POLICY PAPER

MAINSTREAMING ENERGY EFFICIENCY IN URBAN WATER AND WASTEWATER MANAGEMENT IN THE WAKE OF CLIMATE CHANGE

Centre for Science and Environment

Ministry of Urban Development

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CONTENTS

1 Executive summary **6**

2 Introduction **7**
- 2.1 Vision, objectives and scope 8
- 2.2 Approach and methodology 9

3 Understanding the relationship between water, energy and climate change **11**
- 3.1 Water–energy nexus 11
- 3.2 Water–energy and climate change 11

4 Need for energy efficiency in urban water and wastewater management **14**
- 4.1 Energy cost associated with water and wastewater management 14
- 4.2 Resource efficiency and associated costs in water supply and wastewater treatment 14

5 Institutional setup **19**
- 5.1 Institutional arrangements in major states 19
- 5.2 Institutional arrangements in smaller states and union territories 20

6 Challenges in implementing energy efficiency **22**
- 6.1 Institutional challenges 22
- 6.2 Policy challenges 22
- 6.3 Financial challenges 23

7 Achieving energy efficiency in urban water and wastewater management **24**
- 7.1 Existing systems 24
- 7.2 Upcoming systems 25
- 7.3 Approach 27

8 The way forward **31**
- 8.1 Training and capacity building 31
- 8.2 Self-assessment guidelines for municipalities and water utilities 32
- 8.3 Planning for energy efficiency in urban water and wastewater management 34
- 8.4 Steps for developing water supply and wastewater energy efficiency programmes 34

Conclusion **36**

References **37**

Appendices **38**

LIST OF FIGURES

Figure 1: Conventional water and wastewater management by utilities 8
Figure 2: Schematic illustration of water-energy nexus 11
Figure 3: Water and wastewater generation 17
Figure 4: Institutional framework for urban water and wastewater management 20
Figure 5: Different approaches for energy efficiency in water and wastewater management 24
Figure 6: Water and wastewater management chain 26
Figure 7: Energy intensity in the water–wastewater cycle with key opportunities 28
Figure 8: Multi-pronged approach to achieve EE at the design stage 29
Figure 9: Lifecycle costs of an inefficient vs efficient pump 30
Figure 10: EE project assessment flow 33
Figure 11: Energy efficiency plan for water and wastewater management 34

LIST OF GRAPHS

Graph 1: Potential energy savings across states 9
Graph 2: Potential of energy savings in water supply 18

LIST OF MAPS

Map 1: Components of water supply expenditures in different cities 15

LIST OF TABLES

Table 1: Water and wastewater utility systems that use energy 12
Table 2: Expenses on energy in the operation of water supplies in India 16
Table 3: How leakage losses create shortfalls in water supplied 16
Table 4: Costs associated with leakage or transmission losses in water supply 17
Table 5: Institutional arrangements for urban water supply in major states 20
Table 6: Roles and responsibilities of various sectors 21
Table 7: Energy conservation measures for identified areas of intervention 26
Table 8: Fixtures and strategies that reduces water demand and annual CO_2 emissions for municipal water supply 27

LIST OF ABBREVIATION

AMRUT	Atal Mission for Rejuvenation and Urban Transformation
ASE	Alliance to Save Energy
BEE	Bureau of Energy Efficiency
BMP	Best management practice
CoE	Centre of Excellence
CPHEEO	Central Public Health and Environmental Engineering Organization
CSE	Centre for Science and Environment
CPCB	Central Pollution Control Board
DJB	Delhi Jal Board
EE	Energy efficiency
ESCOs	Energy Service Companies
GHG	Greenhouse gas
IGA	Investment grade audit
M&V	Measurement and verification
MoUD	Ministry of Urban Development
MLD	Million litre per day
NAPCC	National Action Plan on Climate Change
NMEEE	National Mission for Enhanced Energy Efficiency
NWM	National Water Mission
NMSH	National Mission on Sustainable Habitat
NURM	National Urban Renewal Mission
PHED	Public Health and Engineering Department
SCADA	Supervisory control and data acquisition
TWAD	Tamil Nadu Water Supply and Drainage Board
ULB	Urban local body
USAID	United States Agency for International Development
VFD/VSD	Variable frequency drives/ variable speed drives

1 EXECUTIVE SUMMARY

The high energy footprint of conventional municipal water management practices and contemporary disharmony between the water and energy sectors has resulted in missed joint opportunities for resource conservation. It has also constrained both sectors from fully reaping financial, environmental and societal benefits. This problem will be further exacerbated with climate change-related uncertainties surrounding both water and energy sector that will act as a significant 'threat multiplier'. Increase in the demand for energy to transport and treat water and wastewater in cities of developing countries is likely to be significant in the next 20 years. The world's urban population is projected to grow by 1.5 billion from 2010 to 2030. About 94 per cent of this growth will occur in developing countries. Extrapolating this urban growth, there would be a 40 per cent rise in the demand for municipal water and wastewater services by 2030. At present, only 73 per cent of urban households in developing countries have access to piped water and 68 per cent have access to improved sanitation, compared with virtually universal coverage of such services in developed countries. This highlights the need for energy efficiency (EE) in water and wastewater management.

This policy paper focuses on the importance of the interdependence of water and energy in India's water and wastewater sector. Energy requirements for provision of basic services like water supply and wastewater treatment is considerably high with utilities and urban local bodies struggling to maintain existing services and even pay the salaries of staff. The paper discusses the water–energy nexus, introduces *'Watergy'* approach and the relationship between water–energy and climate change.

Further, the paper talks about challenges in adoption of 'Watergy' approach. At the municipal scale, water and wastewater EE projects face a number of challenges, such as inflexible procurement systems, lack of institutional capacity, incentives and policy support. Many assessment studies and pilot projects have been commissioned and reports submitted demonstrating the tremendous gains available to municipalities and their rapid returns on investment. However, very few projects have proceeded to completion; and only some have been scaled-up in a structured manner. Neither national- nor state-level energy policies in India provide incentives for reducing the energy intensity of water supply and sewage treatment systems. Moreover, energy-efficient technologies are available, but they are spreading far too slowly. In India, only 10 per cent of all wastewater generated is treated, while the energy demand is soaring. The case for investments in energy-efficient solutions thus seems clear.

Top policy and decision makers in the Central and state governments should devise strategies and practices to achieve EE at every stage of the urban water cycle. Measures such as water conservation, prevention of loss, and sewer system repairs which lead to efficient water delivery and reduction in energy use, and result in savings associated with treating lower quantities of wastewater and delivering lower quantities of water, should be implemented. Also, the Central and state governments need to consider the potential impacts of climate change on water and wastewater management operations, and design more resilient water and sewage treatment systems by investing in solutions that have multiple benefits for different physical systems (water, wastewater, stormwater and energy), the society and the environment as a whole.

The need of the hour is convergence and integration between various programmes, policies, departments and decision makers. The approach used in this policy paper is aligned with 2030 sustainable development goals, which seeks to ensure availability and sustainable management of water and sanitation for all, and also the goals set by National Water Mission (NWM), National Mission on Sustainable Habitat and National Mission for Enhanced Energy Efficiency, emphasising the need of conservation of water, minimizing waste, and promoting alternative technologies to reduce energy demand as well as encouraging community involvement towards the goals of improving the water use efficiency by 20 per cent. Finally, an attempt is made to develop action points to mainstream EE in water and wastewater management in India with guiding strategies for urban areas. Most importantly, it is proposed that a strong legal push that fits the Indian context be given to reduce the cumulative energy demand, related costs and carbon emissions.

2 INTRODUCTION

Conventional water and wastewater management in urban areas is infrastructure-intensive, requiring energy intensive extraction, storage, distribution, collection and conveyance systems. Due to rapid and un-regulated urbanization, cities are looking for new water sources or sites for setting up sewage treatment plants, which may be further away from existing sources or sites. Most of the transmission and distribution pipelines are very old, and many of them are corroded and leaking, resulting in increased water losses and inadequate water quality. In developing countries, one-third to a half of the pumped water is lost to leakages. In India, the numbers reside on the higher end, with an average leakage loss ratio of 40–50 per cent in large metropolitan cities, and 50–60 per cent in smaller cities.[1]

In most Indian cities, wastewater collection networks either don't exist or are not properly designed to serve the purpose of collection and conveyance for treatment and disposal. Urban water economics adds to the crisis, water in India is highly subsidized due to which it is not considered a valuable resource. Municipalities juggle to recover not only what they have supplied, but also what they have not supplied. This is just a part of the overall calculations. Another part involves not water, but the waste that the used water will create. Utility will have to price the cost of taking back the waste. Since more water used means more waste generated, conveying and then treating this waste will cost more. As per Centre for Science and Environment (CSE), it is estimated that two-thirds of the water supplied by the Delhi Jal Board is never paid for. The quantum of non-revenue water (NRW) has been going up from about 53 per cent in 2002–03 to 56 per cent in 2006–07.[2] The cost of water currently lost to leaks in India can cover the water demand growth expected in the next few years, thus diminishing shortfalls so that investments in infrastructure could be postponed, and stretching limited water and energy resources.

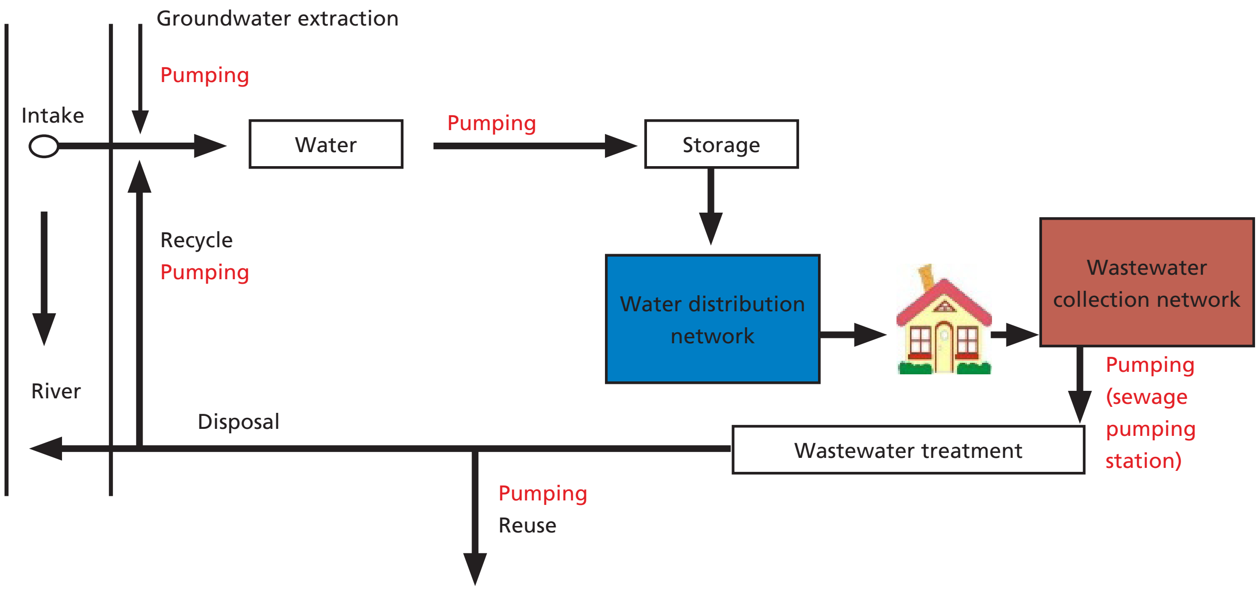
Unfortunately, most new water supply and sewage treatment projects are sanctioned as infrastructure projects without giving much importance to the energy needs of their operations. *Figure 1: Conventional water and wastewater management by utilities* illustrates the major steps involved in providing citizens basic water and wastewater services, each of which requires a significant and quantifiable amount of energy for pumping (conveyance) and treatment. The relative energy importance of the different steps depends on factors like the topography between the water source and its destination (especially elevation change), distance from the bulk water supply, integrity of the primary mains (supply pipes), and secondary mains (distribution pipes), distance from the sewage treatment plant and site of disposal or reuse.

Municipalities and urban local bodies (ULBs) are already facing multiple challenges to meet the demand of growing population, rapid urban expansion and increasing power tariffs. In addition, municipal water supply and sewage treatment infrastructure in India is often outdated and its inefficient operation places a hefty burden on municipal budgets. As per various energy audit studies, about 40–60 per cent of a water utilities' operating cost is spent on energy, thus EE is a significant component of the sectors financial and operating performance improvements. If energy use for water delivery remains at the current level, the energy cost of providing water supply to this growing population will be a huge.

The primary energy demand in India has grown from about 450 million tonnes of oil equivalent (toe) in 2000 to about 770 million toe in 2012. This is expected to increase to about 1,250 (estimated by International Energy Agency) to 1,500 (estimated in the Integrated Energy Policy Report) million toe by 2030, creating significant challenges for the country.[3] In the long term, energy prices are expected to remain high in India, due to ongoing growth in energy demand in both public and private sectors and shortage in supply.

To achieve the water EE targets set by the NWM, which is 20 per cent improvement in water use efficiency,[4] would create cost saving of about Rs 12 billion per year in water utilities, and Rs 7 billion per year in pumping station operations.

Figure 1: Conventional water and wastewater management by utilities



Source: CSE, 2016

Graph 1: Potential energy savings across states shows the potential energy savings in water utilities across Indian states with a conservative assumption of 20 per cent efficiency improvement in bulk water supply and sewage treatment operations. It shows that Maharashtra, Rajasthan, Uttar Pradesh, Karnataka, Haryana, Himachal Pradesh, Tamil Nadu and Punjab have larger potential among other Indian states.

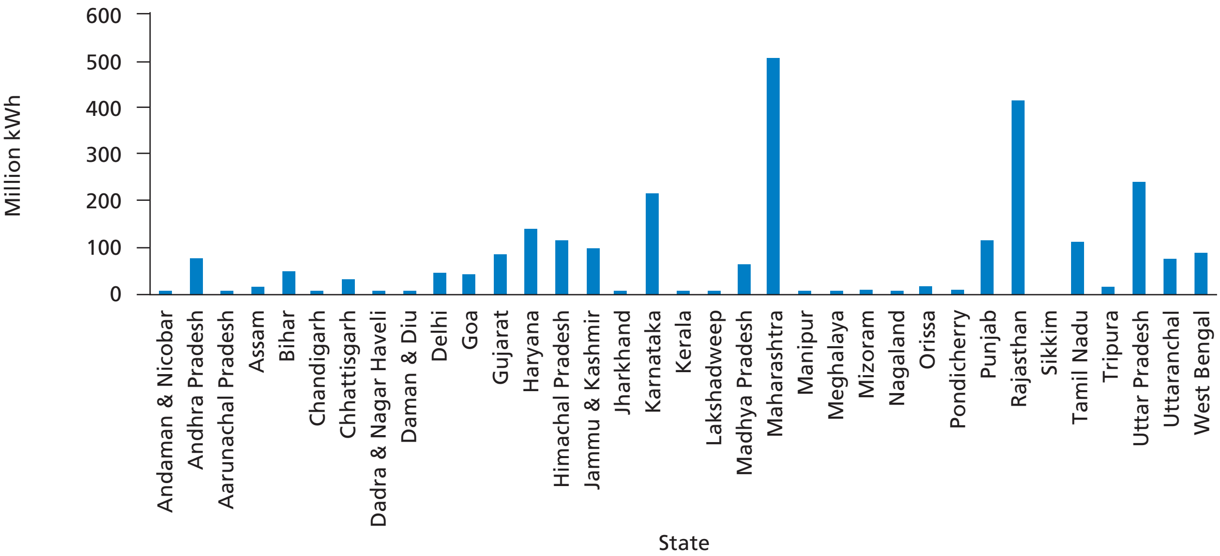
It has become important for decision makers to view EE not only for reduction in cost, water efficiency and sustainable urban water management, but also as a tool for carbon mitigation in cities. The National Mission for Enhanced Energy Efficiency (NMEEE), established under India's National Action Plan on Climate Change (NAPCC), has planned for mitigation measures that aim to save 10 GWh of energy per year. Thus, improving EE makes sense from both energy saving and cost reduction point of view in the wake of climate change. Efficient systems would also reduce the need for additional infrastructure to pump more water.

2.1 VISION, OBJECTIVES AND SCOPE

Vision:
It is envisaged that through this policy paper, the urban areas of the country will develop a better understanding of the value of water and energy as important resources. The paper also describes how water and wastewater facilities can lead by example and achieve multiple benefits (from the municipalities) by improving the EE associated with water and wastewater management for existing, upcoming and renovated systems.

Objectives:
- Develop a comprehensive understanding of the links between water and energy sectors in India
- Provide technological solutions to develop a more cost-effective and sustainable water management paradigm
- Suggest guiding principles and a way forward for EE in water and wastewater management
- Establishing need for energy efficiency in water and wastewater sector
- Understand case studies on best management practices from international and national experience

Graph 1: Potential energy savings across states



Source: Adapted from BEE situational survey and CEA report and author analysis, 2016

Scope:
This document by CSE for the Ministry of Urban Development (MoUD), Government of India is to serve as a background for policy guidelines on EE in water and wastewater management in the wake of climate change. It will also serve as a background document for policy and public sector decision makers who intend to play a part in the development, integration, financing and implementation of water supply and sewage management EE programmes.

It is now important for policy makers to view EE as a way to achieve not only sustainable urban water management but also as a tool for greenhouse gas (GHG) mitigation in cities. Therefore, users for this policy document includes higher and medium level officers of urban development departments, municipalities, service providers and financial institutions. The document may also be used as reference material by other state and non-state officials associated with municipal level water, wastewater and EE projects.

2.2 APPROACH AND METHODOLOGY

This paper is an outcome of CSE's research in the area of sustainable water management for the past two decades with an aim to establish policy principles, innovative technologies and implementation strategies for water and wastewater management in order to help lay the foundations for a water- and waste-prudent society.

A case study of wastewater management titled *Sewage canal: How to clean the Yamuna* was published by CSE in 2007. The book called for re-thinking and re-engineering the approach towards water and wastewater management, not just for the cities along the Yamuna, but also for all rivers in India. A documentary titled *Faecal attraction: Political economy of defecation* was also produced in 2012 to create awareness about urban sewage management. Together, the book and the documentary have started a national debate on the National River Conservation Plan. CSE had been actively involved in its revamp.

In 2012, India's first and most comprehensive survey on water and sewage management titled *Excreta Matters* (in two volumes) was published by CSE. The publication contains data and information collected from over 71 cities in different agro-climatic zones on all aspects of water management—

sourcing, treatment (water and waste), supply, pricing and equity. The book outlines an approach towards sustainable water and sewage management in Indian cities.

CSE has also been designated Centre of Excellence (CoE) in sustainable water management by the MoUD under the Capacity Building of Urban Local Bodies scheme. CSE has been involved in assisting the ministry in policy research, capacitating municipal functionaries through tailor-made training programmes in three key areas—septage management, urban lake management, and water sensitive design and planning. Simultaneously, CSE conducted several short training programmes and national exposure visits for municipal functionaries and trainers from other CoE assisting the ministry.

CSE was also identified as a 'key institution' to support comprehensive capacity building programme under National Urban Renewal Mission (NURM) for 2012–13. Under this initiative, CSE was mandated to conduct capacity-building trainings and workshops, and research in the areas of sustainable water and wastewater management. Under this mandate, a few workshops focusing on energy efficiency in this sector were conducted.

With CSE's record of extensive research and capacity-building programmes on the subject, a policy paper on EE in sustainable water and waste management was conceived as a much needed addition covering some crucial lacunae.

The following approach was adopted to prepare this policy paper:

1. CSE's extensive background research was the first step in preparing this paper.

2. Analysis of relevant information from data available in public domain was done.

3. Discussions and roundtable meetings were held with subject experts to take their opinion on availability of provisions to mainstream EE in urban water and wastewater management within the existing legal framework. Representatives from government, NGOs (like Council on Energy, Environment and Water), National Institute of Urban Affairs, Bureau of Energy Efficiency (BEE), Bureau of Indian Standards (BIS), and other private consultants working extensively in this sector were part of the core group meeting. The comments of these experts found their way into the policy document. (See *Appendix 2*).

4. The draft paper was presented in a consulting national seminar where experts from across the country gave inputs, recommendations and highlighted examples of best management practices in the area of EE at the national and international level (See *Appendix 3*).

3 UNDERSTANDING THE RELATIONSHIP BETWEEN WATER, ENERGY AND CLIMATE CHANGE

3.1 WATER–ENERGY NEXUS

Energy plays a crucial role in the supply, treatment and utilization of water. At the same time, water is an integral part of energy's life cycle of extraction, production, conversion, distribution, use and disposal. This interdependence between water and energy is called the water–energy nexus. While the relationship can be mutually constraining, it also presents an opportunity to address both energy and water issues together, because conserving one leads to conservation of the other. Consequently, the way we manage the delicate relationship between the two will have major implications on whether we will be able to mitigate the impeding water and energy crisis or not. The water–energy nexus implies a mutual cause–effect relationship between water and energy[1] (see *Figure 2: Schematic illustration of water–energy nexus*).

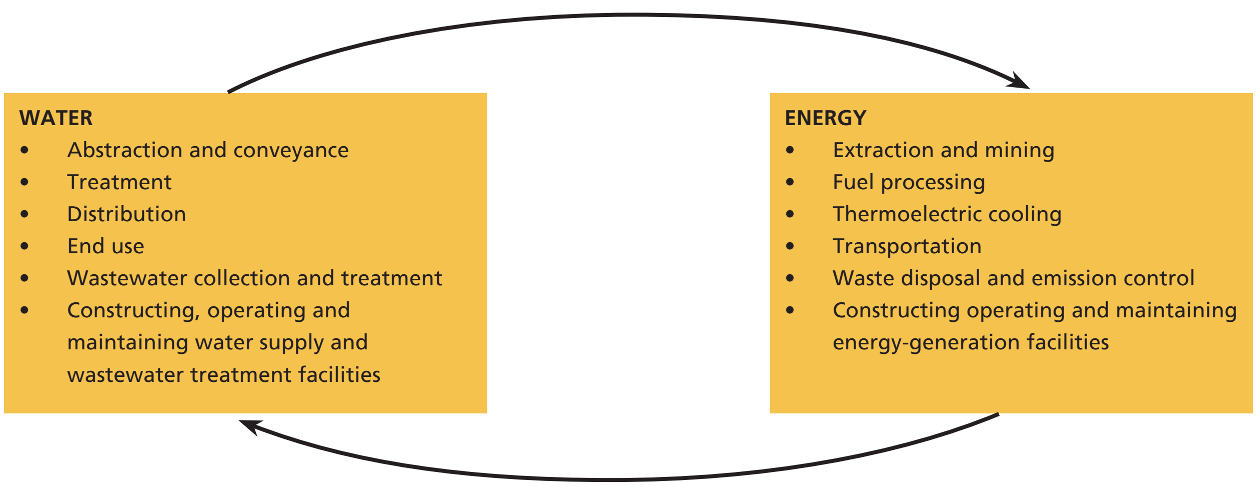
Keeping this water–energy relationship in mind, the term *watergy* was coined by Alliance to Save Energy.[2] The watergy approach helps cities realize significant energy, water and monetary savings through technical and managerial interventions in water and wastewater systems, providing consumers with quality water using minimum quantities of water and energy.[3]

The interdependency between energy and water are set to intensify in the coming years, as both the water needs of the energy sector and the energy needs of the water sector rise. Every litre of water that passes through a supply system represents a significant energy cost. The water–energy relationship is based on the reality that treating water for human consumption and moving wastewater to the consumer are extremely energy-intensive undertakings. *Table 1: Water and wastewater utility systems that use energy* summarizes the various components involved in supplying water and disposing wastewater that uses energy.

3.2 WATER–ENERGY AND CLIMATE CHANGE

A significant share of India's large population lives in areas already vulnerable to floods, cyclones and drought, with rising sea levels also threatening displacement along the country's densely populated

Figure 2: Schematic illustration of the water–energy nexus



Source: CSE, 2016

Table 1: Water and wastewater utility systems that use energy

Stage	Operation	Energy-using systems
Extraction	Deep well extraction	Submersible or shaft turbine deep well pumping systems
	Extraction from a surface source	Horizontal or vertical centrifugal pumping systems
Water treatment	Chemical (disinfection and clarification)	Piston-type dosing pumps
	Physical (e.g., filtration and sedimentation)	Pumping systems, fans, agitators and centrifugal blowers
Piping between source and distribution network	Sending the drinking water to the distribution grid	Submersible or shaft turbine deep well pumping systems, and horizontal or vertical centrifugal pumping systems
	Booster pumping	Horizontal or vertical centrifugal pumping systems used to increase pressure of water going into the distribution system or to pump water to a higher elevation
Distribution	Distribution to end users	Horizontal or vertical centrifugal pumping systems
Storm and sanitary sewer system	Sewerage and drainage	
Wastewater treatment	Physical (e.g., screening and sedimentation)	Pumping systems, fans, centrifugal blowers
	Chemical (e.g. clarification, disinfection)	Piston-type dosing pumps
	Biological	Pumping systems, agitators, aerators, centrifugal blowers
Support systems	Support functions associated with the utility building(s)	Lighting systems, heating, ventilation and air conditioning (HVAC)

Source: WATERGY: Energy and Water Efficiency in Municipal Water Supply and Wastewater Treatment, 2007

coastlines. India is among the most vulnerable countries when it comes to the impacts of a changing climate. The domestic and international challenge for India is to demonstrate serious intent to limit emissions, reducing the rate at which emissions grow in the future, while not affecting the growth of the economy. The government has committed to keep its per-capita emissions below the level of those of industrialised countries in the future and as part of its Intended Nationally Determined Contribution submitted in October 2015, it has also pledged to reduce the emissions intensity of the economy by 33–35 per cent by 2030, measured against the 2005 level.

Managing energy–water linkages is pivotal to the success of a number of development and climate goals. There are several connections between the new United Nations Sustainable Development Goals (SDG) on clean water and sanitation (SDG-6) and affordable and clean energy (SDG-7) that, if managed well, can help the attainment of both sets of goals. There are also many economically viable opportunities for energy and water savings that can relieve pressures on both systems, if considered in an integrated manner. Some low-carbon options are available, such as adopting decentralized wastewater management that requires lesser water and energy for conveyance of waste to a treatment facility as compared to conventional centralized management approaches. Decentralized wastewater management systems generally have a smaller resource footprint and consume less energy through savings on transportation costs and innovative biological treatment systems. They also use 30–35 per cent less energy on-site.[4]

The design and planning teams need to consider a modular approach in designing water pumping machinery for the future. In the recent past, the government of India has launched many programmes supporting EE and climate change mitigation. One such programme is the 'smart cities' mission, which aims to provide a clean, safe and sustainable environment, by ensuring modern, efficient urban infrastructure, and efficient use of resources. Under the Atal Mission For Rejuvenation And Urban Transformation (AMRUT), the government is aiming to improve the existing basic infrastructure services like drinking water supply, sewerage networks and septage management. With such programmes and missions in place, energy-efficient designs during the planning stages will ensure better value for money by spending it on low carbon water and wastewater management infrastructure. In addition, NAPCC outlines existing and future policies and programmes addressing climate mitigation and adaptation. To align with its overall objective, NAPCC also plans to study the relationship between water, energy and climate change. Given the variety of agendas that prioritize targets, ranging from improving water services to efficient energy use, improving energy use in urban water delivery addresses these multiple goals and, therefore, will help in satisfying cross-sector interests.

4 NEED FOR ENERGY EFFICIENCY IN URBAN WATER AND WASTEWATER MANAGEMENT

More than half of the world's population now lives in urban areas and almost all future population growth is projected to occur in cities.[1] Secure supply of energy may be a global concern, but is felt most urgently at the municipal level. The major responsibility for addressing such problems also falls on local officials. India municipal sector is the second largest municipal system in the world and contributes around 4 per cent to the total electricity consumption in the country. As per a Central Electricity Authority report, energy consumption by public water works was around 18,364 million units (MUs) in 2011–12.[2] The report also projected the energy consumption for the year 2021–22 at around 36,861 MUs, with a significant growth of approximately 100 per cent in 10 years. BEE initiated a municipal demand-side management programme during the XI plan with water and wastewater, and street lighting as target sectors. The objective of the programme was to improve the overall EE of the ULBs, which could lead to substantial reduction in electricity consumption, thereby resulting in cost saving for the ULBs. Situational surveys were conducted in 175 ULBs across the country and, based on a techno-commercial assessment, 134 bankable detailed project reports were prepared. An overall potential saving of 120 MW is estimated as part of avoided generation capacity through EE projects in the 134 ULBs.[3] But the implementation of water and wastewater EE projects is still not happening at a large scale.

4.1 ENERGY COST ASSOCIATED WITH WATER AND WASTEWATER MANAGEMENT

Most water and wastewater facilities were constructed many decades ago, when electricity costs were too low to be of much concern. Facilities and the equipment within them were designed to run continuously, without regard for wasted energy. Currently, energy expenditure is usually the highest cost associated with water supply and is one of the top three expenditures at any water utility, often second only to labour wages. In India, energy is usually the highest expenditure associated with water supply, compared with salaries, repair and maintenance, treatment and other costs (see *Map 1: Components of water supply expenditures in different cities*).

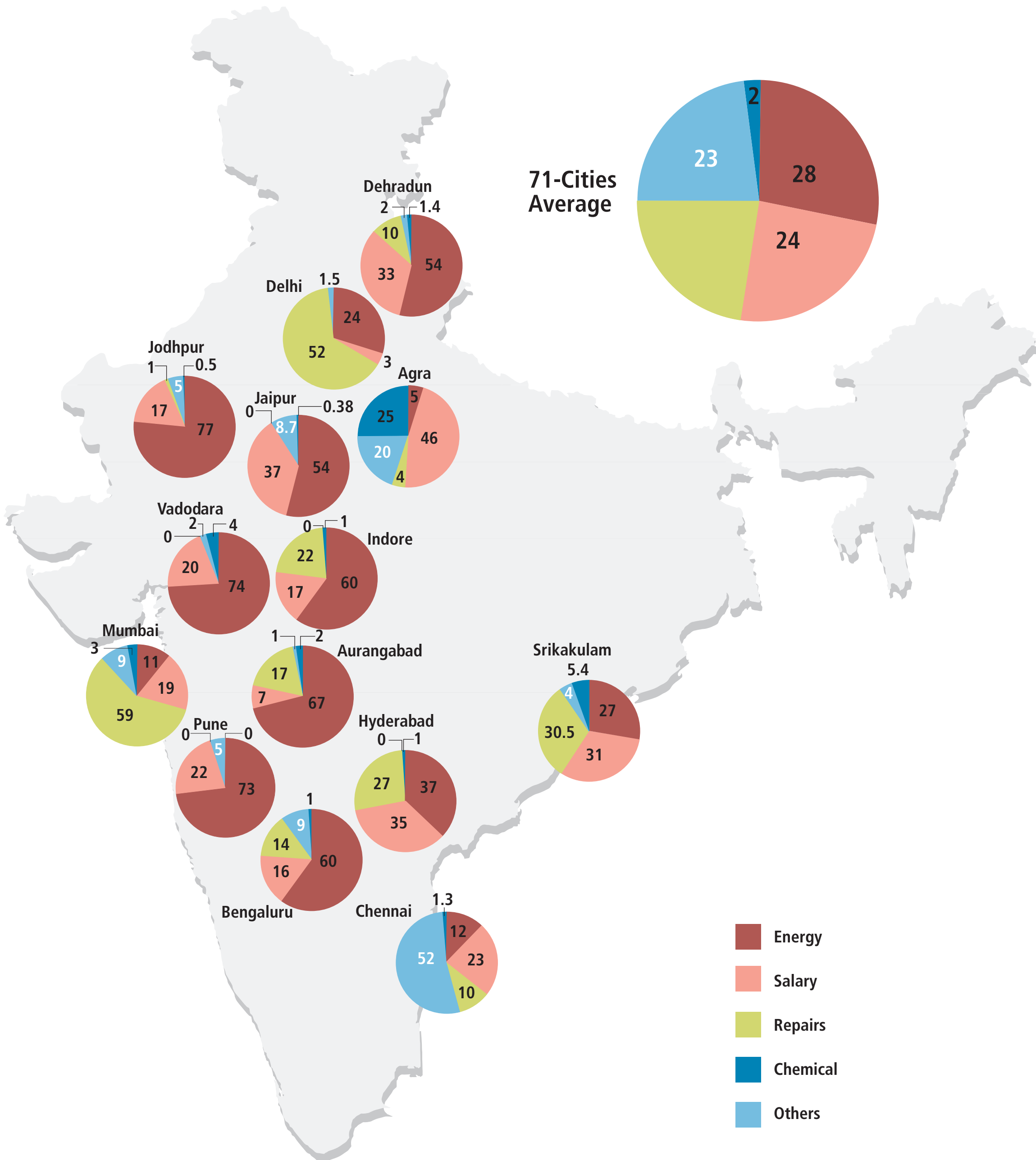
CSE's survey of 71 Indian cities revealed that the single biggest charge on water utilities is the cost of electricity, the need to pump water from long distance sources and then to pump the waste out of the city.[4] *Table 2: Expenses on energy in the operation of water supplies in India* provides data of the top 22 cities that have energy-intensive water supply. Jodhpur ranks the highest with an energy expense of nearly 77 per cent of annual operation costs, while Hyderabad ranks last, spending only about 37 per cent of its annual operation and maintenance cost on power bills.

Another study, *Report on Seventh Electric Power Survey*, indicates that the public water works in India consume more than 12,000 MUs of electricity. Energy costs account for approximately 40–60 per cent of the operating expense of supplying water. By becoming energy efficient, each ULB can reap minimum energy savings of 25–40 per cent.[5]

4.2 RESOURCE EFFICIENCY AND ASSOCIATED COSTS IN WATER SUPPLY AND WASTEWATER TREATMENT

Given the current inefficient paradigm of water management, most cities face 40 per cent of more transmission losses. CSE study of the 71 cities revealed an average distribution loss of around 35 per cent, which translates into a loss of 6,877 million litres per day (MLD) (see *Table 3: How leakage losses create shortfalls in water supplied*). To understand how staggering this loss is, consider the given calculation. The amount of water that these cities lost in 2005 would be enough to take care of their additional requirements in 2011.

Map 1: Components of water supply expenditures in different cities



Note: All figures are in percentage.

Source: Excreta Matters, 2012

Additionally, these substantial leakages or transmission losses can lead to an increase in the cost of the water supply by upto 11 per cent in of metro cities, 5 per cent for Class I cities and 4 per cent for Class II and III cities, as per the CSE study[6] (see *Table 4: Costs associated with leakage or transmission losses in water supply*).

Of the supplied water, roughly 80 per cent of the water that reaches households leaves as waste.[7] According to CPCB, in 2015, total sewage generated in India was 61,754 MLD. Sewage treatment plants

Table 2: Expenses on energy in the operation of water supplies in India

City	Energy expense[1]		
	Rs crore	Percent[2]	Rs lakh/MLD
Jodhpur	54	77	24.40
Vadodara	41	74	15.30
Pune	22.5	73	2.8
Aurangabad	20	67	9.8
Nagpur	20	63	4.3
Bhopal	21	60	7.9
Indore	49	60	24
Mussoorie	3	60	37
Bengaluru	251	60	28
Baramati	0.22	57	1.8
Ranchi	12	57	10.3
Bhubaneswar	14	56	6.9
Dehradun	6	54	5.2
Jaipur	42	54	12
Alwar	5	47	15.8
Bhilwara	0.91	45	4.8
Faridabad	8.55	44	3.47
Aizawl	9	44	46
Jammu	13.79	40	6.3
Jabalpur	5.5	38	3.5
Hyderabad	80	37	8.6

[1] Data for 2004-05

[2] Expense as per cent of annual operation cost MLD (million litres daily)

Source: Excreta Matters, 2012

Table 3: How leakage losses create shortfalls in water supplied

	Demand 2005 (MLD)	Supply 2005 (MLD)	Gap in 2005 (MLD)	Shortfall in supply, 2005 (%)	Leakage loss (MLD)	Supply after loss, 2005 (MLD)	Demand-actual supply gap, 2005 (MLD)	Shortfall in actual supply 2005 (%)
Metro	17,987	16,591	1,396	8	6,150	10,441	7,546	42
Class I	2,879	2,775	104	4	706	2,069	811	28
Class II & III	129	123	7	6	21	101	28	22
Total	20,996	19,489	1,507	8	6,877	12,611	8,385	40

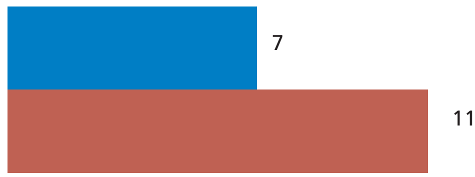
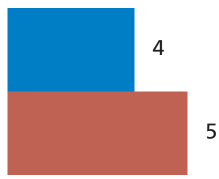
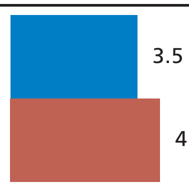
MLD: Million litres daily

Source: Excreta Matters, 2012

had the capacity to treat only 37 per cent or 22,963 MLD of this wastewater.[8] These figures do not take into account the private and unofficial groundwater usage or losses in the distribution system (see *Figure 3: Water and wastewater generation*). It is, therefore, clear that the current water paradigm, with its primary focus on the supply side, is unsustainable, given that more water supply leads to more wastewater generation which also increases costs of treatment.[9]

One major reason for rise in pumping energy cost (KWh/ MLD) is the depletion of water table across

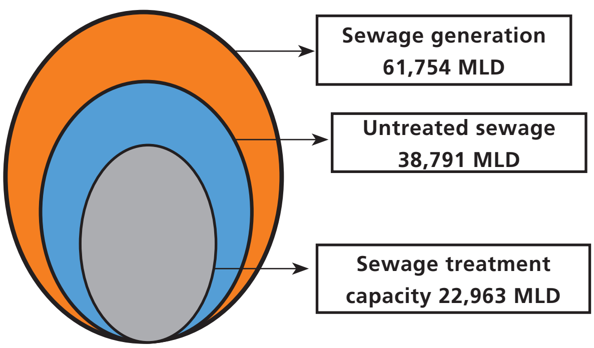
Table 4: Costs associated with leakage or transmission losses in water supply

	City	Energy expense		
		Cost of total water supply (Rs/kl)	Cost after leakage loss (Rs/kl)	Average (Rs/kl) Total water supply After leakage loss
Metro	Bengaluru	13	21	
	Chennai	12	17	
	Indore	11	17	
	Mumbai	11	15	
	Delhi	9	18	
	Dhanbad	9	11	
	Hyderabad	6	11	
	Jaipur	6	11	
	Rajkot	6	8	
	Vadodara	6	9	
	Meerut	0.8	1	
Class I	Aizwal	54	83	
	Khanna	14	18	
	Alwar	9	12	
	Jodhpur	9	11	
	Kozhikode	8	12	
Class II & III	Nainital	17	20	
	Mussoorie	17	24	
	Raman	2	3	
	Uttarkashi	2	3	
	Goniana	2	2	

kl: kilolitre

Source: Excreta Matters, 2012

Figure 3: Water and wastewater generation



Source: CPCB Bulletin, Volume 1, July 2016

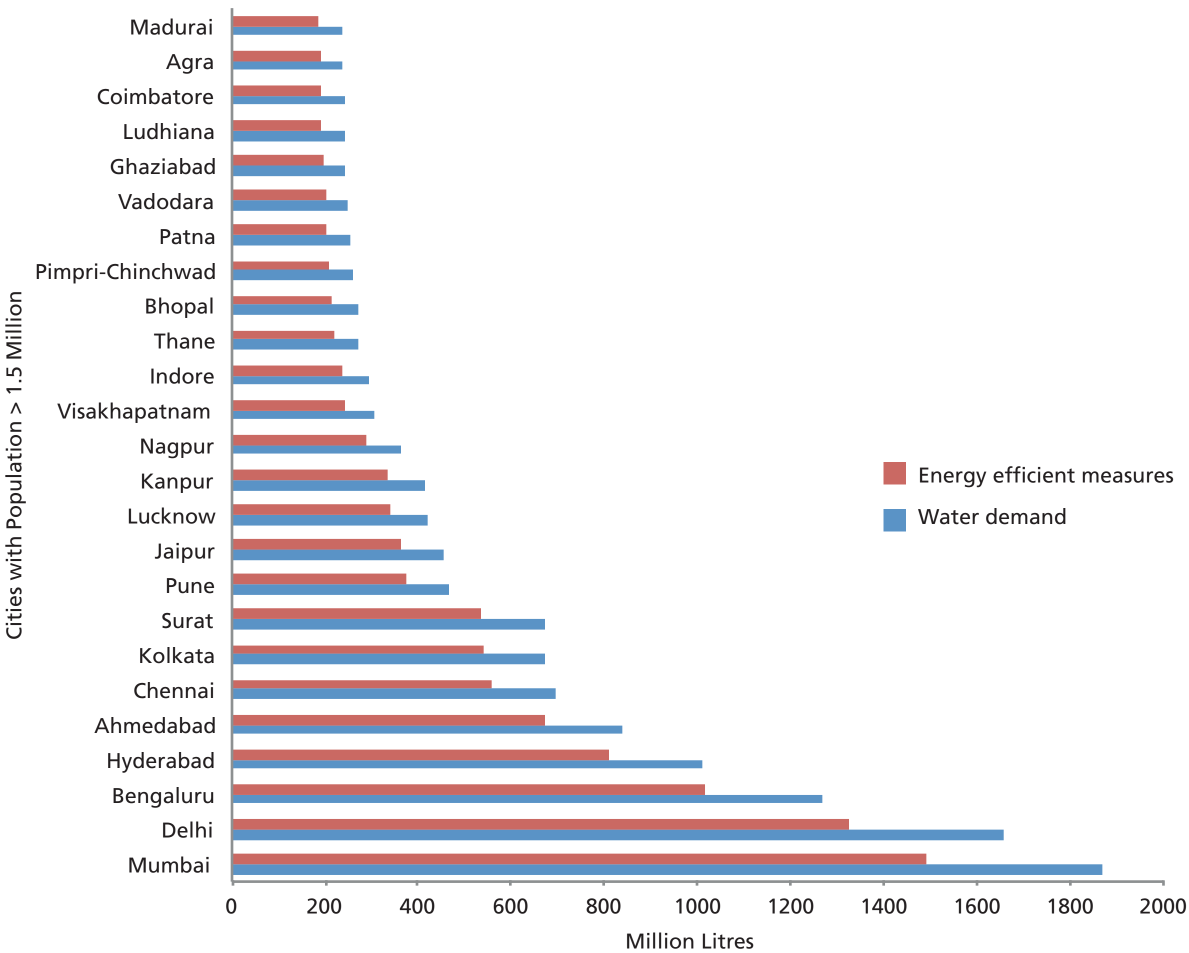
India and scarcity of surface water in rivers and canals.[10] Optimizing pumping operations can result in energy savings in energy-efficient water delivery systems. Yet, most municipalities and water utilities are unaware of the benefits of implementing EE in water and wastewater management.

Pumping and aeration systems are the highest energy users in a water and wastewater treatment plant. Typically, aeration systems are responsible for 50–60 per cent of energy use in a wastewater treatment plant. As a result, systems not properly tuned or unable to reduce redundant aeration blower or pump capacity can waste energy and money for decades. This waste also result in higher GHG emissions over the life of the plant. Currently, in India, the designing of water supply and wastewater systems follows the Centre Public Health Environment and Engineering Organization (CPHEEO) guidelines, which are primarily based on demand forecast analysis. In many cases, the pumping machinery has to operate on reduced load conditions (mismatch in current head and flow requirements) for many years due to lesser supply requirement during the initial years, thus resulting in adopting inefficient operations of the pumps, such as throttling. Equipment retrofits and replacement can create significant energy savings by preventing water and energy loss from inadequate and old infrastructure.

Non-revenue water (NRW, water loss not accounted for) is a broader estimate of water loss, which includes loss of revenue not only from physical leakages of treated water but also from metering inaccuracies, unbilled consumption, and unauthorized connections. NRW is estimated to be 16 per cent in the US, 15 per cent in UK, and 6 per cent in Netherlands, while in Delhi, one of the better perfoming cities of India, it is 59 per cent—the overall NRW in Asia varies wildly between 4–65 per cent. The International NRW comparison shows that tremendous opportunities exist in preventing water loss that will increase EE throughout the water delivery system in India.

Cities with more than 1.5 million population would be able to balance the water demand–supply gap if they execute the policy of EE (see *Graph 2: Potential of energy savings in water supply*).

Graph 2: Potential of energy savings in water supply



Source: CSE, 2016

5 INSTITUTIONAL SETUP

At present, the responsibility of supplying water is divided between two bodies in most urban centers. In most places, the municipal body is directly responsible for supplying water, while in some other places, city-level water supply and sewerage boards have been constituted to perform this function (mainly in metropolitan cities). The common pattern observed in cities is that a state-level agency, such as Public Health Engineering Department or Division (PHED) or a state-level water supply and sewerage board, performs the capital works and once the construction is over, hands over the responsibility of operation and maintenance to the local governments. In some cities, the state-level agency performs the capital works, and also the operation and maintenance, while the revenue functions are with the local governments.

In metropolitan cities viz., Bengaluru, Chennai, Hyderabad and Kolkata, there are separate authorities for water supply and sewerage. In Delhi there is a city-level board that performs these functions.

Some of these boards can be listed as follows:

City	Board or authority
Delhi	Delhi Jal Board (DJB)
Bengaluru	Bangalore Water Supply and Sewerage Board (BWS&SB)
Chennai	Chennai Metropolitan Water Supply and Sewerage Board (CMWS&SB)
Hyderabad	Hyderabad Metropolitan Water Supply and Sewerage Board (HMWS&SB)
Kolkata	Kolkata Metropolitan Water & Sanitation Authority (CMW&SA)

States with state-level water supply and sewerage boards or equivalent state-level agencies are as follows:

State	Board or agency
Gujarat	Gujarat Water Supply and Sewerage Board (GWS&SB)
Karnataka	Karnataka Urban Water Supply and Drainage Board (KUWS&DB)
Kerala	Kerala Water Authority (KWA)
Maharashtra	Maharashtra Jeevan Pradhikaran (MJP)
Punjab	Punjab Water Supply and Sewerage Board (PWS&SB)
Tamil Nadu	Tamil Nadu Water Supply and Drainage (TWAD) Board
Uttar Pradesh	U.P. Jal Nigam

5.1 INSTITUTIONAL ARRANGEMENTS IN MAJOR STATES

Table 5: Institutional arrangements for urban water supply in major states provides an overview of water supply- and wastewater-related department-wise responsibilities of a few states.

The general institutional arrangements remain similar across states, however, there are exceptions to the conventional framework. For instance, in Hindupur and Srikalahasti in Andhra Pradesh, the municipality performs all the above functions. The Thrissur Municipal Council performs the operation and maintenance, and revenue-related functions in Kerala, a state where state water authority performs all the functions for all the towns. In Maharashtra, the Maharashtra Jal Parishad performs all the functions related to water supply in Amravati, Yavatmal and Ballarpur.

Table 5: Institutional arrangements for urban water supply in major states

State	Capital works	Operation and maintenance revenue and functions
Andhra Pradesh	PHED	Municipal body
Bihar	PHED and municipal body	PHED and municipal body
Gujarat	Municipal body and GWS&SB	Municipal body
Haryana	PHED	PHED
Karnataka	KUWS&DB	Municipal body
Kerala	KWA	KWA
Madhya Pradesh	Municipal body and PHED	Municipal body and PHED
Maharashtra	MJP and corporation	Municipal body
Orissa	PHED, rural water supply and sanitation department, and housing and urban development department	Rural water supply and sanitation department, and PHED
Punjab	PWS&SB	Municipal body and PWS&SB
Rajasthan	PHED	PHED
Tamil Nadu	TWAD board	Municipal body and TWAD board
Uttar Pradesh	Jal Nigam and municipal body	Jal sansthan and municipal body
West Bengal	PHED and municipal body	PHED and municipal body

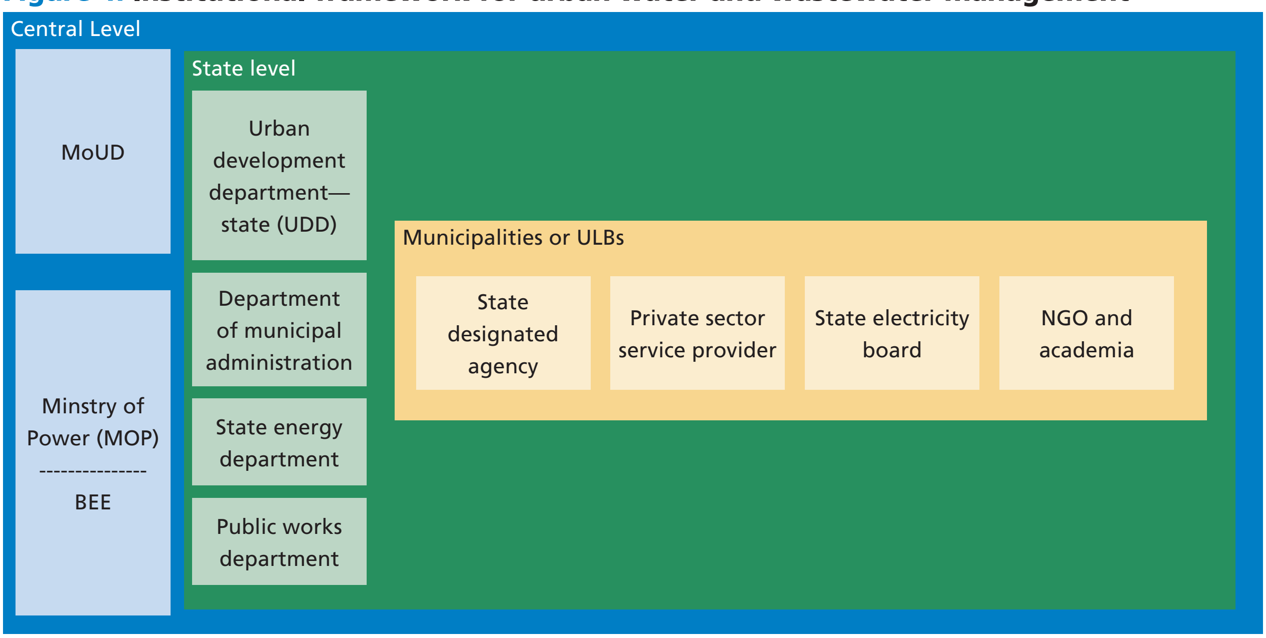
Source: CPHEEO report, MoUD, 2015

5.2 INSTITUTIONAL ARRANGEMENTS IN SMALLER STATES AND UNION TERRITORIES

In most of the smaller states and union territories, PHEDs or public works department perform all the functions related to water supply.

Given such a complex water management hierarchy, the success of the Energy Conservation Act, 2001 depends on a strong collaboration and synergy between multiple stakeholders who need to understand their roles and responsibilities well. *Figure 4: Institutional framework for urban water and wastewater management* and *Table 6: Roles and responsibilities of various sectors* provide an illustrative

Figure 4: Institutional framework for urban water and wastewater management



Source: CSE, 2016

framework of major organizations belonging to different sectors, and their role in the development and implementation of energy-efficient water and sewage management programmes.

Table 6: Roles and responsibilities of various sectors

Sector	Major role	Organization responsible
Public sector		
Energy department	Developing overall policies and regulation	BEE
Urban department	Developing policies related to urban infrastructure, SMART cities, AMRUT; collaborating with the energy department	MoUD
Municipal department	Operating and maintaining: includes payment of energy bills and identifying, designing and implementing retrofit projects	Municipal corporation and ULBs
Implementation organization	Implenting government-supported projects and enabling market for the energy services sector	Energy efficiency services limited and PHED
Private sector		
Water supply and treatment systems vendors and suppliers	Supplying hardware and equipment, and providing energy performance and savings guarantees on hardware and equipment per measurement and verification (M&V) plans	Various equipment manufacturers
Energy auditing firms or energy service companies	Conducting energy audits, drawing project design, development and implementation, and guaranteeing energy savings based on M&V plan	Energy auditor and ESCOs certified by BEE
M&V agency	Providing third party M&V services	CMVPs, certified M&V firms
Advisory sector		
Multilateral organizations or national development banks	Providing project financing and partial risk guarantee fund to reduce risks associated with EE projects; providing technical assistance to help develop M&V application guides, tools, and contractual and legal due diligence on EPCs	The World Bank, Asian Development Bank, KfW Development Bank, United States Agency for International Development (USAID), Department for International Development
Foundations, technical advisory, EE consulting organizations	Providing advisory services to support design and development of EE water supply and treatment programmes, training and capacity building, project facilitation, and other technical support	CSE, Shakti Foundation, IFC, Alliance for an Energy Efficient Economy, ASE, International Institute for Energy Conservation
Financial sector		
Public or private sector banks	Commercial banks investing in water supply and treatment project on the basis of projected cash flows resulting from energy savings	Indian Renewable Energy Development Agency, Small Industries Development Bank of India, Power Trading Corporation, and retail banks

Source: CSE, 2016

6 CHALLENGES IN IMPLEMENTING ENERGY EFFICIENCY

Municipalities spend a significant share of their budgets in providing basic services like water supply, sewage collection and treatment, and street lighting. These energy-intensive services compete with other economic and social development programmes like education and public health for funds. Keeping this in mind, many municipalities recognize the need for energy efficiency, but their efforts in that direction encounter many barriers (as enunciated in the *Box: Common barriers to energy and water efficiency*).

Municipal water and wastewater EE projects face a number of challenges, which can be classified as institutional, such as inflexible procurement systems, lack of knowledge on EE, institutional incapacity, disincentives and weak policy support, challenges due to lack of a concrete policy, and financial challenges.

6.1 INSTITUTIONAL CHALLENGES

Often, there are no clear definitions as to who is responsible for EE in the design organization. The experts involved in a typical design and other important decision makers are not experienced in energy efficiency projects. Also, nobody challenge solutions proposed by manufactures, vendors or suppliers when it comes to EE.

In most Indian states, municipal budgets are locked in a cycle of high energy costs and deferred service improvements. As in most countries, one of the greatest barriers to water supply energy-saving initiatives in India is the lack of adequate technical and managerial capacity within municipal bodies to design and implement efficiency measures. Without specific knowledge or experience of managing EE projects, it is difficult for municipal officials to champion such projects. They face obstacles such as:

1) Competition for public support with more popular investments that have faster payback periods.

2) Public procurement policies that focus on the lowest-priced technologies rather than the lifecycle cost of the investment.

3) Lack of access to financing for such projects.

6.2 POLICY CHALLENGES

In the absence of relevant policies and incentives for energy conservation measures, many municipalities are hesitant to face all of the technical and financial burdens of efficiency improvements without an established precedent or guarantee of payback. Some examples are:

1) Low priority is given to EE considerations in many government-supported water supply retrofits and infrastructure projects.

2) Neither national- nor state-level energy policies in India provide incentives for reducing the energy intensity of water supply and sewage treatment systems.

3) Government procurement procedures tend to favour lowest-cost technology replacements and investments that achieve rapid (though often temporary) service improvements and often result in inefficient structures and equipment systems.

4) When municipalities implement major EE projects, their capacity to retain energy cost savings is severely limited by variable methodologies for determining municipal (versus state) budgets. While the methodology currently in use for estimating municipal yearly budgets takes into account population, area and the services provided, it does not factor in energy costs and savings. Since the expenditures of the current year are used as the basis for determining the next year's budget, reductions in operating costs can result in reduced future budget allocations—a disincentive to reducing energy costs.

Common barriers to energy and water efficiency

1) *Lack of awareness:* People will not make changes towards efficiency unless they are aware of the cost–benefit arguments for doing so. This is especially true in the case of applying energy efficiency to water supply, since those responsible for day-to-day operations in the water sector are not accustomed to focusing on energy.

2) *Aversion to risk:* Deviating from the usual routine is associated with risk, real or perceived, such as added burden on staff or financial risk. Fear of change has a rational basis and breaking through it requires that the fears be addressed and that the benefits of change clearly outweigh risks.

3) *Change may imply a problem with the status quo:* It is not uncommon for staff to be resistant to new ideas and procedures due to a feeling that suggestions for change imply criticism of their performance and ability.

4) *Subsidies:* Although subsidies have a role in providing essential services to the poor, when they are poorly planned or implemented, they often greatly reduce the cost incentives inherent in efficiency. Some subsidies are unofficial, such as the tacit approval by the authorities of water or electricity theft.

5) *Financing efficiency:* There is a lack of understanding of performance contracting mechanism and of awareness that it can be applied to water sector. These financing issues are further compounded by an insufficient supply of service providers capable of performance contracting; even where suppliers exist, the industry is often so nascent that confidence in them is lacking. On the flip side, some municipal bodies do not have a good track record of sound financial management or honouring contracts, making EE service providers reluctant to enter into contracts with municipalities.

Source: Derived from ASE's 2007 reports

6.3 FINANCIAL CHALLENGES

Unlike investments in fixed assets that yield productive output, such as renewable or other energy supply projects, investments aimed at improving operational productivity through cost savings are a financial hard-shell. Given the constraints on public budgets, financing for municipal projects must come from other sources. Additionally, there are conditions upon which those sources—grantors, lenders, or co-investors (in the case of a performance contract) will contribute their resources to municipal projects. Grantors need some assurance that the money they provide to municipal projects will be used for its intended purpose. Lenders and co-investors need a guarantee of repayment and their agreed-upon share of a project's payback.

There are several basic problems constraining investment: lack of equity, customer finance, and access to capital markets. Lack of access to financing for such projects is often perceived to be a key barrier to their implementation and to the widespread adoption of EE technologies. Access to financing depends on the credit-worthiness of the borrower, the cash flow to be generated by a project, and any mechanisms for credit enhancement (such as collateral and loan guarantees).

More than ever, the success factor that determines the financing of new water supply and sewage systems is considered to be the need to minimize 'investment costs'. Even though 'value engineering' phases are included in the design work with the aim of balancing investment costs and, later, operating costs, experience shows that such work usually only focuses on reducing investment costs and not on balancing investment costs and, later, operating costs over a fixed period (say two–three years) which requires life cycle cost-based analysis.

In addition, the potential market value of EE retrofits is distorted by cross-subsidies and energy tariffs that are below cost-recovery levels. Municipalities also fail to market the projects in a way that is attractive to the investor community (quality of bidding documents is not upto the mark, with insufficient background information and baseline details).

7 ACHIEVING ENERGY EFFICIENCY IN URBAN WATER AND WASTEWATER MANAGEMENT

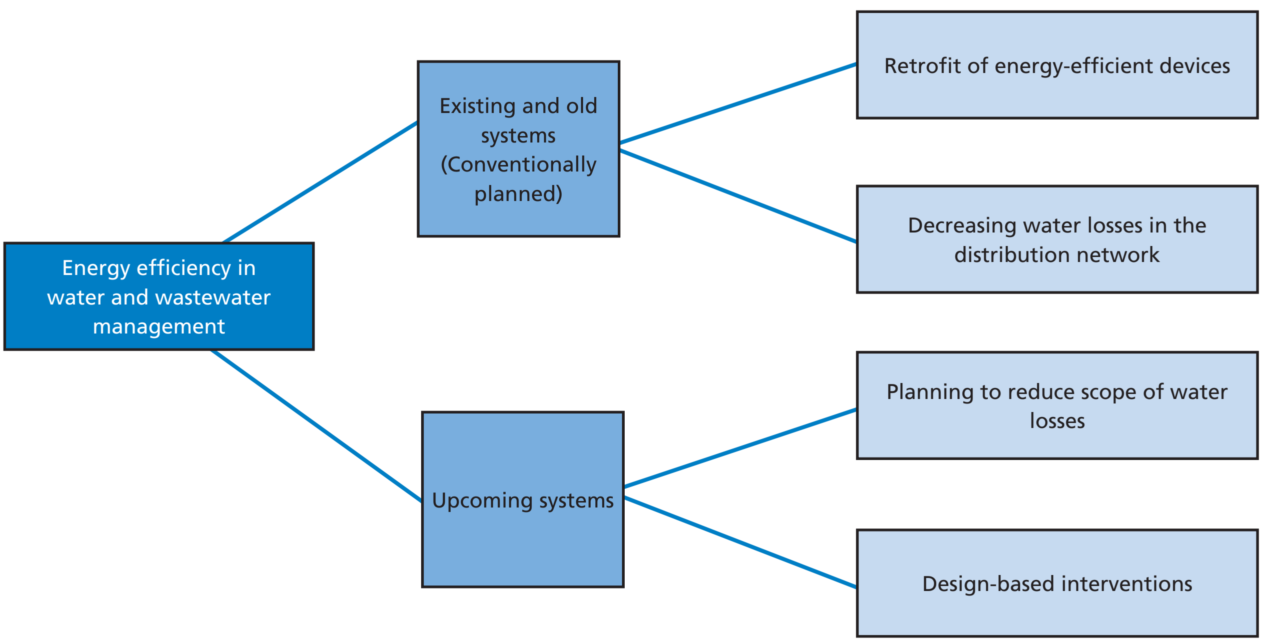
Different approaches are required to implement EE in existing systems and in upcoming systems. The existing systems render themselves to the retrofit method while new systems require design-based interventions (see *Figure 5: Different approaches for energy efficiency in water and wastewater management*).

7.1 EXISTING SYSTEMS

Existing systems can be retrofitted to make them energy-efficient based on comprehensive assessment studies and recommendations.[1]

a) Technology options for more EE in the process of transmission of water (from the source to the point of treatment) include:
   I. Improving the efficiency of the pumping system (pump, motor and valves) within the pumping stations boundary.
   II. Replacement of inefficient (and often over-sized) pumps and motors with efficient and properly sized ones.
   III. Application of variable frequency or speed drives (VFD/VSD).
   IV. Regular preventive inspection and maintenance, including cleaning or replacing impellers and checking the lubrication of bearings.
   V. Rewinding motors, when there are insufficient fund to replace them.
   VI. Trimming impellers, where pumps are too large for the application but are otherwise suitable for the job.
   VII. Transmission pipeline renovation and leakage reduction.
   VIII. Installation of capacitors to improve the power factor.

Figure 5: Different approaches for energy efficiency in water and wastewater management



Source: CSE, 2016

b) Technology options for more EE in the processes of distribution of water and collection of sewage include:
   I. Improving the efficiency of transmission and distribution pipelines, metering, and pumping and tampering storage equipment.
   II. Pipeline renovation and optimization (to reduce losses due to friction).
   III. Leakage detection and repair.
   IV. Improving efficiency of aeration equipment and anaerobic digestion.
   V. Pressure management within the network.
   VI. Measuring and managing minimum flow.
   VII. Installation and maintenance of water meters.

c) Technology options for EE improvement in the overall system include technology improving system automation and monitoring such as:
   I. Automating data and information, remote controlling, regular monitoring, and proper reporting systems.
   II. System performance tracking, benchmarking and targeting.

The cost effectiveness of energy-efficient technologies may be estimated by calculating cost of the conserved energy. Numerous studies worldwide have shown that the cost of conserved energy is lower than the cost of supply in case of a majority of the energy-efficient technologies.[2] A cost–benefit analysis is needed in order for decision-makers to know how long it will take for improvements to pay for themselves. Rate of returns depends on local conditions. An overview of some of the water supply EE measures of different categories, along with their payback time is catalogued in *Table 7: Energy conservation measures for identified areas of interventions*.

7.2 UPCOMING SYSTEMS

Incorporating EE in new systems is especially important over the longer term. The selection of technologies plays an important role from the point of view of energy consumption over the lifetime of the system. 'Prevention is better than cure' goes the age-old adage, and so is the case with energy conservation. EE aspects incorporated into water supply and sewage management systems during planning stages or initial phase of implementation can ensure substantial energy savings from the commencement of operation (see *Box: Areas of intervention for EE in upcoming water and wastewater management projects*).

Areas of intervention for EE in upcoming water and wastewater management projects

- Selection of appropriate technology
- Pumping systems (pump, motor, valves, and piping)
- Leak reduction management
- System piping (distribution network)
- Local recycle and reuse of treated wastewater (avoid long distance pumping requirements)
- System automation, metering and monitoring

To determine appropriate strategies, the design and planning team needs to understand and quantify the six components of energy intensity presented in *Figure 6: Water and wastewater management chain*. The first step during the design stage is to identify specific energy consumption targets for the:
1. Overall systems or processes
2. Individual equipment or sections
3. Distribution or conveyance network

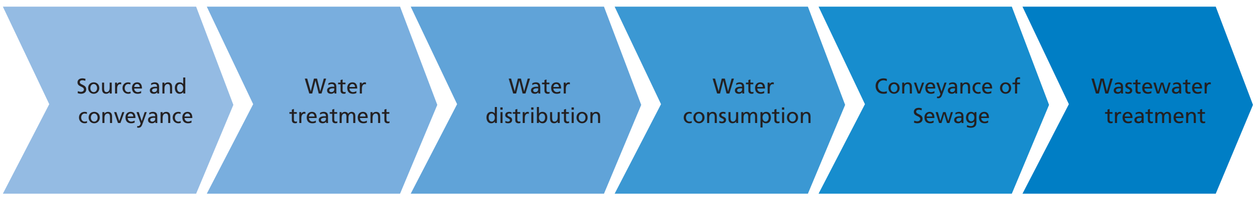
All subsequent actions should be designed to meet these specific energy consumption targets.

Table 7: Energy conservation measures for identified areas of intervention

Area of intervention	Energy conservation measure	Simple payback period in years
Electricity tariff	Reducing demand during peak electricity rates	0–2
Electrical installations	Optimizing power factor with capacitors	0.8–1.5
	Reducing voltage imbalance	1–1.5
Operation and maintenance	Routine maintenance of pumps and motors	1–2
	Maintenance and rehabilitation of deep well and storage facilities	1–2
Production and distribution	Use of automation such as supervisory control and data acquisition (SCADA), telemetry and electronic controllers on modulating valves to control, for example, pressure and output in the networks, and to optimize the operation of pumping equipment	2–5
	Installing new efficient pumps	1–3
	Installing new efficient motors	2–3
	Replacing impellers	1–1.5
	Pipeline replacement or rehabilitation	2–5
	Optimizing distribution networks by sectoring, removing unnecessary valves and installing variable speed drives and regulating valves	0.5–3

Source: Adapted from Watergy: Energy and water efficiency in municipal water supply and wastewater treatment, 2007

Figure 6: Water and wastewater management chain



Source: CSE, 2016

Cities get water from a variety of sources and locations, and each one relies upon different method of transport and a different amount of energy use. The design teams at water utilities or in municipality should incorporate standard EE guidelines at the design stage of the work, and during the tendering stage of any procurement. Many players are involved in the selection of equipment such as pumps and motors, starting at the specification and design stage, through installation and operation. Safety margins (in terms of size) are added at each of these stages, primarily due to the high degree of uncertainty in pinpointing design parameters. However, this practice leads to considerable loss of efficiency and energy in pumps. Energy-efficient operation of any system or equipment depends on the right specification, selection and installation at the design, retrofit or project expansion stages. Hence, design-based interventions that involve energy-efficient design, and energy-efficient guidelines at the design stage work wonders. For example, making a shift towards decentralized sewage treatment facilities significantly reduces the need for long-distance pumping and reduces the scope of water loss during conveyance. In addition, decentralized wastewater treatment systems directly promote local recycle and reuse which helps in reduction of fresh water demand and, in turn, reduces the water–energy consumption. Similarly, use of water-efficient fixtures reduces demand for water. Use of efficient plumbing fixtures, sensors, auto-valves, and pressure-reducing devices, wherever possible, can result in significant reduction in water consumption. These strategies, in turn, also help in reducing carbon emissions (see *Table 8: Fixtures and strategies that reduces water demand and annual CO_2 emissions for municipal water supply*).

If empowered, the municipal engineers or consultants can strategically design systems, devise and enforce guidelines to assist the various divisions developing new water supply and wastewater systems, and oversee incorporation of EE practices.

7.3 APPROACH

Figure 7: Energy intensity in the water–wastewater cycle with key opportunities shows a conventional water–wastewater management model where huge amount of energy is used at each stage, along with key opportunities for improving EE, conserving water, and using renewable energy. Municipal engineers or consultants can perform energy audits or install monitoring devices that feed into their SCADA system to learn where energy is being used in their facility and identify opportunities for EE improvements. The most effective way for communities to improve EE in their water and wastewater facilities is to use a systematic, holistic approach that considers all of the facilities within their jurisdiction. This allows communities to prioritize resources, benchmark and track performance across facilities, and establish cross-facility energy management strategies. This not only results in larger total reductions in energy

Table 8: Fixtures and strategies that reduces water demand and annual CO_2 emissions for municipal water supply

Install water efficient showers and taps. Use water carefully

Reduce annual CO_2 emissions by 75–189 kg

	Water conserved / household / day (l)	Water conserved / household / year (l)	Emission factor: borewell supply (kg/kl)	Emission factor: municipal supply (kg/kl)	Annual CO_2 emissions reduction: borewell supply (kg)	Annual CO_2 emissions reduction: municipal supply (kg)
Better shower fittings and reduced time under shower	200	73,000	0.67	1.69	48.91	123.37
Using aerator taps and changing dish washing habits	106	38,690	0.67	1.69	25.92	65.39
Total	306	111,690			74.83	188.76

Annual CO_2 emission reduction of 75–189 kg is equivalent to 7–19 additional trees

Change flush tanks in the bathrooms

Reduce annual CO_2 emissions by 39–99 kg

	Times flushed / capita / day	Daily water consumption per household (l)	Annual water consumption (kl)	Emission factor: borewell supply (kg/kl)	Emission factor: municipal supply (kg/kl)	Annual CO_2 emissions reduction: borewell supply (kg)	Annual CO_2 emissions reduction: municipal supply (kg)
Flush tank 10 l	5	250	91.25	0.67	1.69	61.14	154.21
Dual flush tank of 3 and 6 l	5	90	32.85	0.67	1.69	22.01	55.52
Savings						39.13	98.70

Annual CO_2 emission reduction of 39–99 kg is equivalent to 4–10 additional trees

Harvest rainwater

Harvest 1,000 litres per household per day over 40 days of rainfall

In half an hour, a rooftop of 100 m^2 can harvest 1,000 litres in a downpour of 25 mm/h

Reduce annual CO_2 emissions by 27–68 kg

	Water conserved/ household/ year (l)	Emission factor: borewell supply (kg/kl)	Emission factor: municipal supply (kg/kl)	Annual CO_2 emissions reduction: borewell supply (kg)	Annual CO_2 emissions reduction: municipal supply (kg)
1,000 l harvested per day for 40 days	40,000	0.67	1.69	26.80	68

Annual CO_2 emission reduction of 27–68 kg is equivalent to 2–7 additional trees

Source: Low carbon lifestyles, Ministry of Environment, Forest and Climate Change, 2015 costs and GHG emissions, but enables communities to offset the upfront costs of more substantial EE projects with the savings from other projects. Adopting a holistic approach can also help local bodies generate greater momentum for EE programmes, which can lead to sustained implementation and continued savings. As a starting point, ULBs need to understand the steps involved in identifying and implementing EE improvements for the existing water or wastewater management systems.

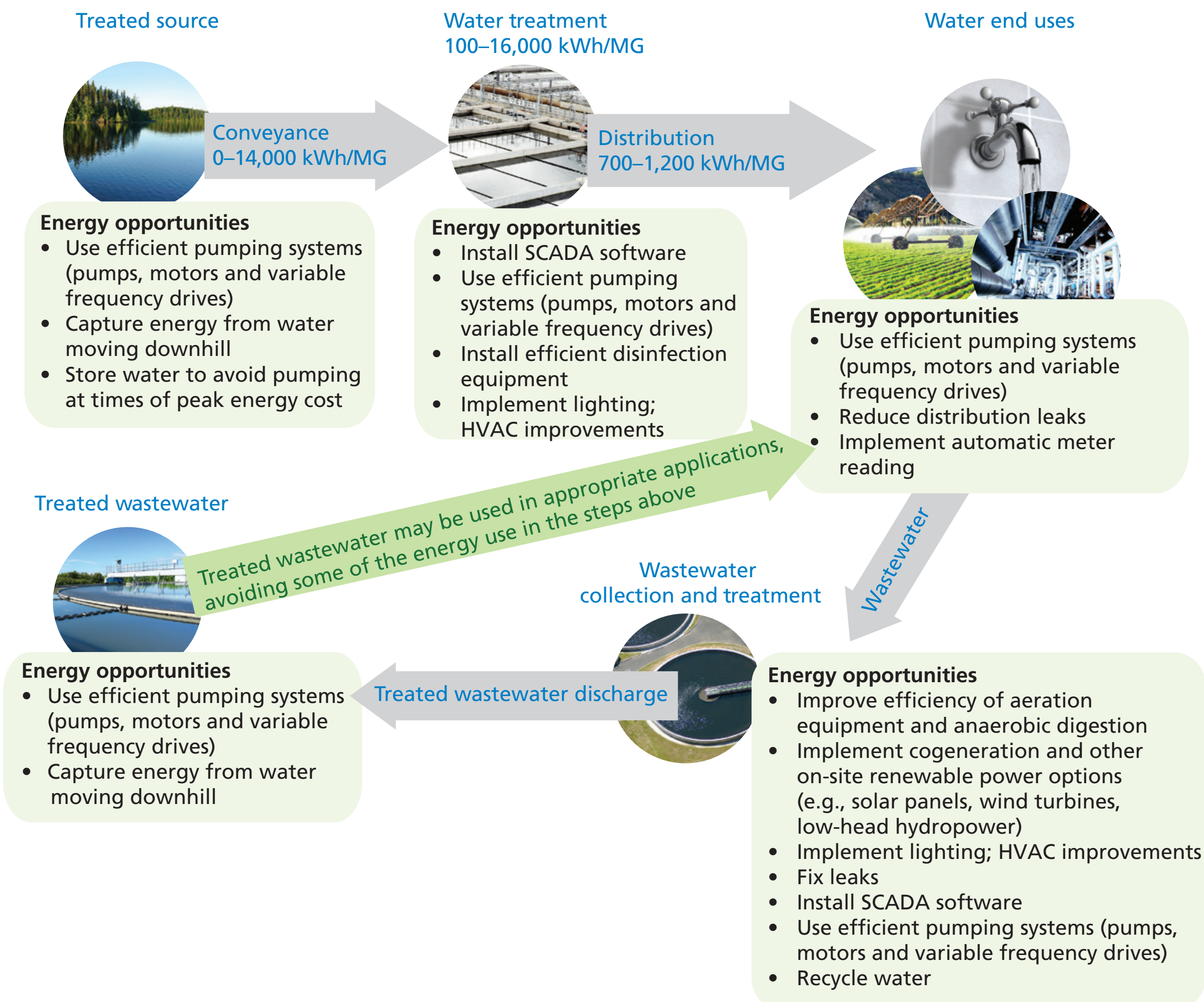
Figure 8: Multi-pronged approach to achieve EE at the design stage describes the most effective approach to achieving EE, a method which is well advocated and recommended.

7.3.1 Selection of energy-efficient technology

For achieving significant increases in EE, the use of efficient technology is vital. Energy-efficient technologies can be adopted most easily at the design stage, when the additional costs involved are only marginal, in comparison to the benefits of long-term energy efficient operations. This may include selection of efficient pumping systems that might involve marginally higher capital cost or wastewater treatment options that require no energy for treatment. See *Appendix 4* for a cost comparison of various decentralized wastewater treatment technologies that use low or no energy for treatment process.

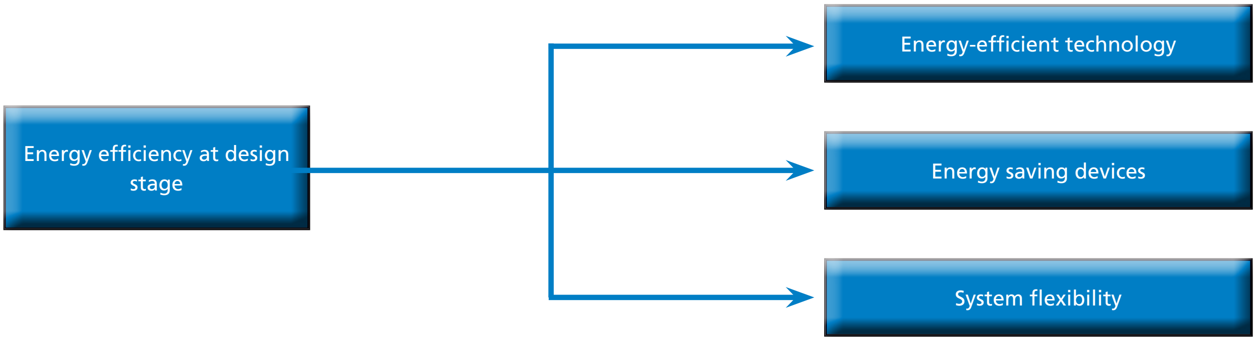
7.3.2 Integration of energy-saving devices

Figure 7: Energy intensity in the water–wastewater cycle with key opportunities



Source: U.S. Environmental Protection Agency 2013

Figure 8: Multi-pronged approach to achieve EE at the design stage



Source: ASC, 2016

While incorporation of the latest technologies sets the stage for energy conservation at the overall facility level, energy saving devices such as automatic power factor controllers, VFDs for motors, and remote control systems such as SCADA, ensure that these technologies are operated at their maximum efficiencies. As with efficient equipment, the incorporation of energy-saving devices at the design stage avoids the many disadvantages of later retrofitting. In some cases, the retrofitting of energy-saving devices may even call for replacement of the original major equipment, underscoring the value of their inclusion from the beginning.

7.3.3 System flexibility

During the design stage, municipal engineers, officials or consultants involved should suggest a modular approach to allow flexibility in addressing future water supply needs. A well-planned system design can provide flexibility for meeting future demands through options such as increments in the size of transmission mains and adding booster pumping stations for higher head requirements. Provision should be made within the pumping stations for additional pumps and incorporating new pumps to the header line. Although the flexibility of pumping systems does not have an immediate direct bearing on EE, a flexible system can increase long-term efficiency by enabling appropriate changes to be made to the running capacity of the pumping stations throughout the facility's lifetime.

7.3.4 Energy-efficient design considerations

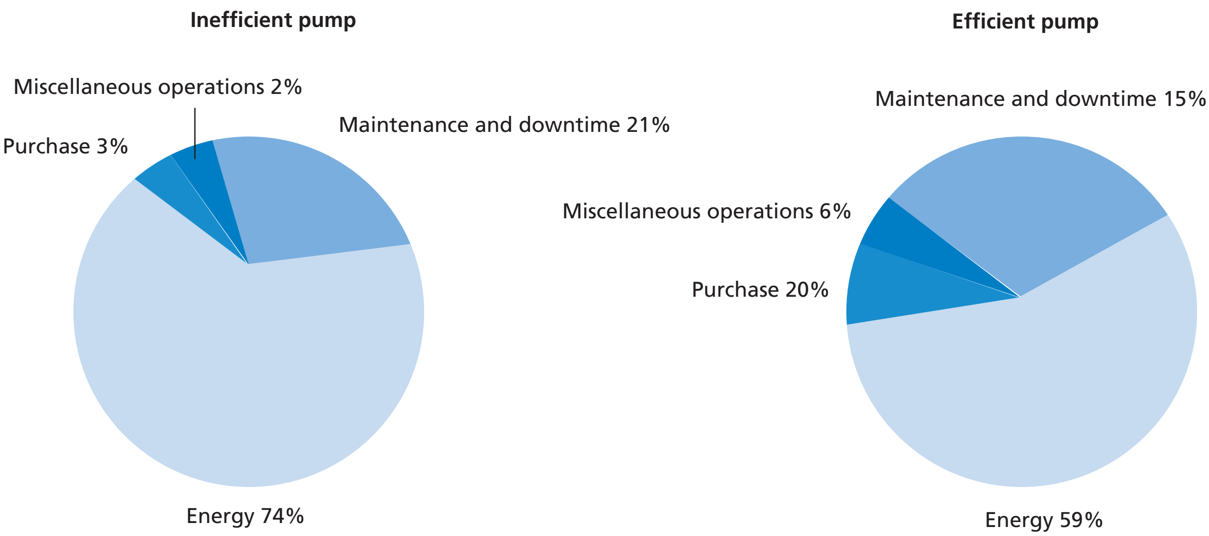
The parameters that a municipal engineer or consultant should consider during the selection or design of a pumping system include:

1. Minimizing over-sized pumps
2. Selection of the right types of efficient pumps and motors
3. Installation of VSDs or VFDs
4. Segregation of high-head and low-head pumps
5. Utilization of gravity flow
6. Utilization of pumps
7. Parallel operation of pumps
8. Piping design

7.3.5 Lifecycle cost analysis

Another key component to an overall cost–benefit analysis is understanding life-cycle costs. This is especially critical in the case of pumps, since pumping systems account for most of the energy usage in water supply and wastewater treatment systems. Over the lifetime of a typical pump, when all costs to operate and maintain the pump are considered, 3 per cent of the total cost is for purchase and 74 per cent is for energy. A more efficient pump also has lower maintenance and downtime costs. *Figure 9: Lifecycle costs of an inefficient vs efficient pump* illustrates the tremendous cost advantage of buying energy efficient pumps. Even though the purchase price of an efficient pump can be significantly higher than an inefficient one, the energy savings make the efficient pump less expensive even in the year in which the purchase was made. In subsequent years, the lower operating costs make such pumps an irresistible choice.

Figure 9: Lifecycle costs of an inefficient vs efficient pump



Source: Watergy: Energy efficiency in municipal water supply and wastewater treatment, 2007

8 THE WAY FORWARD

RECOMMENDATIONS AND GUIDELINES

In recent times, government of India has launched a number of programmes for transformation and rejuvenation of urban areas including the smart cities mission, AMRUT, NMSH, NWM, NMEEE and National Heritage City Development and Augmentation Yojana (HRIDAY). All these schemes involve dealing with water supply and wastewater treatment infrastructure. Incorporating EE aspects as mandatory measures in these schemes will play a key role in ensuring the development of low carbon infrastructure. At this juncture, top policy- and decision-makers need to take the following questions into consideration:

- What are the potential impacts of climate change on water and wastewater operations?
- How should we design our water and sewage treatment systems to be more resilient?
- How can we reduce energy usage and, ultimately, GHG emissions?
- How can we invest in solutions that have multiple benefits for different physical systems (water, wastewater, storm-water and energy), the environment, and the society as a whole?

A first step in the process of engaging with these various layers and their complex interdependencies is to use a systems approach. The energy system, its impact on GHG emissions and, ultimately, climate change are seldom adequately integrated into water planning. A holistic system approach rather than a component-based approach is required in the overall analysis and implementation in the urban water sector. This perspective will allow planners to recognize the potential for water efficiency to not only save water but also to contribute significantly to energy saving. It will also allow a recognition that an end-use approach and the application of integrated resource planning can point to strategies which minimize social costs.

Like any EE programme, the implementation of EE measures in the water sector faces market, financial, informational, institutional and technical barriers. These barriers can be overcome with targeted water- and wastewater-linked EE policies. Once barriers are removed, market forces are expected to ensure economical levels of EE.

EE policies for water sector are important because they can:

- Give direction to EE, by stating the government's overall objective as well as policies and strategies to achieve them.
- Provide a statutory basis for rules and regulations, such as appliance efficiency labeling and minimum efficiency performance standards.
- Assign responsibility for developing rules or implementing programmes, which in some cases involves establishing new agencies or institutions.
- Specify funding requirements and mechanisms for EE activities.

8.1 TRAINING AND CAPACITY BUILDING

Strengthening Local Institutional and Administrative Capacity

There is a wide range of public and private sector stakeholders involved with the water sector EE programme developed at the state and municipal level—from development to implementation to enforcement. Government stakeholders are responsible for developing a policy or regulatory framework and institutional or administrative structure that facilitates EE implementation and enforcement. Meanwhile, the private sector has an exemplary role in applying EE measures in actual practice and showcasing compliance.

Trainings to raise awareness and build technical capacity are also important. They should create a viable business model for EE in water and wastewater, and the most effective technologies and applications for improving EE. A few suggestions for capacity building programmes are as follows:

Awareness and introductory workshop (Level 1): A one–two hour-long presentation introduces the basic concepts of the water sector. It is intended for a non-technical audience with a stake in EE projects, for finance personnel, and top-level decision-makers.

Fundamentals of water–energy efficiency workshop (Level 2): This one-day workshop introduces the basic concepts of the nexus between water and energy in municipal water systems, and present a few case studies. It informs water utility and municipal officials about initiating in-house programmes, EE implementation mechanisms, and the need for specific M&V design.

Advance level training (Level 3): The two–three day training begins with topics covered in the level 2 workshops and then introduces advanced concepts such as performance-based contracts, measurement and verification, EE procurement guidelines, design stage EE, examples and case studies, with interactive sessions that provide opportunities for participants to interact with the trainers and implementers of successful projects at various scales.

8.2 SELF-ASSESSMENT GUIDELINES FOR MUNICIPALITIES AND WATER UTILITIES

Before undertaking EE project, a municipality should do a self-assessment in order to evaluate the importance of the project. This assessment includes identifying and analyzing the reasons and goals of the project, performing a feasibility study, analyzing the project financing, and weighing on the contractor options. The process is outlined in *Figure 10: EE project assessment flow*.

The Municipality should assess its motivation for EE projects based on the following criteria:

1. Reasons for undertaking EE project

The municipality should identify the reasons for prioritizing EE projects over other projects based on decisive factors such as rising energy prices, increase in population, increased energy consumption, increased GHG emissions and increased demand for water that affects effective municipal administration.

2. Goals of the EE project

The second step in self-assessment is to list the goals that the municipality would like to achieve by undertaking EE projects. The goals could include a reduction in the energy bill by optimizing energy use, improving delivery of services, reducing GHG emissions according to Energy Conservation Act 2001, undertaking rehabilitation of existing systems and so on.

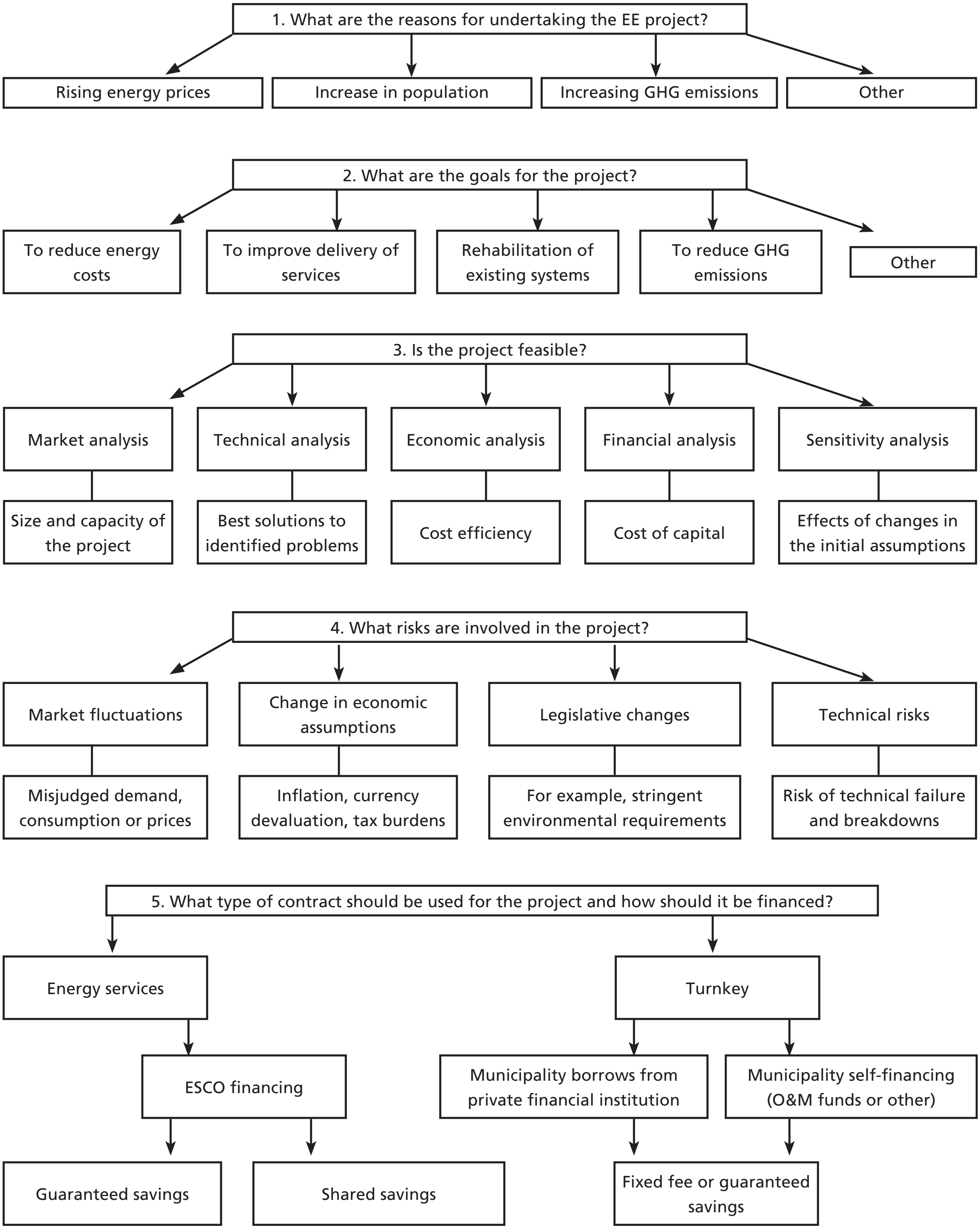
3. Feasibility study of EE project

Feasibility studies are done to verify the viability of a project, that is, decide if it should be implemented or not. They should include an analysis of the market, the economic situation, technical issues, financial efficiency, and sensitivity and risk analysis.

Market analysis is an evaluation of the demand to estimate the required project size and the capacity. Economic analysis expresses the cost effectiveness of the project and should include all revenue and costs for the lifetime of the project, and account for the time value of money. In technical analysis, an assessment of the current situation and a proposal for changes should be incorporated. Accessibility to technology and its suitability for the identified problems needs to be made. Financial analysis has to identify which type of financial sources should be used: internal or external. Thereafter, the costs of capital, like interest rates and bank charges, need to be assessed. Finally, a sensitivity analysis examines how a change in initial assumptions, such as in fuel prices or increased wages, affects the project.

Risk is a part to every project, therefore its analysis helps identify the potential problems and estimate expenses to minimize risks. There are some risks that can significantly affect the economic results of a project and these should be considered. Market fluctuations, such as demand or energy prices, dispersion of the economic assumptions initially made, technical problems and legislative changes, are issues that can occur and need to be addressed.

Figure 10: EE project assessment flow



Source: ASE/IFC Manual, 2008

Based on the results of all these individual component analysis, the municipality can decide if it is ready for EE project implementation.

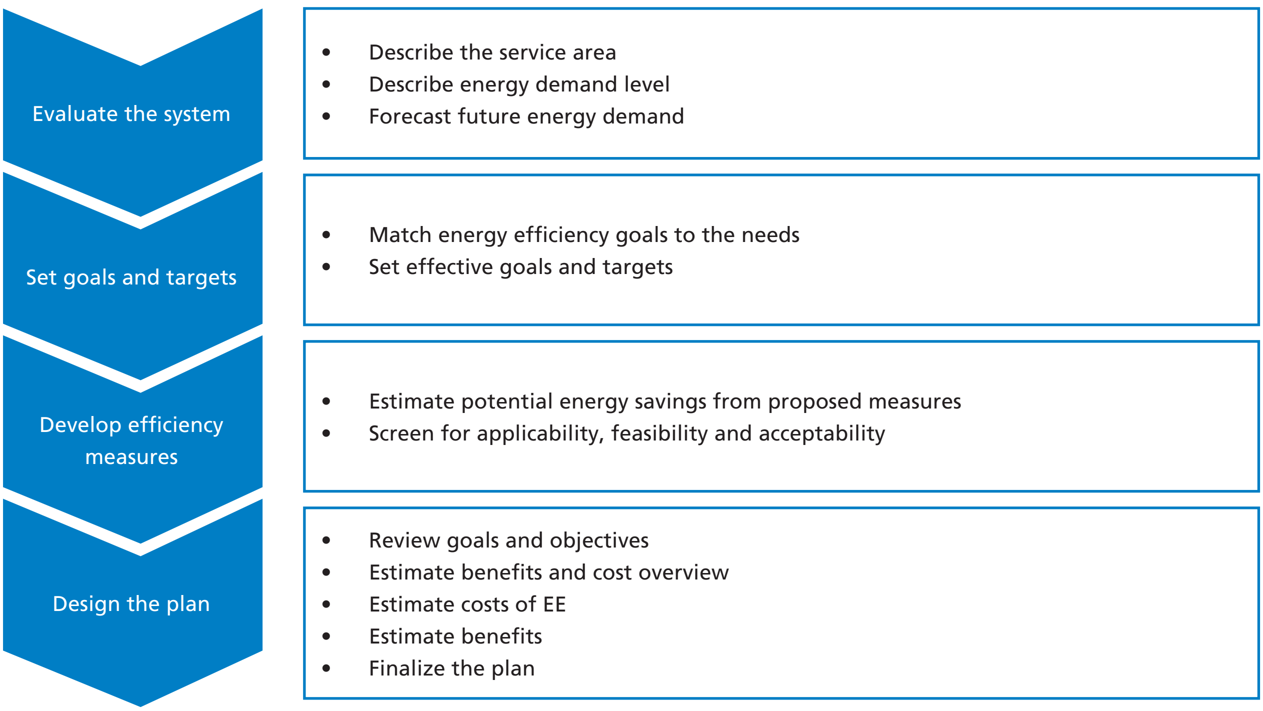
4. EE project contract and financing

Municipalities should decide on the type of contract and financial options based on the needs and procurement regulations. They should evaluate the alternative types of contracts based on some pre-set criteria. Thereafter, one the financial options have been considered, the municipality should evaluate its finances, creditworthiness for procuring and previous experience with private financing, weighing up options of contractor financing, and so on. Based on this analysis, a decision should be made on whether the project should be financed by borrowing from private institutions, using self-financing, by energy service type financing using shared savings, or guaranteed savings mechanisms.

8.3 PLANNING FOR ENERGY EFFICIENCY IN URBAN WATER AND WASTEWATER MANAGEMENT

Planning offers the opportunity to tie different initiatives together leading to transformation of land use, extensive development, and rapid improvements in infrastructure. The first step in the preparation of an energy efficiency plan is the establishment of objectives. *Figure 11: Energy efficiency plan for water and wastewater management* gives an overview of developing a plan and criteria's to be considered.

Figure 11: Energy efficiency plan for water and wastewater management



Source: Adapted from Orillia Water Conservation and Efficiency Plan 2014

8.4 STEPS FOR DEVELOPING WATER SUPPLY AND WASTEWATER ENERGY EFFICIENCY PROGRAMMES

1. **Management cell**: Establish an in-house energy management cell and commit at least three full-time staff members to EE activities. Develop and implement a training and capacity building programme.

2. **Internal communication and "buy-in":** Develop and implement an effective internal information and communication programme to emphasize the importance of EE, and to obtain the commitment of key operating staff to implement the EE programme.

3. **Database:** Develop a comprehensive database on energy consumption, maximum operating loads, contract demands, tariffs and monthly energy bills.

4. **Benchmarking:** Establish a programme of benchmarking energy consumption at major installations to identify opportunities for improvement in efficiency.

5. I**mplementation models:** Develop appropriate implementation models and demonstrate their effectiveness through pilot projects.

6. **Prioritization:** Identify and prioritize options to improve EE.

7. **Operation and maintenance:** Implement an ongoing operation and maintenance programme, with appropriate private sector assistance, to ensure that the major equipment is operating efficiently.

8. **Metering and monitoring:** Establish a metering programme to continually monitor the performance of major equipment and to identify any need for actions to improve efficiency and reduce costs.

9. **Incentives:** Develop and implement a staff incentive programme to reward superior performance in reducing energy costs. The incentive programme should cover staff in both the energy management cell as well as operating personnel.

10. **Management reporting:** Establish a regular (monthly) reporting procedure so that municipal management are informed of the key indicators of energy consumption and costs, and of the major activities undertaken and the results of these activities.

CONCLUSION

Currently, the water sector is at a critical juncture where the country need to take stock of the potential impacts of climate change, how we should design our water and wastewater systems to be more resilient, how we can reduce energy usage, and, ultimately, GHG emissions, and how we can invest in "solution-multiplying solutions" rather than "problem-multiplying solutions". Water and wastewater system planners and designers have an obligation to consider potential climate change impacts and to assess mitigation as a part of overall planning. To achieve a substantial reduction in the climate and water–energy footprint, mitigation measures at the level of the entire water cycle are required. It is recommended to approach the water cycle from a climate perspective.

Water and wastewater sectors present immense opportunities for energy savings due to their scale and untapped opportunities. The success of a water sector EE programme will depend on strong collaboration across multiple stakeholders who need to understand their roles and responsibilities well. Once the programmatic framework is in place, execution of large-scale projects and scaling-up will become easier.

In the last few years some efforts have been made by government and non-government organizations and have had limited success. But the scaling-up of pilot projects and large-scale implementation is yet to happen. One of the key reasons of the low implementation rate is that the water sector EE programme is not a priority or focus sector for the government. Currently, there is no policy and or incentive for reducing energy footprint in the water and wastewater sector. At this stage, the country needs policy which integrate water sector energy efficiency as a "requirement" and not as an "option" or "choice".

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APPENDIX 1: CASE STUDIES

This section presents a few successfully implemented case studies across the world to comprehend the concept of best management practice in EE that could be followed or be a source of inspiration for policy, plan or project implementations to achieve sustainable urban water management.

CASE STUDY 1: PUNE MUNICIPAL CORPORATION (PMC) WATER SUPPLY ENERGY EFFICIENCY PROJECT, PUNE, INDIA

Background

Pune is a city in Maharashtra which relies on fresh water resources. The city has a storage capacity of approximately 30 per cent of its total daily requirement and a distribution network of about 2,500 km. The topography of the city is undulating, and the distribution network is old and unplanned, which adds to the challenges faced by the municipality in reducing the energy cost and efficiency. PMC collaborated with the urban development department (UDD) of government of Maharashtra in January 2005 and took an initiative in consultation with Alliance to Save Energy for this project.

Key Results

- Energy savings: 3.8 million kWh/ year
- CO_2 emissions avoided: 38,000 tonnes/ year
- Cost savings: Rs 146 lakh/ year
- Water pumped: 10 per cent more water delivered to the community with no addition to capacity

Objective

The main objective was to demonstrate that harnessing efficiencies at the nexus between municipal water and energy can greatly help municipalities to address their urban water and energy challenges.

Approach

An energy audit was conducted on PMC's bulk water supply systems by Alliance. The draft audit report was discussed with PMC officials, auditors and municipal engineers. An agreement was reached on the EE measures to be taken and a report was finalized. Simultaneously, in order to build technical and managerial capacity at the PMC, a hands-on training for 45 PMC engineers was conducted. State institutional partners, the Maharashtra Energy Development Agency (MEDA), All India Local Self-Government (AIILSG) and engineers from Nagpur municipal corporation (a neighbouring city) also participated in these training programmes.

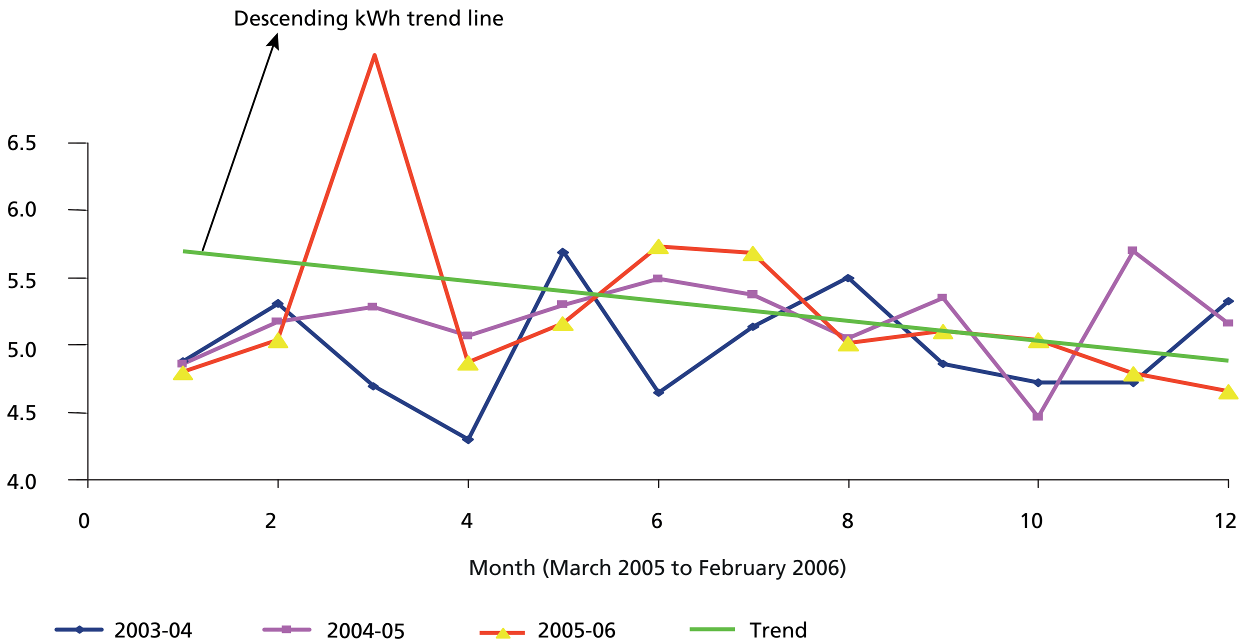
The energy audit report suggested that PMC could save Rs 146 lakh energy costs with an investment of Rs 87 lakh. Nearly 70 per cent of the suggested measures had payback periods of less than a year. Under the aegis of the municipal commissioner, PMC contributed a total of Rs 85 lakh to implement a series of capital-intensive efficiency measures.

The PMC experienced annual energy savings of 37.8 lakh kWh and annual cost savings of over Rs 148 lakh. The savings achieved are higher than what was projected in the initial energy audit report since the PMC municipal engineers implemented additional low- and no-cost EE measures at the pumping stations, including distribution pumping stations, because of their improved knowledge from the trainings.

The efficient operation of the largest pumping station, Parvati Water Works, reduced the energy intensity of water supply by 6 per cent, from 375 to 352 kWh/million litre (see *Results from Parvati Water Works—Pune Municipal Corporation*).
Additional benefits from implementation of EE measures are:

- 10 per cent additional delivery of water to the community without adding to the capacity.
- Saving additional money by qualifying for a rebate programme offered by the Maharashtra State Electricity Board. Under the programme, a rebate was offered to the facilities maintaining a good

Results from Parvati Water Works—Pune Municipal Corporation
(in millions of kWh per month)



power factor and reducing usage during peak hours. Example: Parvati Water Works increased its rebate by almost 8 per cent since fiscal year 2003–04, from Rs 48.57 lakh to Rs 86.27 lakh.

- The PMC's watergy programme ignited the EE movement in Maharashtra as various other ULBs like Thane, Nagpur and the Municipal Corporation of Greater Mumbai undertook similar efforts. Alliance assisted the UDD, AIILSG and MEDA prepare the *Roadmap for Energy Efficiency in ULB in Maharashtra*. Chief Minister of Maharashtra released the *Roadmap* in February 2005. The NURM cities in Maharashtra also added the watergy initiative as an infrastructure-development project in their city development plans for seeking funds for implementation of the project.

Conclusions

The success of the PMC EE programme has encouraged PMC to sustain its EE activities. The Municipality is currently discussing an extension of energy audits to other pumping stations in the network with consultants. Successful implementation of the programme showcases not only the direct cost reduction benefit to the municipality but also serves as a model from where cues for policy, programme and project implementation can be taken up.

CASE STUDY 2: PROJECT ON ENERGY AND WATER EFFICIENCY IN WATER DISTRIBUTION, FORTALEZA, BRAZIL

Background

In Brazil, the design of water distribution systems are based on population projections from statistical and historical data that is projected over a 20–30 year planning horizon. Because of this, many systems are over-designed and have energy consumption levels that are much greater than necessary to provide for adequate demand, especially for booster stations. Water systems need to be able to expand to satisfy increasing demand, but not while sacrificing efficient use of energy. To address this, a project was initiated by Companhia de Água e Esgoto do Ceara (CAGECE), wherein an automation system was introduced in the water distribution system to understand and obtain strategic data to control equipment in real time. The automation of the water supply system in the Fortaleza metropolitan region, managed by CAGECE, was supported by USAID and the Alliance to Save Energy. Automation allowed for correction of deficiencies in the system, particularly those that are caused by over-design and initiated the EE programme.

Key Results

- Energy saved: 88 GWh over four years
- Households newly connected to water while water consumption remained constant: 88,000
- $2.5 million saved per year with investment of $1.1 million
- Standardization of operational procedures and reliability of operational data
- Ability to act in real time with the system control devices

Objectives

The focus of the energy efficiency programme was to develop a methodology, providing CAGECE with the tools and the know-how to produce initiatives that result in savings and to promote rational use of energy and distributed water.

Approach

Following the automation project, the programme approach included the following:

- Establishing a baseline of energy consumed and water distributed
- Implementing efficiency measures that led to a reduction in operational energy consumption
- Developing a financing proposal with the Government of Brazil Fight Against Electricity Waste Program (PROCEL) in order to implement EE projects with CAGECE's operations crew. The technical support provided by the Alliance resulted in the development of EE projects, cost–benefit analysis, and specifications of equipment that could be financed.
- Arranging for R$5 million in financing for EE projects to CAGECE. These projects included automation of operations, rewinding and replacement of motors, maximizing existing pump systems efficiency, and increasing storage capacity to allow the shutdown of pumps during peak hours.
- Creating an operations procedures manual to serve as a reference for daily performance to operations crew and CAGECE management.

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

As a result of this 127 per cent return on investment after four years, CAGECE was initially approved for financing by the EE fund of PROCEL to work with the World Bank to implement further efficiency measures. Alliance helped develop five projects, including replacing motors with high-performance motors, maximizing pumping efficiency, suspending pumping during peak hours, and increasing capacity of the current pumping stations and specifications relating to EE.

Conclusion

If implemented, these projects would add a savings of seven million kWh per year, with a total investment of US $2 million (R$5.4 million) by PROCEL and the World Bank. The cost–benefit analysis predicts a payback period of 3.5 years.

The case study proves to be a model that would be useful to other water and sanitation companies in Brazil looking for ways to increase efficiency.

CASE STUDY 3: BUNDLED MUNICIPAL ENERGY EFFICIENCY PROJECT THROUGH ENERGY PERFORMANCE CONTRACTS, TAMIL NADU, INDIA

Background
Tamil Nadu Urban Infrastructure Financial Services Limited (TNUIFSL) launched a municipal EE project in 45 towns of the state in the year 2007. With REEEP support, the Alliance to Save Energy has provided technical advisory services to TNUIFSL for undertaking this project.

Objective
The project was initiated as an experimental project wherein municipalities were 'bundled' for implementation of EE in water pumping and street lighting by energy service companies ESCOs, through energy performance contracts.

Approach
Preliminary data collection in the 45 towns revealed that 16 towns already had contracts with private companies for street lighting. Since street lighting and water supply was procured in a combined ESCO projects, the 16 towns with existing contracts could not participate. It was, therefore, decided to split the project into two phases. In the first phase 29 towns were bundled to go ahead with the implementation, while the remaining 16 were scheduled to be taken up when the project scaled-up.

The project approach (see *EE project approach*) was formulated with the involvement of stakeholders in two phases. In the first stage of the project, a project committee was formed and bidding documents for the ESCOs were developed. In the second stage, the ESCOs conducted investment grade energy audits (IGAs) and implemented energy-saving measures under energy-performance contracts on a shared saving basis.

- Technical project committee: A cross-functional team was formed at the beginning of the project. The committee comprised of representatives from the following organizations, departments and agencies:
  1) Commission of municipal administration (CMA)
  2) RFP-inviting authority (TNUIFSL)
  3) ULBs
  4) Chief electrical inspectorate

EE project approach

Tamil Nadu municipal EE project approach			
Stage 1		Stage 2	
Programme conceptualization • Top level by in and commitments • Discussions with stakeholders • Assessment of project size • Initial basic data and inventory details • Implementation strategy	**Procurment** • Expression of interest - Evaluation - Short listing • Discussions with stakeholders • Issue RFP - Technical and financial evaluation • Select ESCO - Award contract/ issue work order	**Investment grade audit** • Start IGA study - Draft IGA report submission - IGA report review by project committee - Draft report discussions with ESCOs - Fine tuning • Final report submission - Freezing and acceptance of EE proposals - Baseline and M&V methodology	**Financing and implementation** • Signing energy performance contract • Arrange for 3rd party financing • Establish TRA/ Escrow account • Procure equipment and services • Post installation • M&V report (Hiring of third party verifier) • Repayment • Training

5) Electricity board
The technical project committee has been overseeing the project progress, resolving technical and financial issues that have emerged during the course of the project, approving the IGA reports, facilitating the signing of EPCs, and monitoring implementation on the ground.

- Bid documents: It was decided that the ESCO services, for the ULBs EE projects, would combine water supply and street lighting. To qualify, ESCOs had to bid for both. With technical support from Alliance, TNUIFSL developed the bid documents, which were vetted by the World Bank. A two-cover bid process was used, whereby the technical evaluation preceded the financial evaluation. Alliance also developed the evaluation criteria for the technical proposals. The expression of interest received 13 responses and a request for proposals was issued to eight firms. Of these firms, six responded with proposals. Two leading ESCOs were selected to implement EE measures in 29 municipalities. One ESCO was awarded the projects in the municipalities in Group 1 and 2, and the other municipalities in Group 3.

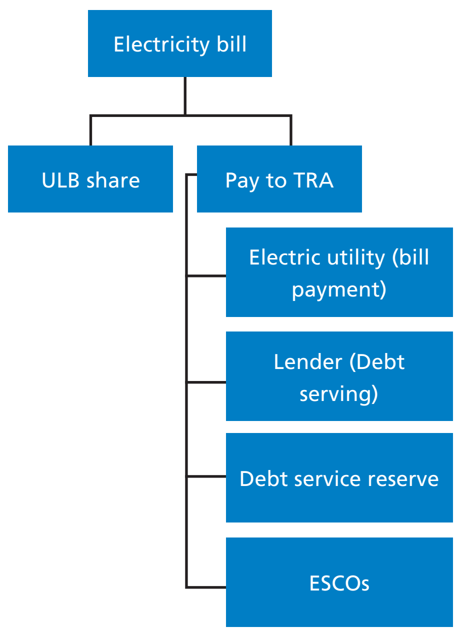
- Investment grade energy audits: The ESCOs completed IGAs and prepared bankable detailed project reports. The technical project committee and the ESCOs have worked out ways of resolving numerous challenges in data collection, metering, and other issues on the ground, and have agreed on baseline energy use data. The technical project committee and the ESCOs have also discussed the IGA reports and have agreed on energy-saving measures that can be implemented on the ground.

- Financing: Availability of finance for ESCOs has been a major issue in India. TNUIFSL is addressing this by providing financing opportunities to the ESCOs for implementing the project using a World Bank line of credit available through TNUIFSL. ESCOs can now choose to borrow from TNUIFSL if the terms of lending are more favorable in comparison to other financial institutions. Thereby, a new and reliable financing mechanism has been put in place.

- Energy performance contracts: The ESCOs and the municipalities are in the process of negotiating and signing EPCs. Once the contracts have been signed, the ESCOs will commence the implementation of energy savings measures and train the municipal staff in the operations and maintenance of the new measures.

- Trust and retention account (TRA): By setting up a TRA account with Escrow of the municipalities' electricity bill payments, TNUIFSL has addressed the ESCOs' payment concerns and has helped establish trust between the parties.

- Measurement and verification of energy savings: Measurement and verification of the energy savings resulting from the implementation of the energy conservation measures is being carried out through the application of the international performance measurement and verification protocol, and by developing measurement and verification standards for water pumping and street lighting in India. To avoid disputes over savings, a third party measurement and verification agency has been hired to independently measure and verify savings on the ground.



Conclusion

Through the implementation of this project, Alliance has facilitated market transformation by creating confidence within the ESCOs about working with the public sector, and vice versa (see *Outcomes and lessons learned*).

Outcomes and lessons learned

Outcomes	Lessons learned
• Reduction in operating costs through reduced energy consumption • Reduction in CO_2 emissions • Reduction in demand and supply gap at the electric utilities • Availability of standardized bidding document for EE projects • Improvement in service delivery • Scaling up of the project in Tamil Nadu to include all ULBs in the state • Replication and scaling up of the project in other Indian states: all 159 ULBs in Gujarat and 213 ULBs in Karnataka	The ESCO industry is dominated by vendor ESCOs (dealing with particular products and offering implementation of the same) and, therefore, the technical and financial capacity of ESCOs has to be evaluated before awarding new projects Municipal EE projects have many challenges in terms of metering, availability of quality data, etc. The project committee and ESCOs should be flexible to allow for adjustments and establishing baselines.

CASE STUDY 4: ENERGY EFFICIENCY IN WATER MANAGEMENT THROUGH WATER USE EFFICIENCY IN SOWETO, SOUTH AFRICA

Background

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

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

For the most part, therefore, customers do not take ownership of consumption, nor of private plumbing fixtures located on their properties, as evidenced in the high recorded levels of water consumption and wastage. The result is that NRW (the difference between the volume of water supplied and the volume billed) effectively stands at 200 per cent for the area of Soweto.

In addition, customers do not in reality receive the benefit of free basic water, which is for all intentions and purposes only a book entry on the monthly bill. Even those customers who are poor or use water sparingly receive no real free water benefits and are required to pay the same amount for water as customers using water excessively or irresponsibly.

Key Results
- Estimated savings (when all phases completed):
  - Energy: 175 million kWh /year
  - Cost: US $45 million/ year
  - Water: 97 million kL/ year
- Ownership of consumption transferred to the consumers (a first in real terms for Soweto)
- Reduction in operating and maintenance costs due to water network upgrades
- Creation of over 1,500 temporary jobs in the communities where project is being implemented
- Public awareness of the true value of water
- Improved sanitation

Objectives

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

Operation Gcin'amanzi was designed to add social and economic value to the community through:
- Rehabilitated municipal infrastructure
- Improved water service delivery and customer interface
- Rehabilitated private plumbing fixtures
- Temporary and permanent employment for unskilled and semi-skilled labour in Soweto
- Empowering the customer to take ownership of water consumption
- Reduced cost of water to the end user
- Free basic water dispensed to all residents, and
- Reduced municipal service arrears based on acceptance of the prepayment metering system.

Approach

JW initiated Operation Gcin'amanzi in Soweto as a multi-faceted intervention project focusing on the rehabilitation of the water network and private plumbing fixtures. A cornerstone of the project is the installation of a prepayment metering device on each property, eliminating the deemed consumption approach to water accounting. The prepayment metering system dispenses 6,000 L of free basic water to each property every month, thereafter dispensing any water according to the availability of credit on the meter.

The project was launched in June 2003 after a lengthy consultative, awareness and approval process with communities, councilors, ward committees, and trade unions. Operation Gcin'amanzi is estimated to cost R 500 million when completed.

The results achieved in all areas where the project has been implemented has average water supply dropping from pre-intervention levels of around 67 kL per residential property per month to post-intervention levels that so far average about 10 kL per property per month. So far, these reductions have saved JW 14.7 million kL of water, 26.5 million kWh of electricity, and US$6.8 million. Once all phases are completed, JW will save almost R 270 million (US$45 million) per year in bulk water purchases alone, along with 175 million kWh of electricity and 97 million kL of water. The effective payback period of the project is less than three years.

The project is now supported at the customer level with nearly 96 per cent of the participating residents responding positively to project outcomes.

Conclusion

This project is ensuring that the true value of water is recognized and that customers are totally empowered to take ownership of consumption, thus ensuring that the service of water remains sustainable and affordable. The issues of Soweto are not unique and occur in many urban areas in South Africa and abroad. Operation Gcin'amanzi shows the tremendous value of creating water efficiencies at the municipal service delivery level, and it illustrates that people's involvement is possible to pay for reliable, clean water—once they experience the benefits of ownership. Additional indirect benefits to water efficiency is energy savings. Soweto is expected to save 175 million kWh/ year as is evident from the results of the project. The project showcases how energy savings can be achieved by reducing NRW and increasing water efficiency.

APPENDIX 2: STAKEHOLDER CONSULTATION MEETING

Held on: 11 November 2016.

Members present: Milind Deore (Energy Economist–BEE), SD Rane (Scientist D-BIS), Uttam Kumar and AK Jain (Former DJB engineers), Dr Usha P Raghupathi (NIUA), Kangkanika Neog (CEEW) and CSE representatives (Dr Suresh Rohilla, Rajneesh Sareen, Dr Mahreen Matto, Chhavi Sharda) and Pradeep Kumar (CSE consultant on the policy paper).

Proceedings: Address by Dr Suresh Rohilla with a brief background about CSE's journey since 2009 as CoE designated by Ministry of Urban Development (MoUD), Government of India (GoI) in the area of sustainable water management. He also highlighted CSE's engagement in preparing a roadmap for water efficient fixtures, sensitization and capacity building programmes in sustainable urban water management, earlier under JnNURM (2013), and now supporting AMRUT cities for mainstreaming BMP. CSE is planning for the 109 SMART cities and focusing on 500 cities in the area of improvement in water and wastewater management.

- Ministry has invited CSE to prepare a policy paper on energy efficiency in urban water and wastewater management in the wake of climate change.
- There is a need for supply-side water management that facilitates the shift towards more water prudent management.
- It has become essential to reduce footprints of our infrastructure in the wake of climate change.

Salient features of the CSE presentation on the policy paper

- The presentation focused on the fact that the point of the policy paper is not selling EE agenda as its assumed that energy agenda is already sold. The emphasis is on prioritizing energy efficiency in government of India's water and wastewater policies.
- It was emphasized that supplying water at the municipal level is energy-cost intensive. Every litre has associated costs and every user is supposed to pay the same. This may be reduced if energy efficiency is considered.
- The SMART cities project cannot be successful if we continue to waste energy.
- Huge amount of cost of meeting the water demand is met by individual consumers through groundwater extraction. Challenges are:
    - Star-rated pumps need to be installed at the household level
    - Lack of awareness among individual consumers
- With regard to pumping water to overhead tanks to maintain pressure at the neighborhood scale, the height of a building increases the energy cost, can this cost be called the embodied energy of water?

Discussions on the framework of the policy paper

- CSE representatives and BIS representative (SD Rane) raised the following points:
    - It is crucial to include the cost of the energy consumption into the cost of the water supply in cities. If cities know the cost of energy that they are spending and how much it can be reduced, it will bring a mindset change in the end user and be a catalyst for the move towards EE.
- CSE representatives highlighted the following:
    - Systems that are designed are more with the revenue collection point of view and not with the conservation and efficiency point of view. Set up an average baseline or benchmark and then incentivize.

  - o Monitoring and household level incentives are important aspects with regard to water and energy efficiency.
  - o Reuse: Energy for tertiary level treatment is much more energy intensive. Scale is a question. If decentralized scale with local reuse, energy for wastewater management is affordable and sustainable.

- NIUA Representative (Dr Usha P Raghupathi) said that this policy paper should incorporate the number of units of energy or its cost.

- Former DJB engineer Uttam Kumar shared the existing framework based on the joint project of DJB and World Bank, where energy efficiency can be anchored in water or wastewater management.
  - o MoUD should lead this subject with respect to handling infrastructure followed by MoWR and MoP
  - o Should cost of bidding be evaluated on the basis of life cycle cost. This has been implemented with DJB. For implementation, bidder should also benefit.

- BEE representative (Milind Deore) shared experience:
  - o Cities provided with documents like RFP, detailed project reports prepared in consultation with municipal authorities, constituted the committees, still this area has not been prioritized. Impact assessment has been done of failure due to lack of capacity and ownership and has been document. BEE will share the document.
  - o Scope of paper—should limit it to only municipal level or ULBs and utilities?
  - o Policy should be market based and not subsidy or incentives based. In the 24 x 7 water supply concept—energy requirement will not increase however, storage will reduce. Demand side management is very important for 24 x 7 water supply.
  - o What is the boundary setting for the policy paper?
  - o Is it possible to have the structural reforms within the institutions (mandatory) that specifically work for energy efficiency?

Conclusion

- Scope of policy paper: Policy document should provide a broader perspective, but the focus should be on providing guidance for EE projects in the water and wastewater sector at the municipal level.

APPENDIX 3: NATIONAL SEMINAR ON "MAINSTREAMING SUSTAINABLE URBAN WATER MANAGEMENT"

27 DECEMBER 2016, MAGNOLIA HALL, INDIA HABITAT CENTRE, NEW DELHI

Through the seminar, CSE proposed a policy framework in the relevant thematic areas and highlighted best management practices and sought stakeholder consultation and involvement before finalization of the same.

Participants involved mixed groups of stakeholders including representatives from the government, non-government agencies, academia, civil society and practitioners.

The proposed policy framework encompasses the following:

- An argument that water efficiency and conservation, and energy efficiency will make India a water frugal economy and help in meeting the SDGs.

- Strategies introduced to improve existing management models by working on demand management including usage of water-efficient fixtures, reducing NRW and also operating, maintaining and monitoring these systems optimally.

- The assertion that energy efficiency is not only useful for sustainable urban water management but also a tool for carbon mitigation in cities.

- The argument that water-sensitive urban design and planning can lead to mainstreaming intervention for water and resource efficiency leading us to becoming a water prudent society.

Press release: http://cseindia.org/content/cse-proposes-novel-policy-framework-planning-designing-and-implementing-best-management

Details: http://cseindia.org/content/national-seminars-%E2%80%9Cmainstreaming-sustainable-urban-water-management-issue-and-challenges-pol

APPENDIX 4: COMPARATIVE COSTS OF VARIOUS DECENTRALIZED WASTEWATER TREATMENT SYSTEMS THAT ARE NOT ENERGY-INTENSIVE FOR WASTEWATER TREATMENT AND LOCAL REUSE

Name of the technology	Treatment method	Treatment capacity	Treated water reuse	Capital cost (Rs/ KLD)	O&M cost (Rs/ KLD/year)
Soil bio-technology	Sedimentation, filtration, and biochemical process	5 KLD–3.3 MLD	Horticulture and cooling systems	10,000–15,000	1,000–1,500
Soil-scape filter	Filtration through biologically-activated medium	1–250 KLD	Horticulture	20,000–30,000	1,800–2,000
DWWTs	Sedimentation, anaerobic treatment, plant root zone treatment, and oxidation process	Should be more than 1 KLD, but plants bigger than 1 MLD are not feasible as would need extensive land area	Horticulture, mopping floors, cooling towers and flushing	35,000–70,000	1,000–2,000
Eco-sanitation, zero discharge toilets	Separation of faecal matter and urine	Individual and community toilets together depending upon number of users	Flushing, horticulture, composting	30,000–35,000 (includes civil work)	35,000–40,000 (includes salary of the caretaker)
Fixed film bio-filter technology (FFBT)	Settling and flow equalization followed by enhanced natural degradation (biochemical process)	0.5 KLD to 1 MLD	Horticulture, car washing	25,000–35,000	1,000–2,000
Phytorid	Settling followed by plan root zone treatment in specially engineered baffled treatment cells which provides both aerobic and anaerobic treatment	5 KLD–1 MLD	Horticulture	14,000–35,000	1,000–2,000

Source: CSE, 2016

APPENDIX 5: TYPICAL ENERGY EFFICIENCY INTERVENTIONS

Typical energy efficiency interventions

Improve pump system efficiency

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

Leak management

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

System automation

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

- Stand-alone devices—perform actions only where placed
- Telemetry—transmits information from remote devices to a central station
- SCADA—remotely controls components such as pumps and provides operational information in real time

Metering and monitoring

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

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