	International Organization for Standardization
Km	kilometer
kW	kilowatt
kWh	kilowatt hour
LAC	Latin America and Caribbean (World Bank region)
m^3	cubic meters
M&T	monitoring and targeting
mA	milliampere
MDB	multilateral development bank
MENA	Middle East and North Africa (World Bank region)
MIGA	Multilateral Investment Guarantee Agency
MW	mega watt
NGO	nongovernmental organization
NRW	nonrevenue water
NYSERDA	New York State Energy Research and Development Authority
O&M	operation and maintenance
OBF	on-bill financing
ORP	oxidation reduction potential
PIU	project implementation unit
PPP	public-private partnership
SAR	South Asia (World Bank region)
SCADA	supervisory control and data acquisition
SECCI	Sustainable Energy and Climate Change Initiative
SRT	sludge retention time
TA	technical assistance
TWh	terawatt (10^{12}) hour
UK	United Kingdom
UNFCCC	United Nations Framework Convention on Climate Change
UNICEF	The United Nations Children's Fund
US	United States of America
US$	United States dollar
USAID	United States Agency for International Development
USEPA	United States Environmental Protection Agency
VSD	variable speed drive
WB	World Bank
WBG	World Bank Group
WERF	Water Environment Research Foundation
WESCO	water energy service company
WHO	World Health Organization
WOP	Water Operators Partnerships
WSI	Water and Sanitation Initiative
WSP	Water and Sanitation Program
WSS	water supply and sanitation
WSSC	Washington Suburban Sanitary Commission
WWTP	wastewater treatment plant
WWU	water and wastewater utility

ACKNOWLEDGEMENTS

This primer was jointly prepared by staff from the Energy Sector Management Assistance Program (ESMAP), the Water Unit, and the Water and Sanitation Program (WSP) of the World Bank (WB). The task team consisted of Feng Liu (ESMAP), Alain Ouedraogo (ESMAP), Seema Manghee (Water Unit), and Alexander Danilenko (WSP). The report benefited from inputs and comments from Jeremy Levin, Elizabeth T. Burden, and Patrick A. Mullen of the International Finance Corporation (IFC). Shahid Chaudhry (consultant) contributed to the review of business models and energy management practices in water and wastewater utilities. Hua Du (consultant) provided research assistance. The team expresses its sincere appreciation for the valuable comments and suggestions from WB peer reviewers Caroline Van Den Berg, Manuel G. Marino, and David Michaud. The team wishes to thank Rohit Khanna and Jas Singh of ESMAP for their advice during the preparation of this report. Editing and production management by Nick Keyes and Heather Austin of ESMAP are gratefully acknowledged.

CONTEXT AND BACKGROUND

WHY DOES ENERGY EFFICIENCY MATTER FOR URBAN WATER AND WASTEWATER SERVICES?

Electricity is a critical input for delivering municipal water and wastewater services. Electricity costs are usually between 5 to 30 percent of total operating costs among water and wastewater utilities (WWUs) worldwide. The share is usually higher in developing countries and can go up to 40 percent or more in some countries, such as India and Bangladesh.[1] Such energy costs translate into high and often unsustainable operating costs, which directly affect the financial health of WWUs, puts strains on public/municipal budgets, and can increase tariffs on their customer base.

In developing countries, WWUs are commonly owned and operated by the government. Many are run by city authorities. As such, electricity used for provision of water and wastewater services can have a significant impact on a municipal governments' budget and fiscal outlook.[2] In India, for example, water supply was reported to be the largest expenditure item among all municipal services.[3] Programs designed to lead to reductions in WWU operating costs can thus become an attractive proposition for both utilities and their municipal owners, potentially creating fiscal space to grapple with other socioeconomic priorities while also lessening the upward pressure on water and wastewater tarriffs.

Improving energy efficiency (EE) is at the core of measures to reduce operational cost at WWUs. Since energy represents the largest controllable operational expenditure of most WWUs, and many EE measures have a payback period of less than five years, investing in EE supports quicker and greater expansion of clean water access for the poor by making the system cheaper to operate (Box 1.1).

On a national or global level, improving EE of WWUs reduces the pressure of adding new power generation capacity and reduces the emissions of local and global pollutants. Available case studies indicate that cost-effective measures can bring up to 25 percent overall EE improvements at WWUs in developing countries.[4] A recent assessment of WWUs in industrialized countries also suggests similar financially viable systemwide energy savings potential (5 to 25 percent).[5] Using the 5 to 25 percent range, the global energy savings of the sector at its current level of operation could be in the range of 34 to 168 TWh per year.[6] The upper bound is roughly the annual generation of 23 large thermal power plants (1,000 MW each), more than the annual electricity production of Indonesia in 2008.

Increase in demand for energy to move and treat water and wastewater in developing country cities is likely to be significant in the next 20 years or so. The world's urban population is projected to grow by 1.5 billion from 2010 to 2030; about 94 percent of this growth will occur in developing countries.[7] Extrapolating by urban population growth alone would imply a 40 percent rise in demand for municipal water and wastewater services by 2030.[8] One must also consider the fact that currently only about 73 percent of urban households in developing countries have access to piped water and 68 percent have access to improved sanitation, compared with virtually universal coverage of such services in developed countries.[9]

BOX 1.1

Saving Energy and Serving More People: City of Fortaleza, Brazil

In Fortaleza, Brazil, the local water utility implemented measures to improve the distribution of water while reducing operational costs and environmental impacts. With an investment of only US$1.1 million to install an automatic control system and other simple measures, the company reduced electricity consumption by 88 GWh and saved US$2.5 million over 4 years. During the same period, the utility was able to establish an additional 88,000 new connections without increasing overall energy use.

Source | ASE, 2006.

BOX 1.2

Trends in Sector Policies and Technologies and Impact on Future Energy Use

PUBLIC HEALTH AND ENVIRONMENTAL REQUIREMENTS | Requirements for and/or enforcement of effluent standards are likely to continue to improve in developing countries. This will result in greater use of secondary and tertiary treatments which will increase energy intensity of wastewater treatment. Trends in developed countries also indicate that new drinking water quality requirements, such as disinfection of microbial contamination, may necessitate the use of more energy-intensive technologies.

TECHNOLOGICAL TRENDS | Many technologies, to meet more stringent regulations, tend to be more energy intensive than prevailing technologies. Examples of these newer technologies include ultraviolet disinfection, ozone treatment, membrane filtration, and advanced wastewater treatment with nutrient removal. Nonetheless, some technologies may offer additional environmental benefits, for example, reduced chemical use (and associated embodied energy).

Desalination of seawater may become more common in water-short coastal areas. Despite technology advances, water supplied by desalination plants remains many times more energy intensive than conventional surface or ground water supplies. In water-short coastal areas with abundant solar energy, the carbon intensity of desalination could be tempered.

Combined heat and power (CHP) systems using biogas from anaerobic sludge digestion, a well established means of generating energy, can provide up to 15 percent of the power requirements at wastewater treatment plants using activated sludge process. Biogas may be used for other energy applications. Anaerobic digestion also reduces the solids content of sludge by up to 30 percent, reducing the energy costs involved in its transport.

IMPACTS OF CLIMATE CHANGE AND RELATED MITIGATION AND ADAPTATION POLICIES | In cities affected by aggravated droughts and freshwater shortages, new water supplies from deeper aquifers, through long distance transfer, or by desalination of seawater require more energy. On the other hand, climate change mitigation efforts in some countries, such as the UK, require or incentivize WWUs to reduce their carbon footprint, leading to greater EE improvements. Water conservation and water-use efficiency are key adaptation strategies for cities and generate significant mitigation benefits by reducing the energy demand of urban water and wastewater services.

Source | Compiled by authors.

In addition, based on trends in developed countries, water and wastewater treatment may become more energy intensive in the next two decades due to stricter health and pollution regulations, which often require additional or more sophisticated treatment that uses more energy (Box 1.2).

Greater efforts to improve EE in municipal water supply and wastewater treatment for both existing and new systems would have a number of positive effects: lower costs to consumers, the ability to serve new urban populations, greenhouse gas mitigation, and help to ensure the long-term fiscal stability of this vital municipal service.

ENERGY EFFICIENCY IN WORLD BANK INVESTMENTS IN MUNICIPAL WATER AND WASTEWATER SERVICES

The World Bank Group (WBG; including IDA, IBRD, MIGA, and IFC) has made significant progress in scaling up EE in its lending portfolio. Total EE lending in fiscal year (FY) 2010 was close to US$1.8 billion. The share of EE financing in total energy lending increased from just about 7 percent for FY2003-2005 to over 15 percent for FY2006-2010.

However, the EE portfolio remains dominated by the industrial and energy sectors. Municipal EE lending projects or components, including those associated with the water and sanitation sector, have been difficult to develop and materialize due to sector barriers (Table 2.2) and competing demand for financing from other urban development needs. Scaling up municipal EE lending is hindered also by limited awareness of the opportunities for positive impacts in this sector and available solutions among WBG urban and energy operations staff.

The scope for leverage is significant. From FY2000-2010, the total investment commitments of the World Bank (WB; including IDA and IBRD) in the urban sector were about US$25.4 billion. Investment commitments in urban water supply and wastewater management during the same period totaled about US$16.1 billion, close to two-thirds of the urban lending portfolio, indicating a major opportunity for mainstreaming EE in the WB's investments in water and wastewater services.

A portfolio review reveals that EE interventions in WB water and sanitation investment operations have been quite uneven, reflecting regional differences in urbanization and urban infrastructure status (Box 1.3; Annex A). A key conclusion is that EE in WWUs can be substantially advanced if energy performance considerations are taken into account and highlighted in project designs. This seems to be most often associated with projects whose primary activity was system rehabilitation. Few new infrastructure projects have considered EE as an explicit project objective.

The International Finance Corporation (IFC), the private sector arm of the WBG, also has engaged in a variety of advisory and investment activities related to efficiency and conservation in water and sanitation sector. Key lessons from the IFC's activities include: (a) the importance of being proactive in policy dialogue and technical advice; (b) the need for stronger partnerships between public and private sectors; (c) the synergies gained through broader alliances and partnerships with the WB, other multi-donor banks (MDBs), donors, and the private sector; and (d) the need for well-balanced model energy service contracts applicable to the water sector.

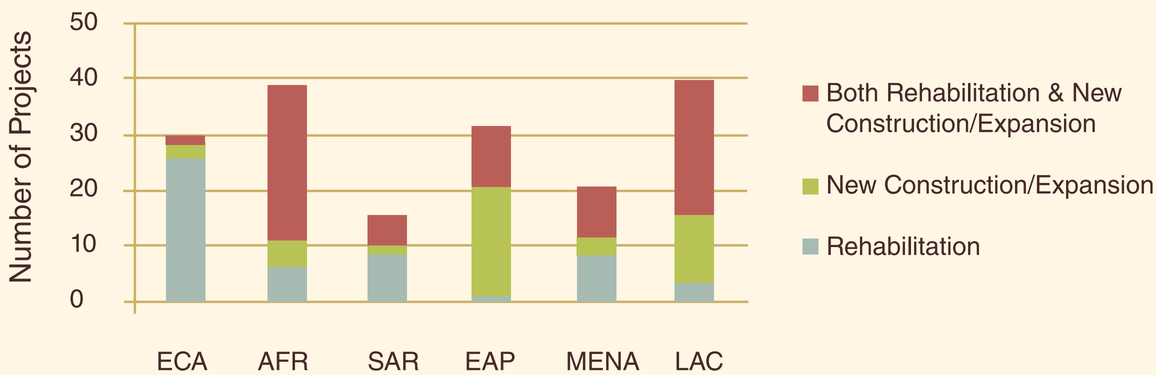
BOX 1.3

Main Findings of a Portfolio Review of World Bank Urban Water and Sanitation Operations

From FY2000-2010 the WB funded 178 projects in urban water and sanitation operations, with total investment commitments of about US$16.1 billion, representing 63 percent of overall investment commitments of the WB on urban projects. This entire portfolio was reviewed, covering urban water supply and sanitation (WSS) projects extracted from the WB Business Warehouse.

The Europe and Central Asia (ECA) and the South Asia (SAR) regions focused on rehabilitating existing infrastructures, while the East Asia and Pacific (EAP) region emphasized new infrastructure. The split between new construction and rehabilitation in other regions was not as distinctive.

Regional Orientation on Rehabilitation and/or New Construction/Expansion



Overall, EE considerations in project design and implementation have been limited in the reviewed portfolio. Only 19 out of 178 projects explicitly considered EE improvements by including EE indicators (EEIs) as key performance metrics in the results framework, and 15 of them were implemented by the ECA region. While this by no means indicates the actual EE content of the reviewed portfolio, it does underscore the fact that explicit EE considerations in projects have been infrequent.

DRIVERS FOR EE CONSIDERATION | Two-thirds of the projects with EEIs aimed to improve utilities' financial viability as operating deficits and lack of financing impeded adequate infrastructure maintenance. High energy costs at WWUs also were an important factor. In cases where energy costs were not well documented, available benchmarks of energy use influenced projects to consider EE measures, too.

EE INTERVENTIONS | EE-related measures included in the reviewed portfolio fell into two categories: (a) Investment measures involving physical changes of the system or equipment leading to energy savings, and (b) soft measures that pave the way to promote or sustain EE improvements, such as cost-reflective tariff.

MODELS FOR PROJECT FINANCING AND IMPLEMENTATION | There were mainly three types of approaches: (a) direct financing with utility-led implementation, (b) municipal development funds using standard criteria, and (c) public-private partnerships (PPPs) with financing for physical investments. There is only one case of carbon financing, which is under implementation. Some specific lessons associated with these approaches include:

- Robust baseline assessment is always important for EE investment projects/components;
- Multi-purpose municipal development fund seem to have rather weak incentives for financing EE investments; and
- Utilities with private sector participation are generally motivated and knowledgeable about the optimal use of funds to reduce energy consumption.

Source | Compiled by Authors.

The WBG operates in countries where there is a large need for rehabilitation of existing municipal water and wastewater infrastructures (such as Ukraine and Armenia), in countries where demand for new municipal water and wastewater infrastructures are growing fast (such as Vietnam, India, and China), as well as in countries where the infrastructure is more developed but needs modernization and expansion (such as Brazil and Mexico).

The approach to rehabilitation is usually incremental, so as to upgrade and optimize often deteriorating systems over time. The approach to new infrastructure projects will need to address the linkages with sustainable urban development in fast-growing economies, especially the integration of water conservation and water-use efficiency into the planning and construction of municipal water and wastewater systems.

NOTABLE ACTIVITIES UNDERTAKEN BY OTHER MULTILATERAL AND BILATERAL ORGANIZATIONS

The Inter-American Development Bank (IDB) has been working with countries in the Latin America and the Caribbean (LAC) region to incorporate more EE interventions into IDB's development assistance in the water and sanitation sector. This ongoing effort includes multiple activities to assist WWUs learn, develop, and implement EE interventions (Box 1.4).

Another notable and long-running donor-assisted activity is the Watergy program implemented by the Alliance to Save Energy (ASE) and funded by the United States Agency for International Development (USAID). The Watergy approach is comprehensive with a goal of improving municipal water service efficiency by addressing inefficiency and waste of energy and water in water supply systems and in water end use (Figure 1.1).[10] The Watergy program is currently active in Brazil, India, Mexico, Philippines, South Africa, and Sri Lanka.

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IDB's EE Assistance Program for WWUs in Latin America and the Caribbean

Activities to improve EE at WWUs of LAC countries have been executed under two IDB initiatives launched in 2007: the Sustainable Energy and Climate Change Initiative (SECCI) and the Water and Sanitation Initiative (WSI). Within these two initiatives, IDB has been promoting EE as a means to reduce utility operating costs and mitigate climate change with the following approaches:

TECHNICAL ASSISTANCE (TA) TO DEFINE EE PLANS | SECCI, which includes EE improvements at WWUs as one of its climate-sensitive intervention areas, has provided WWUs TA grants to conduct energy audits, and develop EE improvement plans as well as new operations and maintenance practices. Since SECCI's launch, energy audits and EE plans have been completed for 14 water and wastewater operators in Colombia as well as 6 operators in the Caribbean and 9 in Central America and other parts of Latin America. EE plans are under development for three additional operators.

INVESTMENT LOANS TO IMPLEMENT EE MEASURES | WSI has followed up on some of the EE assessments supported by SECCI and provided investment loans to implement EE project components proposed by the EE plans. For instance, loans are being prepared for water and sanitation projects in Suriname, Guyana, Panama, Nicaragua, Jamaica, and the Dominican Republic.

PARTNERSHIPS TO SHARE BEST PRACTICES | IDB and UN-Habitat have jointly established the Water Operators Partnerships (WOP), a platform to promote best practices and partnerships among water operators, and between operators and other interested parties, including donors. WOP has sponsored training workshops and seminars on EE in Brazil, Argentina, Ecuador, Costa Rica, Virgin Islands, and Belize. It has also forged 16 twining arrangements among WWUs in LAC and maintains a database.

KNOWLEDGE DISSEMINATION TO HELP WWUS REALIZE ENERGY COST SAVINGS | Knowledge generated from IDB's EE assistance for WWUs is being compiled for dissemination. IDB is preparing tools—energy audit manual, energy savings calculator, maintenance manual—to guide WWUs in realizing energy cost savings.

Source | Based on IDB documents and communications with Rodrigo Riquelme of IDB.

FIGURE 1.1

Watergy

WATER EFFICIENCY is cost-effectively delivering water services, while minimizing water and energy use.

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Supply-Side Efficiency Measures

Water supply systems offer multiple opportunities to reduce water and energy waste directly, while better serving customer needs.

- Leak and loss reduction
- Perations and maintenance
- Pumpingsystems
- Primary/secondary wastewater treatment
- Pump systems

+

Demand-Side Efficiency Measures

Consumers

Residential

Industrial

Reducing demand by helping the consumer use water more efficiently decreases the required water supply, saving both energy and water.

- Water-efficient household appliances
- Low-flow toilets
- Low-flow showerheads
- Industrial water reuse
- Leak and water waste reduction

+

Comprehensive Demand-/ Supply-Side Approach Synergies

Looking at a water system comprehensively and ensuring efficiency projects are designed in tandem, creates even greater efficiency opportunites.

- Right-sizing pump systems after reducing consumer demand
- Avoiding wastewater treatment by promoting reuse and reducing demand

Source | *ASE, 2002.*

2

ENERGY USE AND EFFICIENCY OF MUNICIPAL WATER AND WASTEWATER UTILITIES

DETERMINING ENERGY EFFICIENCY FOR WATER AND WASTEWATER UTILITIES

The overall EE of WWU services can be indicated by electricity use per unit of water delivered to end-users and per unit of wastewater treated (kWh/m^3-water or wastewater).[11] For a given level of service and regulatory compliance, reduction in those energy intensity numbers indicates improvement in EE of service delivery. In practice, applying these aggregate indicators has two main difficulties:

1 | MISMATCH OF ENERGY AND WATER/WASTEWATER FLOW DATA | This arises when end-use metering is not universal and less than 100 percent of wastewater is treated. Oftentimes, energy use per unit of water produced is used as an indicator, instead of water delivered. Doing so leaves out an important efficiency factor—physical losses in the network.

2 | INCOMPARABLE OPERATING CONDITIONS AND PROCESSING TECHNOLOGIES BETWEEN UTILITIES. Using these aggregate indicators for inter-utility comparison is usually fraught with problems because they are significantly affected by system operation conditions (e.g., daily flow, water main length, mix of water sources, distribution elevation, use of gravity for distribution or collection, etc.) and processing technologies (e.g., level of treatment for wastewater). For example, electricity intensity of water supply in the State of New York (varying from 0.158 to 0.285 kWh/m^3-water produced) is significantly below the United States national average of 0.370 kWh/m^3 primarily due to the predominance of surface water sources and a large share of gravity-fed distribution in New York.[12]

Figure 2.1 provides a glimpse of the divergence of energy intensity of water supply in selected countries. The differences do not necessarily indicate actual EE gaps between utilities on a comparable basis for reasons previously indicated.

Since it is difficult and potentially misleading to generalize system-level energy performance over a wide region or a country, benchmarking WWU EE is likely to be most useful for specific processing technologies and equipment, instead of aggregate energy intensities. It is useful to define disaggregate indicators that are most useful for individual WWUs to monitor and manage energy consumption and EE improvement over time.

ENERGY CONSUMPTION PATTERNS[13]

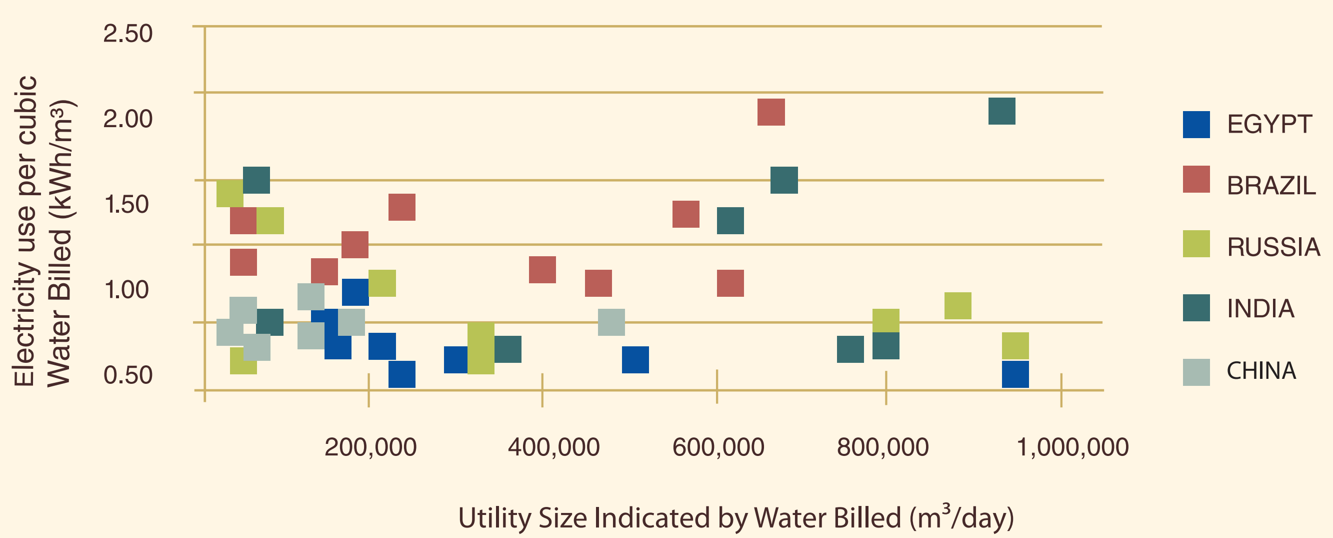
In general, larger systems (to a limit) tend to be less energy intensive than smaller ones. Electricity use in administrative and production buildings of WWUs, such as lighting and space conditioning, is a small percentage of a WWU's overall energy use. The basic energy characteristics of municipal WWUs are summarized in Table 2.1.

With the exception of gravity-fed systems, pumping for distribution of treated water dominates the energy use of surface water-based supply systems, usually accounting for 70 to 80 percent or more of the overall electricity consumption. The remaining electricity usage is split between raw water pumping and the treatment process. Groundwater-based supply systems are generally more energy intensive than surface water-based systems because of higher pumping needs for water extraction (on average, about 30 percent difference in the United States).[14] On the other hand, groundwater usually requires much less treatment than surface water, often only for the chlorination of raw water, which requires very little electricity.

Energy usage of municipal wastewater treatment varies substantially, depending on treatment technologies, which often are dictated by pollution control requirements and land availability. For example, advanced wastewater treatment with nitrification can use more than twice as much energy as the relatively simple trickling filter treatment. Pond-based treatment is low energy but requires large land area. The estimated energy intensity for typical large wastewater treatment facilities (about 380,000 m^3/day) in the United States are 0.177 kWh/m^3-treated for trickling filter; 0.272 kWh/m^3 for activated sludge; 0.314 kWh/m^3 for advanced treatment; and 0.412 kWh/m^3 for advanced treatment with nitrification.[15] The ascending energy intensity of the four different processes is due mainly to aeration (for the latter three treatment processes) and additional pumping requirements for additional treatment of the wastewater. In fact, for activated sludge treatment, a commonly used process in newer municipal wastewater treatment plants (WWTPs), aeration alone often accounts for about 50 percent of the overall treatment process energy use.

FIGURE 2.1

Electricity Intensities of Water Supply (Water Billed) in Select Countries



Note | Water billed may not reflect water delivered due to incomplete metering, pilferage, and other billing issues.
Source | IBNET database.

TABLE 2.1

Indicative Energy Use of Municipal Water and Wastewater Services

ENERGY USING ACTIVITY		INDICATIVE SHARE	COMMENTS
WATER SUPPLY			
Raw Water Extratction	Pumping Building services	Surface Water: 10% Ground Water: 30%	
Treatment	Mixing Other treatment processes Pumping (for backwash, etc.) Water sludge processing and disposal Building services	Surface Water: 10% Ground Water: 1%	
Clean Water Transmission and Distribution	Pumping	Surface Water: 80% Ground Water: 69%	Dependent on the share of gravity—fed water supply
WASTE WATER MANAGEMENT (ACTIVATED SLUDGE TREATMENT PROCESS)			
Waste Water Collection	Pumping	10%	Dependent on the share of gravity-induced collection
Treatment	Aeration Other treatment processes Building services	55%	Mostly for aeration of wastewater
Sludge Treatment and Disposal	Centrifugal and press dewatering Sludge pumping, storing, and residue burial Building service	35%	Energy can be produced in sludge processing

Source | Compiled by authors based on estimates of typical systems in the United States (EPRI, 2002).

ENERGY EFFICIENCY OPPORTUNITIES AND COST EFFECTIVENESS OF COMMON INTERVENTIONS

Based on the review of existing literature, most of the commonly applied technical measures to address EE issues at WWUs generate 10 to 30 percent energy savings per measure and have 1- to 5-year payback periods. Financially viable energy savings depend on the vintage and conditions of facilities, technologies used, effective energy prices, and other factors affecting the technical and financial performances of individual WWUs. A summary of the review is provided in Annex B.

There is evidence that significant energy savings at WWUs in developing countries can be attained cost effectively. Recent energy audits at 12 WWUs across the LAC region reveal energy savings

BOX 2.1

Key Energy-Saving Opportunities and Viable Potential in Water and Wastewater Utilities

There are two areas with most potential—pumps of most types and functions, and aerobic wastewater treatment systems. Potential energy savings include:

PUMPS AND PUMPIMG (COMMON POTENTIAL RANGES: 5-30%)

- 5-10% by improving existing pumps
- 3-7% through improvement to new pumping technology (pump technology is generally mature)
- Gains up to 30% are possible through maintenance improvement and closer matching of pumps to their duties (such as, using VSDs)
- More complex and large-scale pumping energy savings are feasible but frequently show marginal payback using current financial analyses

AEROBIC SEWAGE TREATMENT (UP TO 50%)

- Simple gains of up to 50% are possible on some aerobic wastewater systems by aligning control parameters with the discharge standard
- Up to 25% in activated sludge process wastewater plant

OTHER OPPORTUNTIES

- Up to 20% from drinking water processes, but the energy use in this category is low
- Up to 15% improvement in building services

Source | WERF, 2010,

potential ranging from 9 to 39 percent at utility level with an average payback period of 1.5 years.[16] These energy audits also highlight the main EE problems (interpreted as savings opportunities) with pumps and motors across WWUs due to inadequate pump specifications, change in operating conditions, and lack of regular and structured maintenance. An energy assessment study (including limited energy audits) of 5 WWUs in China identifies multiple improvements with 10 to 25 percent energy savings and 1.7 to 5.9 years of payback periods.[17]

A recent assessment of WWUs in developed economies of Europe and North America concludes that systemwide EE gains between 5 to 25 percent appear to be financially viable under prevailing operation and financial conditions. The main findings are summarized in Box 2.1. The areas of opportunity and their relative importance in terms of the magnitude of energy savings do not differ substantially from findings from developing countries.

A system approach is very important for maximizing energy savings in a most cost-effective manner. This often requires optimization of system architecture and operation, instead of just focusing on specific equipment. Hydraulic analysis of the entire water supply system can help avoid missing strategic actions and identify system design improvements.

It is important to point out that water loss/leakage reduction or, more broadly, non-revenue water (NRW) reduction, has a significant impact on energy consumption of municipal water service delivery, but often is considered as a separate set of activities at water utilities due to its technical and institutional complexity.[18] NRW remains a serious challenge in most developing countries where it usually is higher than 30 percent of produced water volume, compared with less than 10 percent in global best practices. Technical losses (leaks) are frequently the main cause.[19] The standard practice in NRW management is to reduce leakage to a level that breaks even with the cost of new water supply. Measures to reduce both water losses and energy waste, such as leak reduction, can provide double benefits to utilities by increasing salable water without adding energy consumption.

BARRIERS TO IMPROVING ENERGY EFFICIENCY IN WATER AND WASTEWATER UTILITIES

Optimization of energy use in the design and operation of municipal water and wastewater systems remains a patchy practice even in countries where energy costs are high. A number of barriers inhibit proactive energy management to address EE issues at WWUs. Some barriers are deeply rooted in the governance of the sector, referred to as institutional and regulatory issues. Some are associated with the lack of knowledge and know-how about EE opportunities, solutions, costs, and benefits. Others are caused by limited access to and availability of financing. Still other barriers are related to the general EE policy and market conditions of specific countries or sub-national regions where the WWUs operate. The main barriers and commonly observed barrier removal actions are summarized in Table 2.2.

Commitment of top management to EE is often cited as the most critical factor for effective and sustained EE efforts at WWUs. Without a general governance framework or institutional environment that demands good performance and financial accountability specific EE efforts at the utility level are unsustainable.

Overcoming the barriers to improving EE requires solutions that are specific to WWUs and their institutional and regulatory environment, as well as address issues beyond the sector boundary. From a management decision point of view, strengthening the incentive for taking up EE interventions by political, regulatory, and/or financial means and increasing the flow of quality information on EE solutions and associated costs and benefits are essential for decisionmakers at WWUs to become champions for EE.

The experience of SANASA, a well performing Brazilian WWU in the City of Campinas, in improving the overall service quality and efficiency is worth noting. Between 2000 and 2008, SANASA was able to increase tap water connections by 22 percent without additional energy requirements. These new connections are primarily for the urban poor living in peri-urban slums, or favelas, enabling around the clock tap water service to reach 98 percent of the population of the city by 2008, compared with about 88 percent in 2000. The most important lesson learned from SANASA's experience is that sustained EE efforts have to be underpinned by a constant desire to improve business performance, which is primarily driven by the commercial interest of the utility, but also is influenced by their social obligations. Such drivers combined with good corporate governance have been essential for SANASA's success.[20]

TABLE 2.2

Main Barriers to Improving EE in WWUs

BARRIER/ISSUE AREA	CONSEQUENCE	BARRIER REMOVAL ACTION
INSTITUTIONAL AND REGULATORY		
Politicizing of water and wastewater tariffs	Insufficient revenue to cover depreciation and maintenance, leading to protracted decline of infrastructure, service quality and efficiency, and utility creditworthiness	Sector reforms that make financial sustainability of WWUs a priority while addressing social concerns of water and sanitation services
Constraints of public sector budgeting	WWUs whose operating costs are funded by municipal budgets are reluctant to invest in EE improvements due to the potential reduction in operating budget	Financial ring-fencing of WWUs so they become independently accountable and self-sustaining operations, part of sector reform agenda
Low cost of electricity due to subsidies, cost-pass-through, or low electricity prices	Reducing or removing incentive to improve EE	Removal of WWU electricity subsidies and linking tariff adjustments to energy performance, part of sector reform agenda
EE is not a required element for assessing WWU performance	The paramount importance of protecting public health tends to make regulators and WWUs overly conservative when balancing EE and process performance	Starting with operation-enhancing procedural requirements, such as adequate energy/water metering, regular and structured maintenance
Divided responsibilities for energy procurement and operation efficiency	Complicating implementation of EE measures. In many instances, operating personnel do not see utility bills and have no responsibility for reducing energy cost	Large and medium sized WWUs will benefit from an energy management team, which has a mandate to control energy cost
WWU operational staff often are given distinctive roles	Limiting crossover of responsibilities and discouraging development of facility-wide energy awareness	Similar to above
KNOWLEDGE AND KNOW-HOW		
Inadequate information about EE opportunities, solutions, and their costs and benefits, credibility of savings	Contributing to the lack of interest in and support to EE interventions among WWU managers, public policymakers, and financial institutions	• Development and dissemination of case studies of good practices successful projects and programs • Development of a harmonized framework for sharing and comparing data and information • Development of rapid assessment tools, including benchmarking capabilities, to help inform and guide decision making • Awards and recognition

TABLE 2.2

Main Barriers to Improving EE in WWUs continued

BARRIER/ISSUE AREA	CONSEQUENCE	BARRIER REMOVAL ACTION
KNOWLEDGE AND KNOW-HOW		
Limited internal capacity of WWUs to identify and undertake energy optimization	Preventing WWUs to take systematic and well sequenced EE interventions, and undermining WWUs' ability to put together feasible EE investment projects	• External TA in energy assessment, training, and peer-to-peer learning supported by government and international donors • For large countries, multipronged assistance approaches by national and regional government agencies, electric utilities (obliged by regulation), and professional NGOs (see U.S. example in Annex C)
ACCESS TO AND AVAILABILITY OF FINANCING		
Low credit rating of WWUs or cities, a prevalent problem in many countries where WBG operates	Making it difficult if not impossible to obtain commercial financing for EE investments	This will require long-term solutions backed by sector reforms, but can begin with: • Reducing risk to lenders through use of a guarantee facility that pays the lender an initial loss amount or a portion of the full payment default. Such a facility could be funded by the government or by international donor funds • A large national WWU could have its borrowing guaranteed by the government – or additionally receive credit enhancement for its borrowing using a MDB partial credit guarantee • In some cases, the investment could be structured to be viable as a project (separate from the finances of the WWU) and could therefore attract private sector investment. PPPs supported by multilateral or bilateral development institutions

BARRIER/ISSUE AREA	CONSEQUENCE	BARRIER REMOVAL ACTION
ACCESS TO AND AVAILABILITY OF FINANCING		
Small size of EE investments	Making EE investments in WWUs unattractive to commercial lenders or multilateral development banks due to high transaction costs	• Bundling through third-party arrangements, such as ESCOs • Dedicated national or provincial funds to centrally review and supervise EE investments proposed by WWUs or proponents • Accessing climate/carbon financing to offset high transaction costs
Underdeveloped EE financing market	Many financially attractive EE investments cannot be implemented	Require national efforts to develop EE policy framework, energy service industry, electric utility DSM programs, and commercial EE financing. Multilateral and bilateral development institutions can facilitate such efforts by financing targeted TAs and through pilots and demonstrations [21]

Source | *Compiled by Authors.*

3

MANAGING ENERGY PERFORMANCE IN MUNICIPAL WATER AND WASTEWATER UTILITIES

Improving EE is often the focus of WWU energy management activities. But energy management also includes activities that reduce energy cost but not necessarily energy consumption. Maintaining a long-term commitment to improving energy performance requires an organized and sustained effort to identify gaps, develop cost-effective solutions, and secure financing for needed investments. This section presents experiences and lessons learned about energy management at the utility level.

WHAT DOES ENERGY MANAGEMENT ENTAIL?

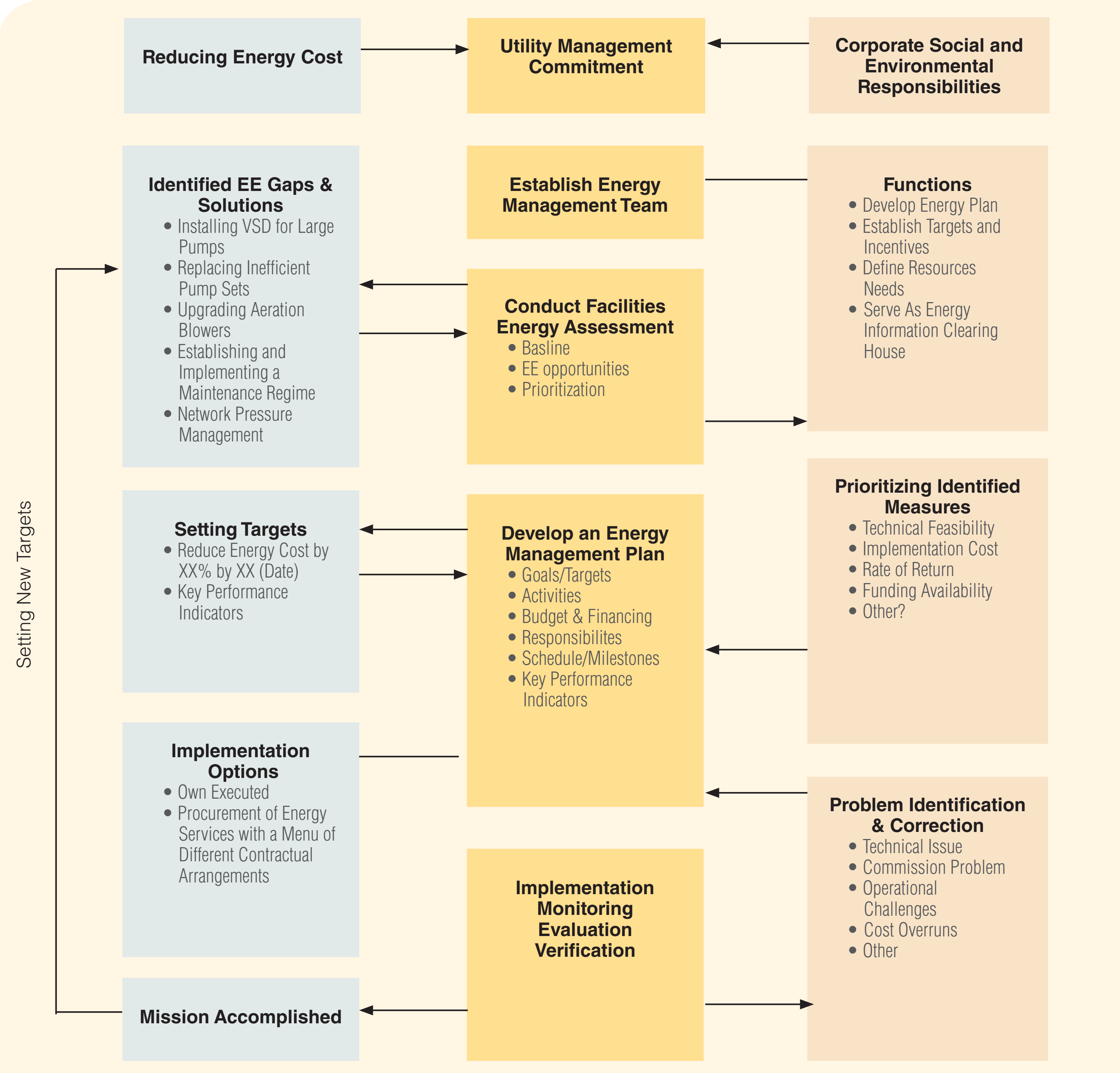
The main goal of energy management at WWUs is to reduce energy cost without compromising public health, environmental regulatory compliance, and service obligations. The premise is that energy management has to pay for itself and provide net financial benefit to WWUs. Energy management activities at WWUs, not all of which necessarily lead to net energy savings, can be divided into three categories by objective:[22]

1 | REDUCING POWER DEMAND AND ENERGY CONSUMPTION by improving EE of equipment, processes, and overall service delivery. This includes all activities/measures that result in actual reduction of power demand and energy consumption while maintaining the same level of service and regulatory compliance, for example, reductions in kW and kWh per cubic meter of water delivered or wastewater treated (compliant with the same effluent standards). Examples of specific EE measures include: regular maintenance; installation of variable speed drives (VSDs) to manage pump duties; lighting and space-conditioning efficiency in offices and control rooms; energy optimization of wastewater treatment processes; rehabilitation of leaky networks; and active leakage control through pressure management.

2 | MANAGING PEAK DEMAND AND OTHER POWER SYSTEM CHARGES by adjusting operation schedule and preventing billing penalties. These activities generate energy cost savings but not energy savings. In many countries, electric utilities charge WWUs for demand/capacity (kW) and charge consumption (kWh) during power system peak load period(s) at a much higher rate than off-peak period(s). WWUs can reduce energy costs by reducing peak power demand by shifting some pumping and treatment operations to off-peak period(s), possibly using automated control systems. This may involve the use of elevated reservoirs and water tanks for off-peak pumped storage.[23] Additionally, electric utilities may penalize WWUs for drawing more power than actually needed due to low power factors, which can be corrected by installing power capacitors.[24]

FIGURE 3.1

Energy Management Process at Water and Wastewater Utilities



Source | *Authors.*

3 | MANAGING ENERGY COST VOLATILITY AND IMPROVING ELECTRICITY SUPPLY RELIABILITY by investing in alternative power supplies. WWUs may adopt a range of activities to protect themselves from future rises in electricity prices and potential supply interruptions by negotiating long-term energy supply contracts, participating in electric utility demand management programs, and investing in financially attractive on-site energy generation, such as utilization of biogas from anaerobic sludge digesters.[25]

The activities under the first two objectives are most commonly adopted by WWUs, though they are sometimes at odds with each other. For example, shifting high-cost operation during electricity peak-use hours to off-peak hours means that network pumping activities will increase (increasing water pressure) during low-water use periods (at night), which may lead to higher water losses (and energy use) than pumping according to the water demand curve. This conflict can be better managed or resolved with hydraulic modeling and network sectorization[26] to better understand leakages under different energy management operation regimes. [27, 28]

To be able to carry out the above activities effectively and efficiently, WWUs need to adopt a structured approach in energy management. The recently released international standard for enterprise Energy Management Systems (ISO50001) offers useful guidance[29] for good energy management. The practices in general follow an iterative process of "Plan-Do-Check-Act." Also, well documented guidebooks provide detailed guidance to WWUs on setting up and implementing an in-house energy management system.[30] The basic elements of this process are discussed below.

GOOD ENERGY MANAGEMENT PRACTICES

For large- and medium-sized WWUs, there are a multitude of opportunities and options for reducing energy cost. System-wide energy optimization is a complex undertaking, involving balancing multiple objectives and substantial efforts in operational data acquisition and analysis, which may require external expertise, and external financing.[31] A long-term and incremental process will enable a utility to better cope with the organizational and financing requirements to achieve cost-effective results. Energy management may start from one facility and expand to cover additional facilities over time as internal capacity increases. The following steps (also depicted in Figure 3.1) are a general pathway toward better energy management. Of course, the scope and scale of activities under each step will need to be managed according to the internal capacity and resources available to a specific WWU:[32]

1 | ESTABLISH ORGANIZATIONAL COMMITMENT AND AN ENERGY MANAGEMENT TEAM | Large WWUs are typically multi-facility and multi-departmental organizations whose energy management requires coordination across division boundaries. Commitment must come from top-tier management via the establishment of an energy management team that can work effectively with different units within a utility, such as operations, engineering, and accounting departments. The energy management team needs to have clear responsibilities and resources to support viable initiatives.

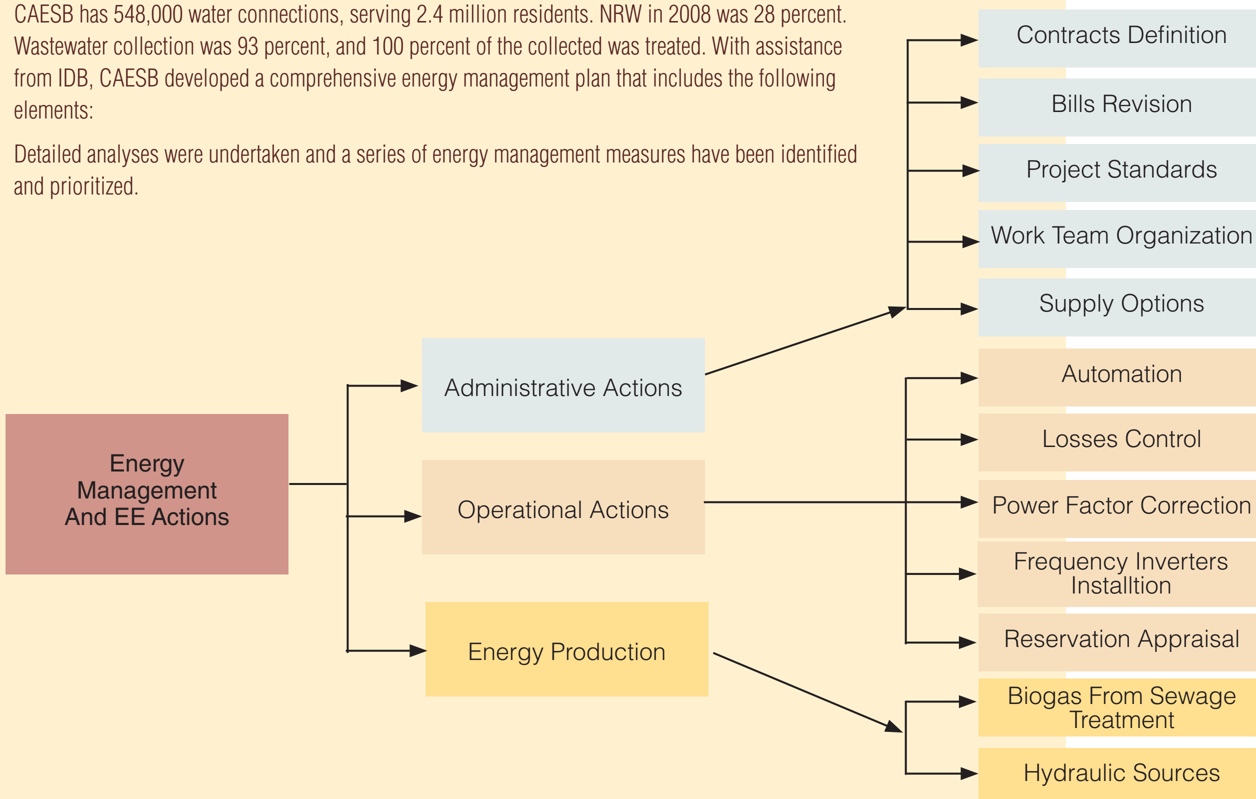
2 | CONDUCT FACILITY ENERGY ASSESSMENT | A basic understanding of energy use and cost of the utility (where, how much, and when) must be obtained to help identify energy cost reduction opportunities and measures, and prioritize measures for implementation. The initial baseline analysis

BOX 3.1

Energy Management at CAESB, Brasilia Federal District Water/Wastewater Company

CAESB has 548,000 water connections, serving 2.4 million residents. NRW in 2008 was 28 percent. Wastewater collection was 93 percent, and 100 percent of the collected was treated. With assistance from IDB, CAESB developed a comprehensive energy management plan that includes the following elements:

Detailed analyses were undertaken and a series of energy management measures have been identified and prioritized.



Source | *Luiz Carlos Itonaga of CAESB, luizitonaga@caesb.df.gov.br.*

may only involve a walkthrough audit of the facilities or even just one facility, staff interviews, and desk analysis of metering and billing data to reveal areas for immediate improvement and those for further investigation. Limited-scale energy audits may be conducted if a WWU wishes to confirm key EE opportunities.

3 | DEVELOP AN ENERGY MANAGEMENT PLAN | As data gathering and analyses progress and key opportunities and options are identified and prioritized, a plan should be developed to guide the energy management efforts with specific targets; underlying measures and activities; budgets; implementation arrangements (own-executed vs. contracted services); financing options; procurement schedule; etc. It is important to make sure that the proposed program is within the utility's implementation capacity and do not overleverage the utility's technical, financial, and management resources. For EE investments slated for implementation, investment grade energy audits may be conducted either by the EE service provider or an entity acceptable to the financier, depending on the financing options and implementation arrangements.

4| IMPLEMENT PLANNED ACTIVITIES, MONITOR PROGRESS, AND EVALUATE AND VERIFY RESULTS | An implementation plan is a living guide and should be adjusted to address issues as they arise during implementation. For example, a proposed financing option may fail and alternate sources of funding may be needed. Progress, changes, and results need to be communicated in a timely manner to staff and management, keeping them informed, engaged, and able to resolve any implementation issues promptly.

WWUs in developing countries, oftentimes with international donor assistance, are embarking on structured utility-wide energy management programs. For examples, IDB has been working with multiple WWUs in Latin America to promote EE. Companhia de Saneamento Ambiental do Distrito Federal (CAESB), which serves Brazil's capital city, has identified a range of EE investment opportunities and is in discussion with IDB about financing those investments (Box 3.1).

ENERGY MANAGEMENT TOOLS

ENERGY MONITORING AND TARGETING (M&T) SYSTEM | An energy M&T system is a computer-assisted energy cost management tool. It is scalable and can be tailored to a single or multiple facilities, providing a good starting point for WWUs to begin a structured and data-based energy management process as suggested in the previous section (Box 3.2).

ESMAP provided technical assistance (TA) to implement energy M&T systems in three Brazilian WWUs in the early 2000s. The results have been mixed. Of the two utilities that actually implemented energy M&T, one was observed to have reduced energy intensity of water supply (measured by kWh/m^3 water-produced) by about five percent, while no significant changes were observed in the other, which also happens to have significantly lower energy intensity because of a large share of gravity-fed water distribution. Nevertheless, Brazil WWUs have shown increased interest in using energy M&T systems in recent years. CAESB, for example is one of the more recent adopters of an energy M&T system.

Energy M&T is likely to gain acceptance and use among WWUs where energy cost is a major management concern and there is already a corporate effort underway to optimize energy use. Energy M&T may also serve as a useful engagement platform to introduce energy management practices to WWUs. As automated data acquisition systems, such as Supervisory Control and Data Acquisition (SCADA), become more widely adopted by WWUs, quantitative energy management through energy M&T should become easier to implement.

ENERGY AUDITS | Any serious pursuit of energy management requires energy audits. The scope and depth of the energy audits must match the purpose of the audits. *Simple energy audits*, which are necessary for gaining a basic understanding of a WWU energy use and are fairly inexpensive, generally involve a walk-through of facilities (handheld measuring devices may be used) and a quick desk analysis of available energy use and costs data. They help identify major issues and focal areas and indicate potential solutions and costs, catalyzing an EE program. In the United States, many states provide free simple energy audit services to WWUs as part of government EE investment support programs. Many electric utilities provide similar services under their demand-side management (DSM) programs.

BOX 3.2

The Basics of an Energy Monitoring and Targeting System

Setting up an energy M&T system involves (i) installation of meters (for WWUs, electricity and water meters); (ii) installation and configuration of hardware, peripherals, and software, which support data logging, communications, storage, analysis, and presentation, and (iii) commissioning of the complete system, including training and support.

Such a system is able to inform how, where, and when energy is being used, highlight performance problems in equipment or systems, alert unexpected excess in consumption, and uncover areas of wastage to target and drive down consumption and waste, and provide objective measurement of savings achieved. It also can check energy bills, provide automated energy reporting, and forecast energy demand to facilitate informed planning.

Uninitiated WWUs may need an external specialist to help establish an energy M&T system. The initial activities usually involve the following:

1 | A briefing of energy M&T for relevant utility decisionmakers and key technical staff

2 | A diagnostic clinic, including simple energy audits, to:

- Identify energy cost centers and metering status and needs
- Proper energy management and reporting structure
- Determine energy cost drivers
- Establish a baseline and initial (first year) improvement targets and related activities
- Evaluate internal capacity and identify training and TA needs for the first year
- Estimate a budget for the fist-year activities

3 | Formation of an internal committee for energy management with clearly defined responsibilities and reporting lines of the staff involved

4 | Identification of reliable funding sources for first-year activities

5 | Implementation of energy M&T requires acquisition of off-the-shelf software for data analysis

6 | Preparation of an implementation plan to formalize utility energy management arrangements, activities, and schedule, with detailed first-year work plan and clear description of the process to ensure the sustainability of the system and required updating of the implementation plan itself

Depending on the availability of funding, the initial diagnostic clinic can involve energy audits that require continuous measurements of energy use of key facilities. This could help produce a more robust initial implementation plan. Annex D provides an example of Terms of Reference for a diagnostic clinic conducted at a water utility in Vietnam.

Source | Compiled by Authors.

FIGURE 3.2

ESPC Modalities and Associated Risks to Service Providers

High Service/Risk

- FULL SERVICE ESCOS design, implement, verify and get paid from actual energy saved ("Shared Savings")
- ENERGY SUPPLY CONTRACTING takes over equipment O & M and sells output at fixed unit price ("Chauffage", "Outsourcing", "Contract Energy Management")
- ESCOs WITH THIRD-PARTY FINANCING design/implement projects, and guarantee minimum level of savings ("Guaranteed Savings")
- ESCOs WITH VARIABLE TERM CONTRACTS act as full service ESCOs, but contract term varies based on actual savings (e.g., "First Out Contract")
- ESCOs WITH 1-YEAR CONTRACTS design/implement projects, receive 60-70% of payent upon successful commissioning and the rest within 6-12 months
- SUPPLIER CREDIT: An equipment vendor designs, implements and comissions projects, and is paid lump-sum or over time based on estimated savings
- EQUIPMENT LEASING, similar to supplier credit except payments are generally fixed (based on estimated energy savings)
- CONSULTANT WITH PERFORMANCE-BASED PAYMENTS assist client to design/implement projects and receive payment based on project performance (i.e., fixed payment with penalties or bonuses)
- CONSULTANT WITH FIXED PAMENTS helps clients design and implement the project, offers advice and receives a fixed lump-sum fee

Low Service/Risk

Source | Singh, et al., 2010, Public Procurement of Energy Efficiency Services.

Detailed energy audits, or *investment grade energy audits*, involve in-depth evaluation of individual equipment and processes to determine individual end-use and facility-wide energy performances with actual tests and measurements, as well as detailed analysis of historical energy use and billing data. This provides robustly quantified energy and cost savings, capital requirements, and return on investments for all identified improvements. Depending on the size and type of a WWU, a detailed energy audit can take up to a week or more to complete and can be costly. *Investment grade audits are not advisable if the investment is not already under serious consideration with assurance of potential financing. In general, investment grade energy audits should be administered by the party bearing the performance risk.*

ENERGY SAVINGS PERFORMANCE CONTRACTS (ESPCS) | An ESPC involves an energy service company (ESCO) that provides an energy consumer or "host facility" a range of services related to the adoption of EE products, technologies, and equipment. By procuring external EE services, a WWU gains much needed technical expertise. The more innovative part of ESPCs is that they can double as financing instruments, in addition to being energy management tools. Full ESCO services may include financing for the EE upgrades, disencumbering the host facility from the burden of securing upfront capital. The modalities of ESPCs for delivering different types of services and the varied scope of associated risks born by ESCOs are depicted in Figure 3.2.

The use of ESPCs in WWUs is fairly common in North America, where the energy service industry is mature and business contracts are well enforced. In the United States, for example, after an ESCO is selected to perform investment grade energy audits, a WWU will arrange its own financing through loans from revolving funds or municipal bonds. Funds can include partial government grants and some bonds have tax exemption status. The WWU will contract the ESCO(s) to implement projects on a performance basis, often with guaranteed savings.[33] If energy savings from the projects are not fully realized, the ESCO payments can be reduced.

In developing countries, the energy service industry is largely underdeveloped and the municipal sector has been particularly difficult for energy service providers to enter because of systemic or sector specific barriers.[34] But there have been some successful cases. For example, the City of Emfuleni, South Africa, was able to undertake a water/energy-savings project through a shared-savings ESPC (Box 3.3).

PUBLIC-PRIVATE PARTNERSHIP ARRANGEMENTS | While public-private partnerships (PPPs) in municipal water supply and wastewater treatment are primarily for improving services, financing, and financial performance of WWUs, they can lead to EE improvement as well, especially when physical loss reduction is an underlying obligation. In a sense, PPPs may be considered an EE delivery mechanism and ESPCs, in many cases, are a form of PPPs, as exemplified in the Emfuleni project. While using PPPs in the municipal water and wastewater sector have yielded mixed overall results, private operators have consistently contributed to improved operational efficiency and service quality.[35] The WB has had successful PPP operations in the sector with significant cobenefit in improved EE (Box 3.4).

FINANCING INSTRUMENTS

WWUs may use funds from internal cash flow to finance EE improvements. But they are usually operating under tight operation and maintenance (O&M) budgets and with limited funds for capital improvements—a situation limiting them to low-cost energy optimization measures with quick returns. In some cases, utilities can revolve these funds internally by phasing in pumping station retrofits. However, accessing external financing is often necessary for implementing capital-intensive energy optimization projects or projects with relatively long payback periods. Depending on national and local situations, WWUs may be able to take advantage of the following external financing instruments to partially or fully fund EE investments:

DEFERRED PAYMENT FINANCING, also considered an internal financing source, is a short-term borrowing process where the utility makes payments to the vendor soon after receiving supplies and services. Such arrangements may allow WWUs to purchase high efficiency equipment to upgrade facilities if the incremental cost can be recouped quickly through operational savings.

PROJECT FINANCING THROUGH ESPCS requires the service provider to cover the project cost using its own funds (e.g., credits provided by equipment suppliers) or arranging for third-party financing (e.g., commercial banks). Repayments for this type of project financing is derived from energy cost savings resulted from the project but will depend on the specific nature of ESPCs (refer to Figure 3.1 and related references).

EE FUNDS, CREDIT LINES, AND PARTIAL RISK GUARANTEE PROGRAMS have been used by several WBG clients, such as Bulgaria, China, Hungary, Romania, Tunisia, Turkey, and Ukraine. But there are no documented cases where these financing mechanisms were applied in WWUs, although recently proposed programs in Russia and Turkey may do so.

MUNICIPAL OR URBAN DEVELOPMENT FUNDS are often a framework-based financing vehicle that the WB uses to address a broad range of investment needs in urban development, including water and wastewater infrastructure improvements. Municipal funds constitute an important alternative in countries where access to financing for municipal infrastructure is limited. Box 3.5 describes the WB-financed Ukraine Urban Infrastructure Project designed specifically for EE investments in WWUs and still under implementation.

MUNICIPAL BONDS are sometimes used for large energy optimization investments (e.g., biogas power generation) or for rehabilitation investments that also generate major energy benefits. In mature economies and for cities with good credit ratings, municipal bonds are a low-cost, tax-exempt, long-term financing option for EE investments. For example, in the United States, WWUs may tap into the municipal bond market by issuing a general obligation bond backed by the local government's pledge to use tax revenues to meet debt service obligations.

BOX 3.3

Using ESPC for Water Loss Reduction and EE Improvement in Emfuleni, South Africa

The municipal water utility Metsi-a-Lekoa of Emfuleni, South Africa, distributes water to 70,000 households in Evaton and Sebokeng. Due to deteriorating infrastructure, about 80 percent of potable water was leaking through broken pipes and failed plumbing fixtures. A technical investigation determined that by adopting advanced pressure management in the distribution network water loss could be reduced dramatically while also lowering pumping costs.

Metsi-a-Lekoa, however, lacked the required technical expertise to prepare and implement the project and was short of funds to finance the investment. A shared savings ESPC could help address both issues. Emfuleni engaged the Alliance to Save Energy as the technical advisor to help Metsi-a-Lekoa design and prepare the project, as well as procure engineering services, and monitor and verify savings.

Through a competitive bidding process, Metsi-a-Leoka signed a water and energy performance contract with WRP Engineering Consulting Company under a Build-Own-Operate-Transfer arrangement for a period of five years. WRP acted as an ESCO—providing turnkey services—while underwriting all financial and performance risks for which WRP was able to obtain project financing from the Standard Bank of South Africa.

Under the "shared savings agreement" in this contract, WRP received remuneration for its services based on verified energy and water savings from the project over a five-year period. Twenty percent of the project's savings were to be accrued by WRP and 80 percent were retained by Metsi-a-Lekoa. After five years, operations would be transferred to the utility at no cost and the utility would keep 100 percent of the savings. The project was designed to operate for at least 20 years under this scheme.

The project achieved impressive results | 7-8 million m^3 annual water savings and 14,250 MWh annual electricity savings, worth a total of US$3.8 million per year. WRP recovered the capital cost of its investment in one year; the total return to WRP represents four times its initial investment. But the lion's share of the benefit stayed with Emfuleni Municipality.

Source | ESMAP, 2010, Good Practices in City Energy Efficiency, http://www.esmap.org/esmap/node/231.

BOX 3.4

An Example of PPP Contribution to Water Utility Energy Performance

The Yerevan Water and Wastewater Services Project, which started with a 5-year management contract followed by a 10-year lease contract, has succeeded in improving services while significantly improving the EE of the water supply. During the management contract phase (2000-2005), water supply was increased from 6 to 18 hours per day; collection rates improved from 20 percent to 80 percent; and annual electricity consumption was reduced by 30 percent compared with 2000 levels.

The management contract, awarded in 2000, had specific objectives for increasing water supply hours; metering and revenue collection; and reducing water losses and energy consumption through rezoning of the water distribution network, upgrading motors and pumps upgrades, and rehabilitating leaky infrastructure.

The lease contract, awarded in 2006, already achieved a further reduction of annual electricity consumption by 18 percent between 2006 and 2010. Among other things, the lessee established pressure zones in the distribution network, supplying nine communities in Yerevan City. It rehabilitated 292 boreholes; replaced 27.9 km of water lines; and installed over 150 new energy efficient pumps at water treatment plants and several stations, boosting water pressure for apartment buildings.

Source | ESMAP case study: http://www.esmap.org/esmap/node/1172.

ELECTRIC UTILITY DSM PROGRAMS, in many developed countries, governments and electrical utilities provide rebates and other financial incentives to encourage EE investments. Such programs are also available in some developing countries, like the EE program mandated by Brazil's electricity regulator Agência Nacional de Energia Elétrica (ANEEL).[36] In locales where electric utilities are required to promote end-use EE, such as Brazil, South Africa, and many states in the United States, electric utilities may offer reduced-interest loans or rebates for EE projects. On-bill financing (OBF) can be used as a means to defray EE investment costs overtime. Under OBF, an electric utility provides a WWU with an unsecured loan that may cover up to 100 percent of EE investment cost. The WWU then pays the loan via an OBF surcharge that is added on to the regular electricity bill. Cost savings realized from the investment typically equals or exceeds the monthly OBF repayment.

CARBON FINANCE,under the Clean Development Mechanism (CDM), has proven to be cumbersome in funding EE projects due to a combination of difficulties in monitoring and verification of energy savings and CO_2 emission reduction, the small-scale nature of many EE projects, and the high transaction costs. WWUs are one of the few cases where these factors may be handled satisfactorily for carbon financing transactions, owing to the relative predictability of their operations. The ongoing municipal water supply CDM project in India offers some lessons for tapping into the carbon market for EE in WWUs (Box 3.6).

OTHER CLIMATE FINANCING MECHANISMS, such as the Global Environment Facility and the Clean Technology Fund, may also be used to finance EE in WWUs, generally through a national program that includes EE investments in sectors where the use of such funds is justified for helping reduce or remove barriers to accessing financing for EE improvements.

BOX 3.5

Ukraine Urban Infrastructure Project

In Ukraine, water and sewerage utilities have been operating in a difficult financial situation. Collections, the main source of revenues, cover only 88 percent of operating costs. The lack of utility operating surplus and the lack of private long-term financing have made it difficult for utilities to provide reliable and quality service.

The ongoing Ukraine Urban Infrastructure Project financed by the WB includes a US$76.47 million stand-alone EE pilot component to address urgent retrofits with potential to reduce energy costs. The component provides funding to any Ukrainian municipal WWU that fulfills the following criteria: (i) complete a Business Plan in a satisfactory manner according to the Ministry of Housing and Communal Services; (ii) provide economic and technical analysis confirming the potential energy savings of a minimum of 15 percent through the proposed investments; and (iii) be allowed to borrow from the World Bank as confirmed by the Ministry of Finance.

Source | Compiled by Authors.

BOX 3.6

Use of CDM Water Pumping EE improvement in Karnataka

The objective of this CDM project is to reduce the energy required for bulk water service delivery from eight pumping schemes in six municipalities in the state of Karnataka, India. The project is expected to save about 23.7 million kWh of electricity per annum, which will reduce the volume of greenhouse gas emissions from the southern electricity grid in India by 21,333 CO_2te average per annum.

The measures implemented include: (i) installing more energy efficient pumps, including the correct size of pumps or larger and more energy efficient pumps to respond to higher water demand (vs. increasing the period residents will not have access to water); (ii) decommissioning old multi-pumps; and (iii) introducing improved metering and monitoring and other practices.

The CDM project adopted an approved small-scale methodology—demand-side EE activities for specific technologies—and modified it to enable pumping system level monitoring. The project originally developed a CDM methodology that included water loss reduction but later retired this methodology due to reduced project scale and lack of baseline information on water supply.

This CDM project is associated with the Karnataka Urban Water Sector Improvement Project financed by an IDA loan of US$39.5 million to Karnataka Urban Infrastructure Development and Finance Corporation (approved in April 2004). Three of the CDM-identified municipalities were included in the WB project.

This CDM project continues to experience long delays and is reduced significantly in scale. It, nevertheless, represents an innovation in water utility EE financing and lessons learned should help expedite the implementation of similar CDM projects in the future. As most municipalities did not pay electricity bills prior to the project, it was a major challenge to collect the baseline water and electricity data required to calculate greenhouse gas emissions from the project. The project is under validation and expected to be registered with the UNFCCC in 2011.

Source | Base Project Design Document of the CDM project.

4 SCALING UP ENERGY EFFICIENCY IN MUNICIPAL WATER AND WASTEWATER UTILITIES

A FRAMEWORK FOR ACTION

The main challenges to scaling up EE in municipal water and wastewater services for WBG clients stem from sector governance issues, knowledge gaps, and financing hurdles. Utility governance affects the overall performance of individual WWUs and influences decision making, incentives and actions for energy management. This is likely the most significant barrier to WWU EE in many developing countries. Addressing knowledge gaps requires efforts to systematize data collection, training and capacity building at utilities, supported by local and national governments. Access to EE financing is a hurdle because of systemic credit risk issues associated with the municipal sectors in developing countries, as well as a lack of a broad-based enabling environment for EE investments (e.g., EE institutions and policy framework). Table 4.1 describes the critical actions in these three areas needed in many of WBG client countries, as well as for multilateral development banks (MDBs). More examples are provided in the ensuing sections.

ACTIONS FOR NATIONAL AND LOCAL GOVERNMENTS

National and/or sub-national governments remain the controlling force in urban water and wastewater sectors in developing countries both as the financer/owner of the infrastructures and the regulator. Their commitment to market reforms and EE are most critical in removing the main barriers to improving EE in WWUs. The specific actions include:

- Market reforms to improve sector governance and WWU financial sustainability and independence. The basic market principles include mandatory requirements for consumer **metering and consumption-based billing, removing operational subsidies** (including energy subsidies), and moving toward full **cost-recovery tariffs** coupled with service improvements and targeted social assistance. Tariff reviews should include operational performance requirements, including improved collections and EE. Other government leverage through incentives may include linking government funding to utility service quality and operational performance, including EE.

- Efforts and resources to support sector-wide capacity building for improving operational performance, including EE. This may include **establishment of key EE metrics** as part of WWU performance evaluation, in addition to basic regulatory compliance, and linking such evaluation to **eligibility for public financing.** Other areas of government support for capacity building may include technical and informational support programs, funding for energy audits, template contracting options for ESCOs, etc., to help WWUs identify performance gaps and solutions (e.g., the United States experience detailed in Annex C).

TABLE 4.1

Critical Actions for Scaling up Energy Efficiency in Municipal Water and Wastewater Utilities

	NATIONAL/LOCAL GOVERNMENT	WWUs	MDBs
Governance	• Using market principles to improve the sector's financial sustainability • Incentivizing operational efficiency improvement through financial levers • Making EE a pillar of national and local development strategy	• Committing to delivery of high quality services while minimizing costs • Embedding accountability for energy across utility management hierarchy • Setting targets for operational performance improvement, including EE	• Advising sector reforms and EE strategies by bringing in good international experiences • Assisting in design and implementation of specific incentive mechanisms for improving performance
Capacity Building	• Providing leadership and support through designated agencies • Establishing/enhancing sector performance measurement, including EE • Mobilizing NGOs and the private sector for broad-based assistance to WWUs	• Conducting basic assessment of energy use and cost accounting • Learning by doing through pilots and low-cost interventions • Systemizing efforts through planning, seeking external assistance when needed	• Assisting national efforts to establish sector performance tracking systems, including EE • Assisting utilities through special TA programs for training and peer-to-peer learning and specific investment operations
Access to Financing	• Supporting investments in EE and loss reduction through dedicated financing • Leveraging commercial financing through various guarantee instruments • Leveraging climate financing through national/sector programs	• Tapping into available special financing for EE (grants, subsidized loans) • Preparing bankable proposals to attract commercial financing • Seeking third-party financing through ESPCs	• Scaling up EE financing in WWUs, especially in middle- to high-income developing countries • Leveraging private sector expertise and financing through PPPs • Mobilizing climate financing

Source | Authors.

- Policies and resources to shore up financing for EE and loss reduction. This may include creating special financing vehicles for investments in EE improvements and loss reduction in WWUs, such as **dedicated EE funds** (e.g., Brazil's public benefit wire-charge mechanism, refer to Endnote 38), developing markets for ESPCs, and promoting PPPs. The government may also facilitate commercial financing for large-scale rehabilitation projects through **loan guarantees**. For countries with many urban centers and scope for **sector-wide climate financing programs,** the national government could play a key role in setting up such programs to tap into climate investment resources, such as Global Environment Facility and Clean Technology Fund.

ACTIONS FOR WATER AND WASTEWATER UTILITIES

It is critical that utility management is committed to service quality and operational efficiency. For WWUs that have not embarked on a systematic program to manage energy use, initial steps can be taken to organize and gradually ramp up energy management programs, starting with:

- Establishing a small energy team to begin improving internal energy (consumption and billing) data collection, reporting, and analysis
- Implementing small/low-cost, high-return measures to demonstrate energy management benefits and build capacity and interest while creating a revenue stream to finance future initiatives
- Learning from peer WWUs that have established energy management practices and sharing performance benchmark data

With initial results and support from utility management and staff, the energy team could begin to address broader issues and scale up efforts, possibly with external specialists assistance, by:

- Further strengthening data collection and analysis via automated system(s) for energy use monitoring and data acquisition, and customized analysis and reporting
- Conducting a more comprehensive energy assessment and developing internal procedures and checklists
- Mobilizing internal or external financing (with bankable proposals) for scaled-up implementation, system optimization, and enhanced system designs
- Looking outside the utility for technical expertise lacking in-house, such as twinning with other better-performing utilities, contracting with ESCOs, and accessing national associations
- Developing an energy management plan and beginning to institutionalize efforts across utilities (i.e., setting specific energy targets; implementing regular and structured maintenance; training for operational staff, etc.)

Activities at WWUs can be assisted by national associations of WWUs, a mechanism that works well in countries where the associations have the strong support of their member WWUs.

THE ROLE OF THE MULTILATERAL DEVELOPMENT BANKS

MDBs, such as IDB and the WBG, have had a long history and broad experience in helping clients *improve sector governance and financial sustainability, develop technical capacity, and increase financing* in water and wastewater services. Scaling up EE assistance and financing in MDB water and wastewater operations should build on those experiences.

IMPROVING GOVERNANCE AND STRENGTHENING INCENTIVES | In large policy reform efforts, EE is mostly a cobenefit, but often there are opportunities to link energy performance of WWUs to aspects of the reform agenda. For example, WWU energy performance could be made a part of the key performance indicators associated with intergovernmental transfers and/or an explicit item in tariff adjustment basis.

In countries where market reforms are firmly endorsed, working directly with local governments and utilities through investment lending operations will be important for demonstrating good practices and engaging clients.

DEVELOPING KNOWLEDGE AND EXPERTISE | The MDBs are key contributors to the global knowledge base on water and sanitation, however, more can be done to strengthen their contribution to energy management of municipal water and wastewater services. One of the key areas under this effort could be development and deployment of a set of robust energy performance benchmarks for WWUs, demonstrated through MDB investment operations, and disseminated through the International Benchmark Network for Water and Sanitation Utilities (IBNET) or the International Water Association.

BROADENING AND INCREASING FINANCING | Overall financing for municipal EE, particularly EE improvements in WWUs, have been limited. There are two potentially large opportunities for the MDBs to broaden and increase financing for EE in WWUs:

- **EE RENOVATIONS IN MIDDLE-INCOME COUNTRIES** (such as Brazil, China, Mexico, and South Africa) where extensive water and wastewater infrastructure and a general EE policy framework exist; and EE financing is not a major constraint. Close collaboration between the energy and urban teams in these countries could lead to the development of financially attractive EE projects, such as bundling of small individual projects across multiple WWUs.[37] IFC's China Utility-based Energy Efficiency (CHUEE) platform offers replication potential in other middle-income countries.
- **EE INNOVATIONS IN NEW ACCESS AND SERVICE EXPANSION INVESTMENTS** includes both technical innovations in designing and building more flexible water and wastewater infrastructure to most effectively handle growing demand and capacity, as well as innovations in service delivery to incorporate results or performance-based requirements. The latter would require development and implementation of relevant procedures and performance indicators for EE.

MDBs can increase EE investments in WWUs using their traditional operation models of: (i) *utility-led implementation* in which utilities establish either project teams or project implementation units to implement specific EE projects; (ii) *dedicated municipal development funds* in countries where municipal EE financing is in its early stage; and (iii) *PPPs* involving management contracts, leases, and other new mechanisms, such as ESCOs. To be effective in delivering EE results, EE improvement must be an explicit outcome of such operations.

Some new approaches to promote EE at WWUs through WB engagement are worth noting. For example, a large urban water supply project under preparation in the SAR will incorporate energy management good practices in the operational manuals of participating water utilities. A partnership with Mexico's national water agency has led to the development and implementation of a pilot for improving water utility operational efficiency (including measurable EE improvements) using output-based financing (Box 4.1). A new investment operation under preparation is helping a national water utility in South America develop and implement a comprehensive energy management program. More such efforts and innovations are needed for scaling up EE investments in municipal water and wastewater services.

BOX 4.1

Output-Based Financing for EE Improvements at WWUs: Mexico Pilot

In Mexico, prior to 2005, 55 percent of connected households had intermittent water supply, 44 percent of water produced was lost through leakages, and 31 percent of water billed was not paid. In response to these challenges, the WB provided the Government of Mexico with a US$25 million TA loan to modernize its water and sanitation sector. The TA project, known as PATME, was implemented from 2005 to 2010. A US$100 million loan for a Water Utilities Efficiency Improvement Project (known as PROME) was approved in 2010 to scale up improvements made under PATME. PROME included an innovative output-based disbursement window for operational efficiency investments.

Supported by PATME, CONAGUA, Mexico's National Water Commission, developed a benchmarking and monitoring tool and funded improvement proposals that led to increased operational efficiency. It established a standardized set of input data and performance indicators, which was applied to 80 utilities. The performance indicators included water/wastewater coverage, service continuity, metering level, NRW, labor efficiency, commercial practices, and energy efficiency.

Under PROME, the indicators and benchmarking tools developed under PATME will be refined, complementary standards and manuals will be prepared, and efficiency improvement good practices will be disseminated among Mexican water utilities. While most of the investments in operational efficiency improvements follow traditional disbursement procedures, PROME has a US$5 million investment window to pilot output-based investments. Access to this output-based financing will be limited to utilities that participated in the PATME project, showed solid results, and improved activities for:

1. energy efficiency (electricity savings per m^3 of water produced per month),
2. physical efficiency (m^3 of water saved per month), and
3. commercial efficiency *(*additional m^3 billed on the basis of metered volume).

CONAGUA will reimburse the capital cost of investments required by participating WWUs to deliver agreed outputs described in a manual to be prepared.

Source | Project Appraisal Document, Mexico Water Utilities Efficiency Improvement Project, 2011.

ENDNOTES

[1] Van Den Berg, et al., 2011.

[2] In the United States, where municipal owned and operated WWUs dominate, WWUs often account for a third of the energy bill of local governments (USEPA, 2008).

[3] Mukesh Mathur, 2000.

[4] Barry, 2002.

[5] WERF, 2010.

[6] Rough estimates assuming that globally 4 percent of electricity is used for municipal water supply and wastewater treatment. Global electricity consumption in 2008 was about 16,815,510 GWh (IEA Energy statistics).

[7] UN Population Division, 2007.

[8] Authors' estimate based on projected population figures by UN.

[9] WHO/UNICEF, 2010.

[10] Barry, 2002.

[11] This paper does not discuss embedded energy, such as energy for making the chemicals used for water treatment.

[12] For wastewater treatment, the statewide average of 0.391 kWh/m^3-wastewater-treated is significantly higher than the national average of 0.317 kWh/m^3 because of the higher share of advanced wastewater treatment in New York (NYSERDA, 2008).

[13] Municipal water use accounts for about 11 percent of estimated global fresh water withdrawal (about 3,862 km^3 in 2003), compared with 19 percent for self-extracted industrial use and 70 percent for agricultural use. Other sources of municipal water, such as desalted brackish or sea water, are negligible. There are significant country and regional variations for these ratios. Rural household water consumption is often reported in agricultural use (Aquastat: http://www.fao.org/nr/water/aquastat/water_use/index.stm). Municipal water supply and wastewater treatment contribute to a relatively small portion of global energy consumption, approximately 2 percent in primary energy (Authors' estimate based on United States data (EPRI, 2002)). In the United States, one of the highest in per capita water consumption globally, less than 4 percent of the nation's electricity use (about 1.5 percent of primary energy consumption) goes to the transport and treatment of municipal water and wastewater. Primary energy accounts for losses in generation, transmission, and distribution of electricity. The overall energy use for global consumptive water extraction and supply, including self-supplied industrial use and agricultural use, is about 7 percent of global primary energy consumption (Barry, 2002).

[14] EPRI, 2002.

[15] EPRI, 2002.

[16] World Water: Energy Efficiency Audits Reveal Potential Savings, 2010.

[17] ASAEP, 2006.

[18] Kingdom, et al., 2006.

[19] Van Den Berg, et al., 2011.

[20] Good practices in city energy efficiency: Energy Management in the Provision of Water Services, Campinas, Brazil, http://www.esmap.org/esmap/node/1171

[21] Ashok Sarkar, et al., 2010.

[22] NYSERDA, 2010.

[23] The use of water tanks in distribution systems has other benefits, such as maintaining the hydraulic balance of the system. But the water tanks also need to be regularly flushed to prevent the growth of bacteria. For this reason, whether they lead to cost savings is likely to be case specific. Off-peak pumping also tends to increase leakages, a factor that needs to be considered on a system level.

[24] Power factor, with value from 0 to 1, is a measure of efficiency of turning supplied electric current into useful power. Power factors below 1.0 require an electric utility to supply more current than the necessary minimum, increasing generation and transmission costs. A power factor below 0.95 is often assessed a charge by electric utilities. Inductive industrial motors commonly used by WWUs tend to reduce power factor.

[25] Backup power generators, while necessary for emergency situations or in countries with a highly unreliable power supply, are not considered as an alternative power supply source under normal operation conditions.

[26] Water sectorization consists of dividing a large interconnected city distribution network with multiple supply points into smaller sectors that have one (or two, in exceptional cases) supply inlets. Dividing a large distribution network into small supply sectors results in regular supply flow and pressures, which can be difficult to achieve in large networks. Additionally, it results in the reduction of pumping energy use and the consecutive costs associated with it.

[27] Hydraulic models can be used to simulate the dynamics of a water distribution and help identify strategies to optimize operations. Sectorization of water distribution by district meter area enable the separation (closure of valves) and control of water entering and leaving the metered areas, a key enabling element for active leak detection and management.

[28] Mordecai Feldman, 2009.

[29] http://www.iso.org/iso/iso_50001_energy.pdf

[30] For example, USEPA, 2008.

[31] Scott Olsen, et al., 2003.

[32] NYSERDA, 2010.

[33] For example, the Washington Suburban Sanitary Commission has completed many EE investment projects since 2000 through guaranteed savings arrangements, including installing VSDs; replacing coarse bubble aeration with fine bubble aeration; installing dissolved oxygen controls at the wastewater aeration basins; replacing old blowers with new/relocated blowers; and installing new grit removal, new piping, valves, biosolids conveyor systems, and back-up/peak shaving generation. The investments in these projects were more than US$10 million with guaranteed savings of about 8.6 million kWh/year (Taylor, 2009).

[34] Jas Singh, et al., 2010.

[35] P. Martin, 2009.

[36] Brazil's Public Benefit Wire-Charge Mechanism: Fueling Energy Conservation, http://www.reeep.org/file_upload/2785_tmpphpC9wvEx.pdf

[37] A study funded by the Asia Sustainable and Alternative Energy in five Chinese water and wastewater facilities in two cities identified over US$3 million worth of EE investments with an overall payback period of 4.3 years. China has several dozen cities of similar or larger sizes (over 1 million core urban population).

REFERENCES

ASE (Alliance to Save Energy). 2002. Watergy: Taking Advantage of Untapped Energy and Water Efficiency Opportunities in Municipal Water Systems.

-----. 2006. Municipal Water Infrastructure Efficiency as the Least Cost Alternative. Prepared for Inter-American Development Bank.

Baietti, Aldo, William Kingdom, and Meike van Ginneken. 2006. Characteristics of Well-Performing Public Water Utilities. (Water Supply & Sanitation Working Notes). The World Bank.

Barry, Judith. 2007. Watergy: Energy and Water Efficiency in Municipal Water Supply and Wastewater Treatment – Cost-Effective Savings of Water and Energy. Alliance to Save Energy. http://www.watergy.org/resources/publications/watergy.pdf

Consultant report to Asia Sustainable and Alternative Energy Program. 2006. Washington, DC: The World Bank.

"Energy Efficiency Audits Reveal Potential Savings." World Water 33.2 (March/April 2010): 13-15. WEF Publishing UK Ltd.

EPRI (Electric Power Research Institute). 2002. Water and Sustainability: U.S. Electricity Consumption for Water Supply and Treatment – the Next Half Century. Palo Alto, CA: Electric Power Research Institute.

Feldman, Mordecai. 2009. "Aspects of Energy Efficiency in Water Supply Systems." http://www.miya-water.com/user_files/Data_and_Research/miyas_experts_articles/08_Other%20aspects%20of%20NRW/01_Aspects%20of%20Energy%20Efficiency%20In%20Water%20Supply%20Systems.pdf

Gleick, P.H., D. Haasz, C. Henges-Jeck, V. Srinivasan, G. Wolff, K. Cushing, and A. Mann. 2003. Waste Not, Want Not: The Potential for Urban Water Conservation in California. A Report of the Pacific Institute for Studies in Development, Environment, and Security. Oakland, CA.

Kingdom, Bill, Roland Liemberger, and Marin Philippe. 2006. The Challenge of Reducing Non-Revenue Water in Developing Countries – How the Private Sector Can Help: A Look at Performance-Based Service Contracting. (Water Supply and Sanitation Sector Board Discussion Paper Series #8). Washington, DC: The World Bank Group.

Marin, Philippe. 2009. Public-Private Partnerships for Urban Water Utilities: A Review of Experiences in Developing Countries. Washington, DC: Public-Private Infrastructure Advisory Facility, The World Bank.

Mukesh, Mathur. 2000. Municipal Finance and Municipal Services in India: Present Status and Future Prospects.

NYSERDA (New York State Energy Research and Development Authority). 2010. Water & Wastewater Energy Management: Best Practices Handbook. New York: New York State Energy Research & Development Authority.

-----. 2008. Statewide Assessment of Energy Use by the Municipal Water and Wastewater Sector. Final Report 08-17. New York: New York State Energy Research and Development Authority.

Olsen, Scott and Alan Larson. 2003. "Understanding Process Energy Use in a Large Municipal Water Utility." http://www.cee1.org/ind/mot-sys/ww/mge2.pdf).

Sarkar, Ashok and Jas Singh. 2010. "Financing Energy Efficiency in Developing Countries – Lessons Learned and Remaining Challenges." Energy Policy. Elsevier 38.10 (2010): 5560-5571.

Singh, Jas, Dilip Limaye, Brian Henderson, and Xiaoyu Shi. 2010. Public Procurement of Energy Efficiency Services: Lessons from International Experience. Washington, DC: The World Bank.

Suzuki, Hiroaki, Dastur, Arish, Moffatt, Sebastian, Yabuki, Nanae, and Maruyama, Hinako. 2010. Eco2 Cities, Ecological Cities as Economic Cities. Washington, DC: The World Bank.

Taylor, Rob. 2009. Lowering Carbon Footprint at WSSC Plants Saves $. WEF Residuals and Biosolids Conference May 3, 2009. PowerPoint Presentation. Washington Suburban Sanitary Commission.

UN Population Division (United Nations Population Division). 2007. World Urbanization Prospects: The 2007 Revision Population Database. http://esa.un.org/unup/

UNESCO (United Nations Educational Scientific and Cultural Organization). 2009. Water In A Changing World, Third UN Water Development Report, United Nations Educational Scientific and Cultural Organization. http://www.unesco.org/water/wwap/wwdr/wwdr3/tableofcontents.shtml

USEPA (United States Environmental Protection Agency). 2008. Ensuring a Sustainable Future: An Energy Management Guidebook for Wastewater and Water Utilities. Washington, DC: United States Environmental Protection Agency.

Van Den Berg, Caroline and Alexander Danilenko. 2011. The IBNET Water and Sanitation Performance Blue Book, 2011. Washington, DC: The World Bank.

WERF (Water Environment Research Foundation). 2010. Energy Efficiency in the Water Industry: A Compendium of Best Practices and Case Studies. Global Water Research Coalition.

WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation. 2011. Progress on Sanitation and Drinking Water – 2010 Update. http://whqlibdoc.who.int/publications/2010/9789241563956_eng_full_text.pdf

ADDITIONAL RESOURCES

ENERGY AUDIT/ASSESSMENT

Energy Audit Guidebook for Water Utilities in the Philippines, Alliance to Save Energy (ASE)

The book presents step-by-step guidance on how to conduct an energy audit at water utilities based on experience acquired through the ASE's Watergy program in the Philippines. The book also includes several case studies of energy audits of water utilities. Downloadable at http://watergy.org/resources/publications/auditguidebook_philippines.pdf

Energy Audit Manual for Water/Wastewater Facilities, Consortium for Energy Efficiency (CEE)

The manual describes how to conduct walk-throughs and detailed energy audits at WWUs and offers tips to develop a successful energy conservation program. Downloadable at http://www.cee1.org/ind/mot-sys/ww/epri-audit.pdf

Energy Assessment for Pumping Systems, American Society of Mechanical Engineers (ASME)

The book provides guidance on how to organize and conduct energy assessments at water pumping stations, analyze the data collected, determine energy saving measures, document, and report findings. Downloadable at http://www.cee1.org/ind/industrial-program-planning/ASMEStandard.pdf

Evaluation of Energy Conservation Measures for Wastewater Utilities, US Environmental Protection Agency (USEPA)

The report provides a comprehensive approach to energy management at wastewater utilities, including developing an energy management program; and presents energy conservation measures for pumping systems, aeration systems, and selected innovative wastewater treatment processes, including solids processing. It also contains case studies from nine wastewater treatment plants in the United States. Downloadable at: http//water.epa.gov/scitech/wastetech/upload/Evaluation-of-Energy-Conservation-Measures-for-Wastewater-Treatment-Facilities.pdf

ENERGY MANAGEMENT

Ensuring a Sustainable Future: Energy Management Guidebook for Wastewater and Water Utilities, USEPA

The guidebook provides WWU managers with a step-by-step method—based on a Plan-Do-Check-Act management system approach—to identify, implement, measure, and improve EE and renewable opportunities at their utilities. Downloadable at http://www.epa.gov/owm/waterinfrastructure/pdfs/guidebook_si_energymanagement.pdf

Water & Wastewater Energy Management: Best Practices Handbook, 2010, NYSERDA

The handbook guides water and wastewater practitioners on how to develop an energy management program, implement capital and operational improvements, track performance, and assess program effectiveness. Downloadable at http://www.nyserda.org/programs/Environment/best_practice_handbook.pdf

ANNEX A

ENERGY EFFICIENCY IN WORLD BANK GROUP URBAN WATER AND WASTEWATER OPERATIONS

Improving EE in water utilities is a basic means for controlling operational costs. The World Bank Group (WB, IDA, and IBRD) has helped finance the upgrading of existing infrastructures in many countries with this in mind. A large portion of the investments in urban water and wastewater have been for construction of new infrastructures, especially in fast-growing economies. EE in such projects often is not identified as an objective even though it is important to address energy performance in project design and equipment specifications. This may be due to the difficulties in benchmarking energy performance of new systems.

WORLD BANK URBAN WATER AND WASTEWATER INVESTMENT PORTFOLIO REVIEW

The reviewed portfolio is part of the WB's urban portfolio of projects approved from FY2000 to FY2010 and contains 178 projects with total investment commitments of about US$16.1 billion, representing 63 percent of overall investment commitments of the WB on urban projects. The review covered urban water supply and sewerage (WSS) related projects extracted from the World Bank Business Warehouse using codes of both WSS sector and urban development themes.

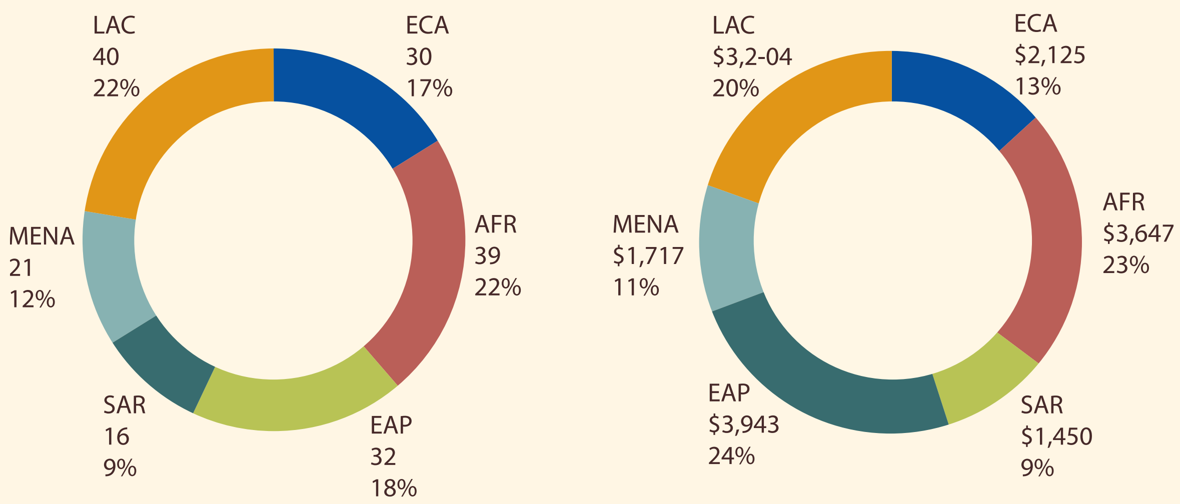
CHARACTERISTICS OF THE PORTFOLIO | Among the 178 reviewed projects, 54 percent are municipal/urban infrastructure projects that cover multiple services—roads, street lighting, solid waste, drainage, housing, electricity provision, and water and sewerage—and 46 percent are dedicated WSS sector projects. The regional breakdown of projects is presented in Figure A.1.

The majority of the review projects, 44 percent, financed both rehabilitation and expansion of existing WSS infrastructure. The number of projects dedicated for rehabilitation accounted for 32 percent of the portfolio, and the remaining 24 percent were for new construction only. The distribution of the above three types of projects varied significantly by region (Figure A.2). The Europe and Central Asia (ECA) and the South Asia (SAR) regions focus on rehabilitating existing infrastructures while the East Asia and Pacific (EAP) region emphasize new infrastructures, highlighted by large investments in new sewerage collection and treatment systems in China. The split between new construction and rehabilitation in other regions is not as distinctive.

Overall, EE considerations in project design and implementation has been limited in the reviewed portfolio. Only 11 percent of the projects (19 projects out of 178) explicitly considered EE improvements by including EE indicators (EEIs) as key performance indicators in the results framework of the project. While this does not indicate the actual EE content of the reviewed portfolio, it underscores the fact that explicit EE considerations in project design have been infrequent. Figure A.3 shows how projects with EEIs differ by region.

FIGURE A.1

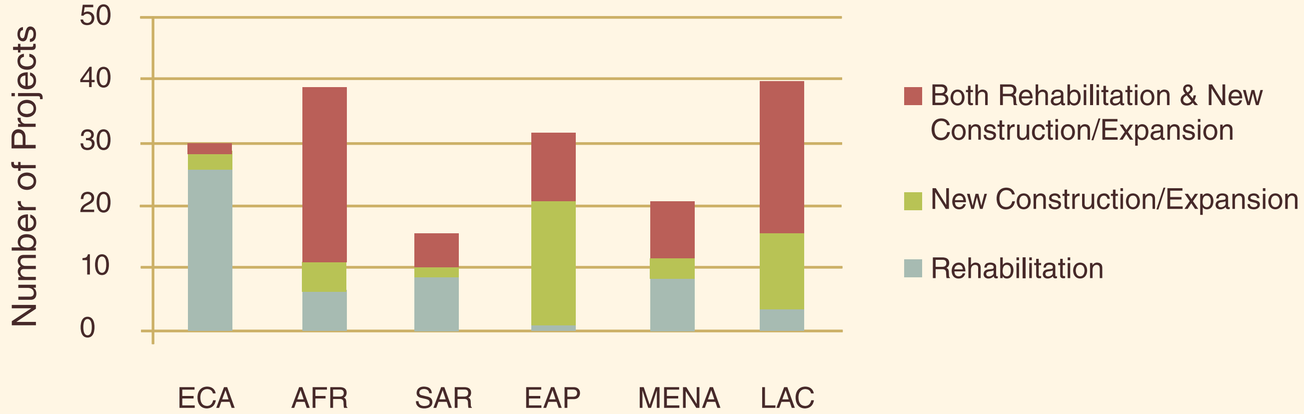
Regional Breakdown of Projects Reviewed by Number and WB Investment Commitment (US$ thousands)



Source | *Authors*

FIGURE A.2

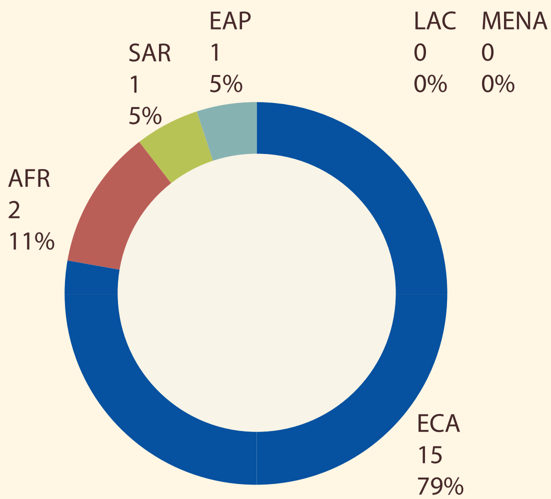
Regional Orientation on Rehabilitation and/or New Construction/Expansion



Source | *Authors*

FIGURE A.3

Regional Breakdown of Projects with Explicit EE Indicators



Source | Authors

DRIVERS FOR EE CONSIDERATION | Two-thirds of the projects with EEIs aimed at improving utilities' financial viability had operating deficits and lack of financing impeded adequate infrastructure maintenance. Where data on energy use data exist, it is clear that high energy costs at WWUs have led projects to include EE improvements. For example, in Moldova, prior to 2003, when the Pilot Water Supply and Sanitation project was appraised, electricity costs of water and sewerage utilities made up 50 percent of O&M costs. This was partly due to a threefold increase of electricity tariffs following the privatization of power utilities. In Armenia, in 2000, electricity bills of Yerevan Water and Sewerage Enterprise were the largest O&M cost item, even higher than collected revenues.

In cases where energy costs were not well documented, available benchmarks of energy use have influenced projects to consider EE measures. For example, at the municipal water and sewerage utility in Lviv, Ukraine, concerns over energy use figures that were double that of similar water utilities in Western Europe and North America stimulated EE measures in a water and wastewater project approved in June 2001. Years later, assessments revealed that Ukraine's energy intensity in the water sector is much higher than in developed European economies and that replacing energy-intensive pumps could yield over 1,000 GWhs in savings per annum. This led to the development of a dedicated EE fund for investment in EE renovations in WWUs in Ukraine (Box A.1).

EE INTERVENTIONS | EE-related measures included in the reviewed portfolio can be grouped into two categories: (i) investment measures, involving physical changes of the system or equipment leading to energy savings; and (ii) soft measures that pave the way to promote or sustain EE improvements. The main investment measures include:

- **Rehabilitation of water/wastewater pumping stations and replacement of old pumps** includes replacing outdated, oversized, or worn out pumps; installing frequency invertors into pumps; and replacing leaky suction and overhead pipes connected to those pumps.
- **Rehabilitation of mains and distribution network** consists of replacing transmission mains and portions of distribution networks known for frequent water leakages. Because the measure reduces the volume of physical water lost, it indirectly leads to energy savings.
- **Leak detection and repair** consists of implementing a leak detection and repair program, which involves purchasing instruments to survey, pinpoint, detect, and repair leaks in the network; undertaking leak detection and faster repairs; and training utility staff. This measure also indirectly contributes to energy savings.
- **Pressure management** consists of installing pressure reduction valves; constructing pressure-break chambers; rehabilitating reservoir(s); and distributing network sectorization. Pressure management was often applied to improve the reliability of and increase duration of water supply, which may lead to increased physical water losses if not accompanied with leaky pipes replacement.
- **Increased gravity-fed supply** consists of diverting water production and supply from pumping to gravity-fed systems by installing water pipes that transport water by gravity. The measure often resulted in phasing out pumps.

The soft measures include demand-side management measures to utility planning. For example, a project in Uzbekistan funded campaigns to raise public awareness about the need for conserving water and paying for water and sewerage services. Installing meters at consumer connections is one of the most frequent activities to manage water demand. In Armenia, an innovative way of expanding meter installation involves setting up a revolving fund to offer credits for purchasing and installing meters. The Ukraine Urban Infrastructure Project supports water and sewerage utilities in their preparation of business plans with EE targets and economic and technical analysis of EE investments.

MODELS FOR PROJECT FINANCING AND IMPLEMENTATION | WB uses three main approaches for financing and implementing EE projects in WWUs: (i) direct financing with utility-led implementation, (ii) dedicated municipal funds using framework criteria, and (iii) public-private partnerships (PPPs) with financing for physical investments. There is only one case of carbon financing, which is under implementation.

Utility-led implementation involves establishment of either project teams or project implementing units (PIUs) inside utilities. If there are multiple utilities in a project, PIUs are sometimes established at a central level Ministry to facilitate project implementation and coordination (such as in the Moldova Pilot Water Supply and Sanitation Project). Project implementing teams or units that are mainstreamed within utilities and staffed by utility personnel who will return to their jobs in the utility after project closing are considered a good practice.

Dedicated municipal funds are another option in countries where EE investing is in its early stages and the banking sector is not ready to provide financing either due to lack of knowledge or reluctance to work with utilities, liquidity problems, reforms and restructuring, or general lending preferences.

Municipal funds constitute an important alternative in countries where access to finance for municipal infrastructure is limited. Three projects in ECA have used this mechanism. Box A.1 describes the case of the Ukraine Urban Infrastructure Project, which is still under implementation.

PPP arrangements, involving private operators taking over urban water and sewerage services through formal contracts, have been used in a number of cases. For example, in Armenia, significant energy savings are being realized through a lease contract that followed a successful performance-based management contract with Yerevan Water and Sewerage Company, the state-owned water utility servicing Yerevan (refer to Box 3.4).

LESSONS LEARNED | Project experience indicates that EE in WWUs can be substantially advanced if energy performance considerations are taken into account and highlighted in project design. This is often associated with rehabilitation projects. It is difficult to pursue EE as an explicit project objective in other types of projects where benchmarking EE performance is difficult. To encourage clients and WB task teams to look into potential EE interventions and costs and benefits in those projects, there may need to be a general facility to fund relevant investigations during project preparation.

Some specific lessons associated with different financing and implementation models include:

- Robust baseline assessment is always important for EE investment projects/components. While investment grade energy audits are required for CDM projects and ESPCs—a scheme that has not been applied yet in any WB financed EE investments in WWUs—it is not clear whether they have been used to justify and define EE investments through other approaches (e.g., direct financing with utility-led implementation and dedicated municipal funds).

- Multipurpose municipal funds seemed to have rather weak incentives for financing EE investments. The fact that they lend for a wide range of services makes it likely that their expertise is wider but also shallower. There might also be stronger incentives for implementation agencies to fund projects with visible results (such as new connections) instead of funding EE measures.

- Utilities with private sector participation have been motivated and knowledgeable about the optimal use of funds to reduce energy consumption. Their incentives grow with the risk presented in their contract. A management contract generally has weak incentives unless the remuneration of the management contractor is contingent, at least partly, on reduced energy consumption in relation to baseline consumption. Leases and concessions should produce the higher incentives and scope for energy-saving investments.

INITIATIVES BY THE INTERNATIONAL FINANCE CORPORATION

IFC WATER BUSINESS STRATEGY | The 2010 IFC Water Business plan addresses the cumulative effects of population growth and urbanization on global demand for food, water, and energy over the next 20 years. IFC's integrated water strategy encourages interventions on both supply and demand-sides of the sector, looking at investments in both infrastructure and efficiency. Through efficiency projects, IFC seeks to catalyze an end-to-end value chain approach, driving changes to support market

BOX A.1

Ukraine Urban Infrastructure Project

In Ukraine, water and sewerage utilities have been operating in a difficult financial environment. Collections, the main source of revenues, cover only 88 percent of operating costs. The lack of utility operating surplus and private long-term financing has made it difficult for utilities to provide reliable and quality service.

The ongoing Ukraine Urban Infrastructure Project financed by the WB includes a US$76.47 million stand-alone EE pilot component, to address urgent retrofits with potential to reduce energy costs. The component provides funding to any Ukrainian municipal WSS utility that fulfills the following criteria: (i) complete a business plan in a satisfactory manner according to the Ministry of Housing and Communal Services, (ii) provide economic and technical analysis confirming the potential energy savings of a minimum of 15 perecent through the proposed investments, and (iii) be allowed to borrow from the World Bank as confirmed by the Ministry of Finance

Source | Authors

BOX A.2

Examples of IFC Innovations in Water

TRIPLE A BARRANQUILLA (COLOMBIA)
IFC is carrying out feasibility studies for NRW and energy reduction for a private sector water distribution client, and is in discussions regarding follow-up financing options.

METITO (MENA AND CHINA)
IFC invested in this private company focused on water and wastewater treatment plant construction and operations, which has implemented EE in their wastewater treatment plants through the use of variable speed aeration systems that adjust dosage based on dissolved oxygen (DO) instrumentation feedback. This technology allows approximately 25% savings in aeration power costs, which generally form the majority of power costs at wastewater treatment plants.

WATER CAPITAL (MEXICO)
IFC invested in this water equipment leasing company that provides water and energy efficiency systems including wastewater treatment and recycling plants for approximately 250 facilities in Mexico.

Source | Authors

transformation while developing a flow of downstream opportunities. In addition, IFC seeks to prioritize and scale up sectors and products by leveraging global knowledge structures, particularly in the following key strategic areas:

- **Efficiency** – agricultural (irrigation, water basin mapping), industrial (water footprint, large user solutions), and municipal (NRW reduction, WESCOs)
- **Key Access Subsectors** – sanitation/reuse, desalination, solid waste, district heating/cooling, bulk water, agricultural/industrial reuse, information technology for water management
- **Base of the Pyramid (BOP) Access** – distributed services (W&S)
- **Climate Change Agenda** – clean technology, adaptation technologies, and innovative business models (in partnership with IFC Climate Business Solutions Group)

IFC offers an integrated package of long-term financings, equity investments, sub-national finance, risk-sharing, and advisory interventions.

PROJECTS ADDRESSING THE WATER/ENERGY NEXUS | IFC activities to promote efficiency have broadly fallen into two categories: (i) piloting, refining, and replicating new business models that encourage energy and water efficiency in agricultural, industrial, and municipal sectors; and (ii) piloting innovative financial tools that encourage financial institutions to focus on and replicate water and energy efficient practices. IFC is active in upstream investigations into new and emerging water efficiency technologies.

Piloting New Water Efficiency Business Models

- **Distributed Services Systems** (urban vended water models)
- **NRW Reduction** - IFC is considering several opportunities for investing in companies and projects focused on NRW reduction. Water loss management includes several opportunities for EE including: (i) reduced water treatment plant production power consumption; (ii) reduced water transmission and distribution pumping and power usage; and (iii) pressure management, which as an NRW-reduction mechanism also has the added benefit of reducing power requirements.
- **Water ESCOs (WESCOs)** - IFC is considering investment in several specialized companies that provide efficiency services to water utilities. These companies identify energy savings opportunities through NRW reduction, water pump efficiency optimization, WWTP aeration optimization, and other options. They typically operate on a performance-based contracting model in which a portion of capital expenditure contribution for improvements is financed by the ESCO and a portion of the revenue is linked to meeting energy and/or cost reduction targets.
- **Low Energy Desalination** - IFC is evaluating investments in several low-energy desalination technologies through its clean technology venture capital investment fund. These technologies include solar desalination and nano-membranes for reverse osmosis, with energy savings ranging from 20 to 80 percent.

Piloting Water Efficiency Financial Tools

- **AmInvest Private Equity Water Fund (East Asia)** - IFC invested in a private equity fund that will finance water and wastewater projects throughout East Asia. Many of these projects involve recycling effluent wastewater for industrial use. Water and energy savings are achieved by avoiding use of other sources of water that might otherwise require long-distance pumping or desalination.

- **China Utility Water and Energy Efficiency (CHUEE**) - IFC established a debt-financing facility with risk coverage for EE projects in China, which will be expanded to cover water efficiency projects with special focus for the industrial water sector in China.

Results to Date / Lessons Learned

To date, IFC's focus on efficiency, innovative delivery models, new water subsectors and equity has resulted in 18 deals with a volume of US$503 million. Current clients include Veolia Voda, Dalkia, AAWF, Epure, Jain, JK Paper, among others.

The key lessons learned from IFC's experience include:

- Providing innovative and cutting-edge solutions is important in policy dialogues and technical advice
- Stronger partnerships between public and private sectors are needed
- More effective and focused partnerships between IFC and WB, other MDBs, donors and the private sector are needed
- Asset risk can be diversified through equity
- Water sector needs well-balanced model ESCO contracts

ANNEX B

WATER AND WASTEWATER UTILITY ENERGY MANAGEMENT MEASURES AND COST EFFECTIVENESS

The following table includes empirical evidence of cost and/or energy savings potential of specific technical measures gathered from various sources.

TABLE B.1

WWU Energy Optimization: Empirical Evidence

OPPORTUNITY AREA	EMPIRICAL EXAMPLE OF MEASURE	SAVINGS ACHIEVED	SIMPLE PAYBACK PERIOD (YEARS)
Reducing Power Demand and Energy Consumption			
Pumping	VSDs for raw water extraction pumps and clean water distribution pumps at a Brazilian water treatment plant, Brazil (ESMAP)	33% - electricity 19% - kW demand 44% - energy bill	4
	VSD for 11 well pumps, Belgium (GWRC, p. 24)	15% - electricity	2.5
	Replacement of a submersible borehole pump with a line shaft pump, UK (GWRC, p. 29)	Reduced energy intensity	5
	Reprogramming duty software for 2 well pumps operating together to control well levels, UK (GWRC, p. 19)	Reduced energy intensity	0.5
	Changing control algorithm of 6 pumps from pressure control to flow and pressure control so operating pressure derives from flow rate, Australia (GWRC, p. 34)	5% - electricity	<0.1
	Installing new cooling pumps, UK (GWRC, p. 16)	Reduced energy intensity	7.8 (based on £6.6p/kWh)
	Variable speed pump control changes – reduction in operational frequency on VSD and pumping rate, UK (GWRC, p. 21)	12% - electricity	N/A
	Adding VFD Control of oxidation ditch rotors using 4-20mA signal from optical dissolved oxygen (DO) probes, USA (USEPA Case No. 4)	13% - electricity 39% - kW demand 22% - cost	1.5
	Installing VFDs and programmable logic controllers, upgrading to energy efficient motors, retrofitting the pump bowl at 1 well to optimize operation, USA (CEC)	Reduced energy intensity	N/A
	Installing programmable logic controllers and VFDs on wastewater system, regulating lift station wastewater levels, and using energy efficient motors in new projects, USA (CEC)	Reduced energy intensity	N/A

OPPORTUNITY AREA	EMPIRICAL EXAMPLE OF MEASURE	SAVINGS ACHIEVED	SIMPLE PAYBACK PERIOD (YEARS)
Reducing Power Demand and Energy Consumption			
Pumping	Installation of a hydraulic connection of water pumping stations, Netherlands (GWRC, p. 13	19% - electricity	N/A
	Plant pumping systems optimization, BNR pulsed aeration and Dissolved Air Floatation (DAF) Solids Thickening Process optimization using proprietary process control algorithms, USA (USEPA Case No. 8)	23% -electricity (pulsed air mixing) 64% - electricity (DAF optimization)	0.25

Treatment	New high speed, magnetic bearing turbo blowers for a facility's first stage aeration process, USA (USEPA Case No. 1)	50% - electricity 38% - energy bill	13.3
	Optimization and automation of activated sludge system in wastewater treatment – new meters and software, USA	20% - electricity	5 (energy only) 2.5 (inc. labor & chemical savings
	Reduction of returned activated sludge rate from a fixed flow to a lower fixed flow, UK (GWRC, p. 36)	Reduced energy intensity	N/A
	Using raw water quality monitoring to determine if DAF plant is required to treat water to outlet quality, UK (GWRC, p. 52)	21.4% - electricity	N/A
	Designing and operating the aerobic sludge retention time (SRT) and hydraulic retention time (HRT) based on the conditions in warm climates, Singapore (GWRC, p. 46)	46% - electricity	N/A
	Single-stage centrifugal blowers with inlet guide vanes and variable outlet vanes, and of air control valves, USA (USEPA Case No. 2)	30% - electricity	14
	Replacing mechanical aeration with Sanitare fine bubble diffusers and air bearing KTurbo blowers, upgrading to automated DO control and installing automated Oxidation Reduction Potential (ORP)-based control for nitrification (dNOx Anoxic Control System), USA (USEPA Case No. 3)	10% - electricity	135 (strictly from an energy savings perspective) 33 (using electricity consumption and cost per pound of CBOD removed)
	Optimization and control of SRT and DO using proprietary process modeling based control algorithms, USA (USEPA Case No. 5)	20% - electricity	5
	Aeration system upgrade; increased number of diffusers; installed DO probes and automatic blower and aeration system control, USA (USEPA Case No. 9)	36% - electricity	2.4
	Changing programmable logic controller control to implement new aeration regime, including modification of aeration cycles, Australia (GWRC, p. 42)	Reduced energy intensity	immediate
	Application of anaerobic digester mixing – linear motion mixers, USA (GWRC, p. 48)	90% - mixing energy	2.5
	Performance-based management contracting in water and sewerage with a number of improvements in water distribution networks, meters and pumping efficiency, water leakage reduction, and gravity-fed water supply, Armenia (ESMAP)	7.5% - electricity	3.5

OPPORTUNITY AREA	EMPIRICAL EXAMPLE OF MEASURE	SAVINGS ACHIEVED	SIMPLE PAYBACK PERIOD (YEARS)
Reducing Power Demand and Energy Consumption			
Treatment	Performance-based management contracting in water and sewerage with a number of improvements in water distribution networks, meters and pumping efficiency, water leakage reduction, and gravity-fed water supply, Armenia (ESMAP)	7.5% - electricity	3.5
	Adding energy-efficient motors; installing VFDs on flocculation and chemical feed pump motors; installing fluorescent light and lighting control; and launching water conservation education, promotion, and enforcement programs, USA (CEC)	Reduced energy intensity	N/A
	Pigging of a raw water pipe, Germany (GWRC, p. 28)	Reduced energy intensity	N/A
Water leakage reduction	Active leakage control by investing in new pressure management facility to reduce high physical losses, South Africa (ESMAP)	30% - water	<0.3 (energy only)
	Active leakage control through pressure management, combined with water main renewal and flow meter upgrade, Australia (GWRC, p. 6)	45% - water	Variable (financially justified on a break even basis)
	Optimization of distribution network using hydraulic modeling to regulate water pressure and flows; network sectorization, leakage detection and repairs; new pumps and motors, Mexico (ESMAP)	27% - electricity Reduced leakage Increased revenue	1.9 (inc. increased water revenue)
	Retrofitting and replacement of plumbing fixtures like cisterns, taps, pipes and valve, South Africa (GWRC, p. 8)	31% - electricity	2.32 (calculated on water price, not energy price)
	Development of a preventative maintenance strategy (retrofitting a flap valve and ongoing audit of wastewater pumping stations' constructed overflows) for future inspections, Australia (GWRC, p. 10)	Reduced energy intensity	N/A
	Applying new coating to pump casing volute and impeller to reduce water friction loss, Australia (GWRC, p. 39)	20% - energy cost	3.2
	DO optimization using floating pressure blower control and a most open valve strategy, USA (USEPA Case No. 6)	11.6% - electricity 13% - cost	1.5
	Implementing personnel and operational changes, and use of wind Power, USA (GWRC, p. 69)	10-15% - cost	N/A

OPPORTUNITY AREA	EMPIRICAL EXAMPLE OF MEASURE	SAVINGS ACHIEVED	SIMPLE PAYBACK PERIOD (YEARS)
Managing Peak Demand and Other Power System Charges			
Pump prioritization & scheduling	A common practice found in Brazil where there are large differences in peak and off-peak electricity prices. May require new storage facilities	Contributing to cost savings only	N/A
Power factor correction		Contributing to cost savings only	Depending on situation
Managing Energy Cost Volatility and Improving Electricity Supply Reliability			
Energy recovery & generation	One-stage mesophilic anaerobic digestion with dual fuel engine CHP, Singapore (GWRC, p. 77)	About 15% reduction in purchased power	8.8
	Methane cogeneration using microturbines at a small wastewater plant, USA (Eaton and Jutrus, 2005)	About 35% reduction in purchase power	5.6 3.6 (with incentives)
	Solids processing system upgrade, including: waste heat recovery; flue gas recirculation; and circle slot jets air injection system, USA (USEPA Case No. 7)	76% - natural gas (projected)	11.3
	Using sludge and other organic waste as fuel in the process to improve their overall energy balance, France (GWRC, p. 68)	80-88% - energy (for thermal drying of sewage sludge)	N/A
	Installation of a 502 kW DC ground-mounted, dual-array PV systems in 2005 and a 99 kW solar PV system in 2008, USA (GWRC, p. 73)	Reduced power purchase	5 (with incentives)
	Increasing CHP generation with new 320 kW CHP engine to reinforce an existing CHP generation comprising 104 kW and 165 kW engines, UK (GWRC, p. 76)	Reduced power purchase	2.5
	Use cogeneration to produce onsite electricity and thermal energy; use fine-bubble diffusers for aeration; enact demand control strategies; pump water more efficiently with variable-frequency drives; and upgrade to energy-efficient motors, USA (CEC)	Reduced power purchase	N/A
	Cogenerating electricity and thermal energy onsite from waste methane; installing high efficiency influent and effluent pumps, high efficiency motors, and VFDs; discontinuing second-stage activated sludge mixing; adding plastic balls to prevent heat and evaporation losses in oxygen production vaporizer pit; and replacing two small compressors at the pure oxygen plant with 1 large unit, USA (CEC)	Reduced power purchase	N/A

Sources |

1. GWRC (Global Water Research Coalition), *2010, Energy Efficiency in the Water Industry: A Compendium of Best Practices and Case Studies, Global Report, UK Water Industry Research Limited*
2. ESMAP, *Good Practices in City Energy Efficiency*, http://www.esmap.org/esmap/node/1171.
3. USEPA (United States Environmental Protection Agency), 2010, *Evaluation of Energy Conservation Measures for Wastewater Treatment Facilities.*
4. Eaton, G. and J. L. Jutras, 2005, *Turning Methane into Money: Cost-Effective Methane Co-Generation Using Microturbines at a Small, Rural Wastewater Plant*, American Council for an Energy-Efficient Economy, http://www.aceee.org/proceedings-paper/ss05/panel02/paper02.
5. CEC (The California Energy Commission), *Water/Waste Water Treatment*, http://www.energy.ca.gov/process/water/index.html.

ANNEX C

DEVELOPING ENERGY MANAGEMENT KNOWLEDGE AND KNOW-HOW IN WWUS; U.S. EXPERIENCE

The United States is a good example of how national and regional government agencies, electric utilities (obliged by regulation), and professional non-governmental organizations (NGOs) can help bridge gaps in knowledge and know-how. Such multipronged engagements are of useful reference for large countries when considering approaches to scale up EE in municipal water and wastewater sector.

FEDERAL AGENCIES

The **US Environmental Protection Agency (USEPA)** is the leading agency that provides federal government support on EE in WWUs with a range of knowledge services including:

- Guidance and training on developing an in-house energy management program, for example, "Water and Wastewater Energy Best Practice Guidebook". Its Energy Star program has an online benchmarking tool called Portfolio Manager, which allows comparison of energy use with peer plants, as well as monitoring energy use, energy costs, and associated carbon emissions. USEPA conducts a series of energy management workshops.

- Guidance on identifying and implementing EE projects, including publications on how to hire an energy auditor or an energy services company and how to draft requests for proposals for EE projects. USEPA also maintains a list of motors with efficiencies higher than new federal minimum standards, as well as information on existing programs that offer grants and funds for energy audits or no-cost energy assessments.

- Sharing best practices on energy management and specific EE measures at WWUs. USEPA's website contains a number of relevant publications and case studies.

STATE AGENCIES

The **New York State Energy Research and Development Authority (NYSERDA)** is a public benefit corporation funded by a surcharge on electricity consumption in the state. One of NYSERDA's programs focuses on EE at WWUs. The program provides tools and handbooks to help WWUs identify, evaluate, and implement EE projects. Among the tools featured in its website are: (i) a Payback Analysis Tool that calculates energy and cost savings based on investment costs and utility characterization, and (ii) energy benchmarking tools that guide in setting baselines for energy performance improvement. Besides the tools, NYSERDA has assessed the energy use by the municipal water and wastewater sector in New York and published a Water & Wastewater Energy Management Best Practices Handbook.

The **California Energy Commission (CEC)** is California's primary energy policy and planning agency. Its responsibilities include the promotion of EE in buildings, industries, agriculture, and water/waste water utilities. CEC has funded a number of research, development, and demonstration projects to improve the EE of industrial processes, agricultural operations, and water and WWTPs. CEC's website presents a number of energy efficient equipment, technologies, and operating strategies, such as variable frequency drives, energy-efficient motors, electrical load management strategies, cogeneration optimization, etc. The website also includes supporting case studies to demonstrate successful experience of using these technologies.

NON-GOVERNMENT ORGANIZATIONS

The **American Water Works Association (AWWA)** offers a variety of professional and technical resources, which include standards, manuals of practice, utility survey reports, and tools. Among the tools, the WaterWiser—a comprehensive clearinghouse of resources on water conservation, efficiency, and demand management—incorporates EE considerations. AWWA also provides other resources such as electronic journals and bulletins, eLearning courses, and utility quality programs. EE is one of the topics covered in the resources.

The American Council for an Energy-Efficient Economy (ACEEE) is a nonprofit organization dedicated to advancing EE. ACEEE has acted as a TA advisor to numerous local governments and authorities on EE potential analyses and policy opportunities. It developed a toolkit to assist local governments in promoting EE in WWUs. The toolkit offers measures that local governments should consider, such as:

- Requiring utilities to determine their baseline energy use and develop an EE implementation plan, which local governments can help finance
- Developing voluntary, multisector environmental and energy programs, which include EE in WWUs
- Amending existing regulations for public water and wastewater systems to include energy considerations in equipment procurement and improvements

ANNEX D

ENERGY PERFORMANCE ASSESSMENT STUDY/AUDITS FOR WATER AND WASTEWATER UTILITIES

TWO SAMPLES OF TERMS OF REFERENCES

Terms of reference used in a recent WB-funded water utility energy study

Objectives

The Consultant will collect energy performance data and performance information for the Water Supply Company (WSC).

This analysis and information collection should reflect reliability and use of the energy resources for the water utility.

The Consultant will review the previous data collection, verify and update it accordingly, considering infrastructure development plans of the WSC and prepare the final report which will reflect all items of the study and summarize the next steps of the WSC development in energy conservation and efficiency improvement.

Scope of Work and Deliverables

1 | Establish baselines of energy consumption and energy efficiency in the WSC:

1.1 | Develop a complete inventory of energy end-uses classified in the following categories: raw water extraction and pumping, water treatment, water distribution, and administrative function. Include separately any other uses such as sewerage pumping.

1.2 | For the above end-users of energy, separate consumption among the three electricity tariff categories, aggregated by categories and season of the year. Identify high consumption elements of the system which have significant operation in high cost time zones and evaluate their contribution to the overall energy cost of the company.

1.3 | On the basis of pumps operating conditions (head, flows and accumulated quantities pumped), assess pumps efficiency and compare with manufacturers provided efficiencies and comparable modern equipment operating at design efficiencies. Identify potential high consumption elements susceptible of operational improvement and assess their overall contribution to energy consumption and cost of the company.

1.4 | Prepare an energy balance of the WSC for the most recent three years according to the above categories, separating out own-generated electricity from purchased electricity.

1.5 | Prepare a complete O&M cost breakdown of the WSC for the most recent three years. For energy cost, separate cost of purchase electricity and cost of own-generated electricity.

1.6 | Identify locations and number of electricity meters and billing points.

1.7 | Conduct a campaign of measurements in the 4 production facilities (one is ground water extraction) identified in the initial assessment study for 7 consecutive days.

2 | Identify cost-effective measures for reducing energy cost and improve energy efficiency in the WSC

2.1 | Base on analysis of inventory and consumption data, and especially the measurement data generated in Activity 1.5 above, develop a list of measures which addresses energy cost and efficiency issues in all end uses as identified in activity 1.1 above, according to the assessment approach described at the workshop. Aggregate such measures by network. Identify separately those that are intended for better knowledge and management of the system.

2.2 | Conduct cost-effectiveness analyses of the identified measures, using actual local cost and pricing information and document assumptions. For the purpose of this work, only simple payback period calculation is requested. Rank measures by simple payback period and investment needs.

2.3 | Carry out a sensitivity review of these estimates and cost-benefit analysis, for different energy cost evolution, personnel cost evolution and water produced and delivered (identifying at least three scenarios with separate figures for the different networks managed by the company). Add one additional scenario including progressive sewerage collection and treatment of collected wastewaters.

2.4 | Assess the impact of identified mitigating measures on service quality (pressure, continuity, etc).

3 | Document the NRW reduction program by the WSC in the following aspects:

3.1 | How has it been organized? List main representative indicators used in the assessment of NRW by network and category and values for the last three years

3.2 | What measures were taken in the program's two phases?

3.3 | What have been achieved (quantitative data) and how much is the total investment and additional O&M cost of the activities specifically undertaken for this purpose (including all associated costs)?

3.4 | What are the key lessons learned?

4 | Recommendations for the WSC to improve energy management and energy efficiency

4.1 | Break the options into short-term (measures which can be taken immediately with minimum cost), medium term (measures require capital investments but with short payback period, e.g. less than 2 years), long-term (measures require fairly long payback period and may need further analysis). Propose an investment scenario and calculate its present value considering related energy cost savings.

4.2 | Next steps for BIWASE in terms of how they may organize themselves and mobilizing financing for energy management and energy efficiency.

5 | The final report should reflect all items and summarize the next steps of the BIWASE development in energy conservation.

UKRAINE | ENERGY AUDITS OF WATER AND WASTEWATER UTILITIES
TERMS OF REFERENCE

Background

1 | The World Bank has provided financing for an Urban Infrastructure Project (UIP) that was declared effective in late 2007. The total loan amount is US$140 million, of which about US$80 million will be used under the "Open Component" to finance investments to raise energy efficiency (EE) in water and wastewater utilities (vodokanals). The Open Component, which is also known as the EE component, is expected to finance a broad range of activities, such as replacement of obsolete electro-mechanical equipment, metering to reduce wastage, optimization of plant and processes for producing and distributing potable water; optimization of plant and processes for collecting and treating wastewater; plant and processes to increase the production of biogas; and plant and processes to capture the energy content in water and wastewater. The activities under the EE component is expected to sharply bring down the consumption of energy in the vodokanals that at the present time use twice or more energy per cubic meter of water distributed and wastewater collected and treated as compared to European benchmarks.

2 | The Swedish International Development Agency (SIDA) has approved a grant in the amount of SEK 45.0 million (US$5.6 million) that will be administered by the World Bank under a Trust Fund to support activities under the UIP. An estimated SEK 18 million (US$2.2 million) of this amount will be used for detailed design, supervision, and energy audits. The results of the energy audits are supposed to feed into the implementation of the US$ 80 million EE component under the UIP. In this fashion, the energy audits will serve as mini-feasibility studies since they will indicate which investments to undertake in each vodokanal. The selection criterion for the EE sub-projects will likely be the pay-back period of the investments made. The general rule would be to approve and implement EE sub-projects in such a way that those with shorter pay-back periods would be implemented before those with longer pay-back periods. It is expected that the implementation of this first batch of energy audits in XX vodokanals will be followed by similar audits in other Ukraine vodokanals. The present number of vodokanals in Ukraine is about 1,900 - providing water supply and/or wastewater services in urban areas. The Ukraine water supply and wastewater sector was last analyzed in a study that was published in June 2002 and that was drafted by the Danish consulting firm COWI under the Danish Cooperation for Environment in Eastern Europe (DANCEE).The Ministry of Housing and Communal Services has recently requested the World Bank to carry out a follow-up water supply and wastewater sector note that is expected to be completed in April 2009.

Objectives of the Energy Audits

3 | The objective of the energy audits is to estimate the present consumption of all kinds of energy in selected vodokanals; to indicate the approximate potential for improving the energy balance; and to suggest a tentative list of investments in rehabilitation and optimization of existing plants and processes in the audited vodokanals. The cost and expected energy savings of each proposed investment should be estimated so that the economic pay-back period could be calculated.

Scope of Work

The scope of work should consider the following six aspects of activities to raise EE in the vodokanals:

4 | Geographic: The energy audits will be carried out in XX vodokanals that are enumerated in Annex 1 with their basic data related to their water supply and wastewater operations.

5 | Systemic: The energy audits should estimate, based on metered consumption or explicit calculations, the energy (of all kinds) used in the following activities of each vodokanal:

- Water production
- Water treatment for domestic consumption or industrial use
- Wastewater collection
- Wastewater treatment
- Auxiliary activities such as space heating, operation of vehicles etc.

6 | Temporal: Past and future energy use should be assessed, taking into account past or future efforts by the vodokanals to raise their EE, including obvious measures such as reducing water wastage through increased metering of consumption; operating the water supply system in better ways; capturing the heat in raw water or collected wastewaters through heat exchanges; generating biogas from treated sludge; and optimizing processes (such as reducing the use of chemicals (such as lime) with a high energy content.

7 | Financial: The approximate cost of each sub-project should be calculated.

8 | Economic: The approximate cost of each proposed measure and investment should be estimated and the corresponding benefits in the form of reduced energy costs (with an estimate of likely future escalations of Ukraine energy prices), reduced maintenance costs (in case obsolete electromechanical equipment is replaced); reduced operations costs (in case processes are optimized); and the value of increased energy production (as in the case of heat energy captured from raw water and wastewater through heat exchanges, or through the production of biogas from treated sludge.) An economic pay-back period should be calculated for the total package of each vodokanal, where the investment costs should be divided by the expected annual savings.

9 | Institutional: It should be indicated if each vodokanal is up to date in its payments for energy (such as to the regional power company) and if not, what the totality accounts payable to the power company is. Measures should also be suggested how the energy use could be monitored in the future so that utility benchmarks of EE could be established. Finally, measures to motivate staff (such as creating incentive programs for energy conservation) should be suggested.

Required Reports

10 | Three reports will be required during the duration of the assignment:

- A first draft report, at the conclusion of the field visits to half of the participating vodokanals, meeting the scope and objectives of the terms-of-reference;
- A second draft report, at the conclusion of the totality of field visits to vodokanals; and
- A third and final report after receiving the comments, observations and requests from the Central Project Management Unit (CPMU) in the Ministry of Housing and Communal Services (MHCS) that is managing the Urban Infrastructure Project (UIP). The CPMU will provide its comments, if any, within 30 days of receipt of the second draft report. The consultants are expected to respond to any such CPMU comments within 15 days of receipt of the same.

Period of Implementation

It is expected that the whole assignment with energy audits will require six months, counted from mobilization of consultants to submission of the second draft report.

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PRODUCTION CREDITS
PRODUCTION EDITOR | HEATHER AUSTIN
DESIGN | MARTI BETZ DESIGN
REPRODUCTION | PROFESSIONAL GRAPHICS PRINTING, CO.