सत्यमेव जयते

Ministry of Housing and Urban Affairs
Government of India

Energy Efficient Wastewater Management System

TRAINING MANUAL

NIUA | C3 Climate Centre for Cities

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Supported by:

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ClimateSmart Cities Assessment Framework

Water Management

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Energy Efficient Wastewater Management System
Training manual

Developed by:
Climate Centre for Cities, NIUA in association with Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ)

Author
Tapan Patel

Editors
Umamaheswaran Rajasekar, Vaishnavi. T. G. Shankar, Amanjot Kaur and Pallavi Thool

December, 2022

Contact information
Climate Centre for Cities
National Institute of Urban Affairs

1st Floor, Core 4B, India Habitat Centre,
Lodhi Road, New Delhi -110003, India
Telephone: (91-11) 24617517, 24617543, 24617595
Website: www.niua.org, www.niua.org/c-cube

Photo credits: Odors from Portland sewage plant have many residents crying foul - Portland Press Herald, Derek Davis

Executive Summary

Cities are increasingly at the forefront of both urbanization and climate change and to strengthen climate-sensitive urban development, a holistic understanding of the urban development from a climate lens is crucial. Cities are a significant contributor of carbon emissions aggravating climate change, climate disasters considerably impact cities. The recently released Global Climate Risk Index 2021 ranks India as the 7th most-affected country from climate-related extreme weather events (storms, floods, heat waves etc.). Further, studies indicate that poor planning and urban management are expected to cost Indian cities somewhere between $2.6 and $13 billion annually[1]. The ClimateSmart Cities Assessment Framework (CSCAF) launched in 2019 by the Ministry of Housing and Urban Affairs (MoHUA), the Government of India aimed to address this gap. This first-of-its-kind assessment with 28 progressive indicators across five thematic areas helps cities benchmark their development, understand the gaps, and prioritize climate-relevant development.

With a focus on building local capacities to develop and adopt climate measures, the Climate Centre for Cities (C-Cube) at the National Institute of Urban Affairs (NIUA) initiated a series of training aligned to the thematic areas of CSCAF - Energy and Green Buildings, Urban Planning, Green Cover & Biodiversity, Mobility and Air Quality, Water Management, Waste Management. The focus of the training is to provide a step-by-step approach to conducting studies, assessments and stakeholder consultations, establishing committees, developing action plans and implementing relevant measures that make the cities climate-resilient but also help them progress across the CSCAF. The training on the 'Energy-efficient wastewater management system' is under the thematic area of Water Management in the CSCAF.

With increasing urbanization, the amount waste water is bound to increase and energy consumed to treat and manage the same will also increase. Further, around 10% of the waste water generated in India is estimated to be treated using old pumping and electromechanical equipment that consume high amounts of energy.[2] Focusing on energy efficiency waste water management is key for reducing energy demand and hence reduced municipal expenditure. Reduced energy demand also provides a co-benefit of mitigating GHGs emissions.

The objective of the training module on 'energy-efficient wastewater management system' is to

- Provide overview of the regulatory framework for achieving energy efficiency in wastewater treatment
- Explain the implication of energy consumption in the wastewater treatment and the potential in reducing energy needs
- Measures to bring about energy efficiency in wastewater treatment
- Assess and evaluate their options to enhance energy efficiency and move forward in CSCAF performance

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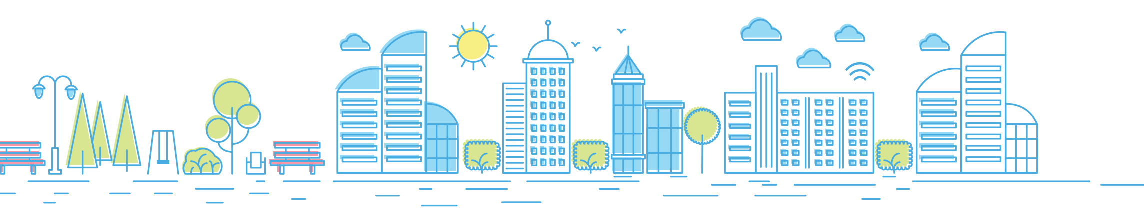
[1] *Mani, M. et al., 2018. South Asia's Hotspots: The Impact of Temperature and Precipitation Changes on Living Standards, WashingtonD.C.: World Bank Group.*

[2]*Kumar, P., Matto, M. & Sharda , C., 2017. Policy Paper on Mainstreaming Energy Efficiency in Urban Water and Wastewater Management in the Wake of Climate Change, s.l.: Centre for Science and Environment, Ministry of Urban Development., https://cdn.cseindia.org/attachments/0.73120800_1505297784_Policy-Paper-Mainstreaming-Energy-Efficiency-in-Urban-Water.pdf*



Who is the training manual designed for?

What is the focus of the training manual?

How to make use of this manual?

What are the Learning outcomes of the training?

Scope and limitations of the training

The training manual is designed for Urban Local Body Authorities and decision-makers to initiate the process of energy audit and achieve higher energy efficiency in wastewater management systems. Besides, training institutes can use the module to further the capacity building of ULB authorities, engineers, consultants and others. A pre-requisite for this training is to have basic knowledge of wastewater and wastewater treatment mechanisms. The training will be conducted in English, so understanding of language may be necessary.

This manual gives an outline of the topics covered in training and the link to further reading. The Module has seven components:

- Energy component in the wastewater treatment process and need to achieve energy efficiency
- Indicator 06: Energy Efficient in Wastewater Management System
- Energy Audit and its components
- Approach and options for achieving energy efficiency
- Rules and Regulations
- Finance and Budgeting
- Best practices

This manual can be used as reference notes to get insights on energy audits in wastewater treatment plants. It provides a brief about the topics mentioned above and links for further reading. Participants can refer to this document before and after the training sessions to equip themselves with knowledge on the relevant subject. It will also help them engage more effectively during the training sessions and identify any queries they can ask the facilitator.

The Learning outcome of training includes:

- Broad overview of regulatory framework for energy audit and achieving energy efficiency in wastewater management.
- Introduction to the Indicator, 'Energy-Efficient Wastewater Management Systems.
- Understand the implication of energy consumption in the wastewater treatment and the potential in reducing energy needs
- Measures to bring about energy efficiency in wastewater treatment

As this is a short online training, it is not easy to get into details of all technologies and applications. The training is intended to serve as an impetus for the CSCAF assessment by enhancing energy efficiency in wastewater management.

Thus, this training provides a broad overview of the approach and energy efficiency processes rather than details of each process.

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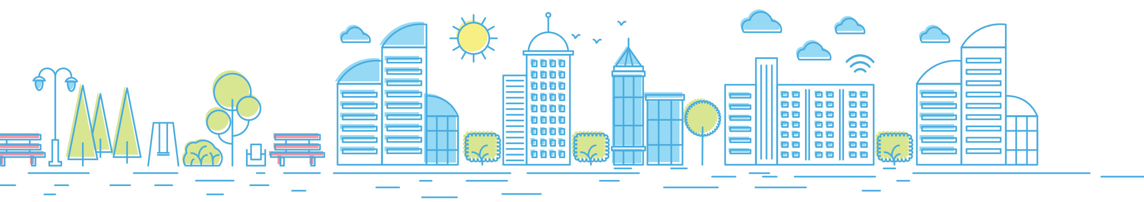
Abbreviations

ASE	Alliance to Save Energy
BEE	Bureau of Energy Efficiency
BOD	Biological Oxygen Demand
CMVP	Certified Measurement and Verification Professional
COD	Chemical Oxygen Demand
CPCB	Central Pollution Control Board
CPHEEO	Central Public Health and Environmental Engineering Organization
CSCAF	ClimateSmart City Assessment framework
CSE	Centre for Science and Environment
DEWATS	Decentralized Waste Water Treatment System
ECMs	Energy conservation measures
ECOs	Energy conservation opportunities
EE	Energy Efficiency
EPA	Environment Protection Agency
EPC	Energy Performance Contracting
ESCO	Energy Service Company
GHG	Green House Gas
IFC	International Finance Corporation
KfW	Kreditanstalt für Wiederaufbau (“Credit Institute for Reconstruction”)
kWH	Kilo Watt Hour
M&V	Measurement and Verification
MLD	Million Litres per Day
MNRE	Ministry of New and Renewable energy
MoUD	Ministry of Urban Development (now called Ministry of Housing and Urban Affairs)
NREL	National Renewable Energy laboratory
O & M	Operation & Maintenance
PHED	Public Health Engineering Department
RUIDP	Rajasthan Urban Infrastructure Development Project
SBT	Soil Bio Technology
ULB	Urban Local Body
USAID	United States Agency for International Development
ULB	Urban Local Body
VFD	Variable Frequency Drive
WWTP	Wastewater treatment Plant



1

Energy Efficiency in Wastewater treatment

Conventional wastewater management in urban areas is infrastructure-intensive, requiring energy-intensive conveyance and treatment systems. Rapidly growing urbanisation has added stress on local administration to cater to the cities' ever rising population. While cities build efficient wastewater treatment, focusing on making it energy efficient is important when seen from the climate lens. India's municipal water supply and sewage treatment infrastructure are 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, Energy Efficiency (EE) is a significant component for making financial and operating performance improvements.[1]

The primary energy demand in India has grown from about 450 million tonnes of oil equivalent (toe) in 2000 to about 770 million ton equivalent 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. 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.[2]

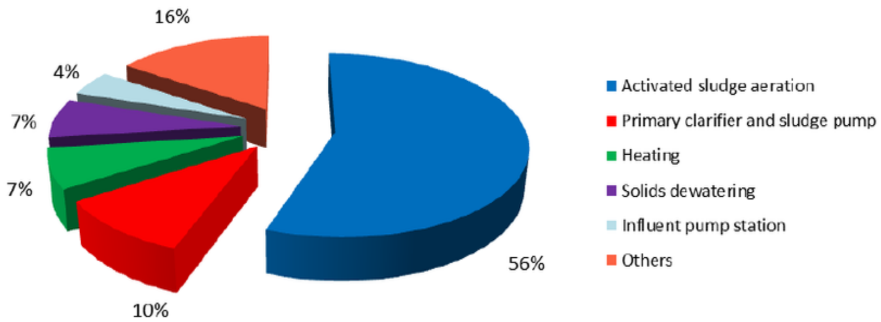
Most water and wastewater infrastructure were constructed many decades ago, and facilities and the equipment within them were designed to run continuously, without emphasis for wasted energy. Currently, energy expenditure is the highest cost associated with a water supply and is one of the top three expenditures at any water utility, often

[1] *Mainstreaming energy efficiency in urban water and wastewater management in the wake of climate change, Centre for Science and Environment, 2017*

[2] *https://powermin.gov.in/en/content/energy-efficiency*

second only to labour wages. The energy consumption cost accounts for 20–40% of the operation costs, and electrical consumption accounts for 60–90% of the total energy consumption.[3]

Figure 1 Breakdown of WTP energy[4]



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[5]. As a result, systems not adequately tuned or unable

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[3]*Application and Evaluation of Energy Conservation Technologies in Wastewater Treatment Plants, Journal of Applied science*

[4]*Source: ResearchGate, Opportunities for process control optimization in Irish municipal wastewater treatment plants, 2014*

[5]*Energy Efficiency in Water and Wastewater Facilities , A Guide to Developing and Implementing Greenhouse Gas Reduction Programs, U.S. Environmental Protection Agency, 2013*

to reduce redundant aeration blower or pump capacity can waste energy and money for decades. This waste also results in higher GHG emissions over the plant's life. Currently, in India, water supply and wastewater systems design follows the Centre Public Health Environment and Engineering Organization (CPHEEO) guidelines, 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, 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.[6]

1.1. Common Barriers to Energy Efficiency

For some, the case for efficiency seems sufficiently compelling that its universal adoption should be a matter of course. In reality, there are severe obstacles to the widespread adoption of more efficient practices and technologies, which can be grouped into five main categories.[7]

Lack of Awareness: Awareness of the cost benefits of energy efficiency is necessary for driving desired change in people's perception and behaviour. It is especially true in the case of applying energy efficiency to water supply since those who operate day to day in the water sector are not accustomed to focusing on energy.

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 concern be addressed and that the benefits of change outweigh the risks.

Challenging Status Quo: It is common for staff to resist new ideas and procedures because suggestions for change imply criticism of their performance and ability.

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

Financing Efficiency: Most Watergy (WATER- ENERGY nexus) measures may not burden the exchequer as they are modifications and adjustments to processes and equipment. Performance contracting approaches pay for project costs from the cost savings on

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[6]*Suresh Kumar Rohilla, et al; 2017, Mainstreaming energy efficiency in urban water and wastewater management in the wake of climate change, Centre for Science and Environment, New Delhi*

[7]*Judith A. Barry February 2007 , WATERGY: Energy and Water Efficiency in Water Supply and Wastewater Treatment , The Alliance to Save Energy*

Photo Credit: EngineeringCivil.org

Figure 2 ClimateSmart City Assessment Framework

water and energy for those requiring capital outlays. Those contemplating efficiency improvements often lack an understanding of performance contracting mechanisms, especially the awareness that they can be applied to the water sector. In some countries, financing issues are compounded by an insufficient supply of service providers capable of performance contracting, or the suppliers exist, but the industry is so nascent that confidence in them is lacking. This lack of confidence usually translates into an inability of these firms to provide the project financing since their unproven creditworthiness either denies them access to loans altogether or the terms are poor. On the flip side, in some countries, municipal governments do not have a good track record of sound financial management or honouring contracts, making efficient service providers reluctant to enter into agreements with municipalities.

1.2. Aligning with the ClimateSmart Cities Assessment Framework

The Indicator 6 of the Water Management sector enables ULBs to adopt progressive steps to achieve energy efficiency in wastewater treatment systems, starting from introducing energy audit processes.

Wastewater Management System is defined here as collecting wastewaters from the city's stakeholders and its treatment. There are types of equipment that use energy in a wastewater management system. However, wastewater pumps account for the maximum usage of energy. Different methods, types of pumps/ equipment and solutions can reduce energy use in the entire wastewater management system. Energy Audit is an assessment and analysis of energy flows in a process or system to reduce the amount of energy input into the system without negatively affecting the output(s). The reuse system is not be considered in this analysis and or assessment. The main objective is to explore various possibilities for energy conservation. An energy audit requires a thorough and detailed study of every aspect of the system through the performance of multiple tests and measurements.

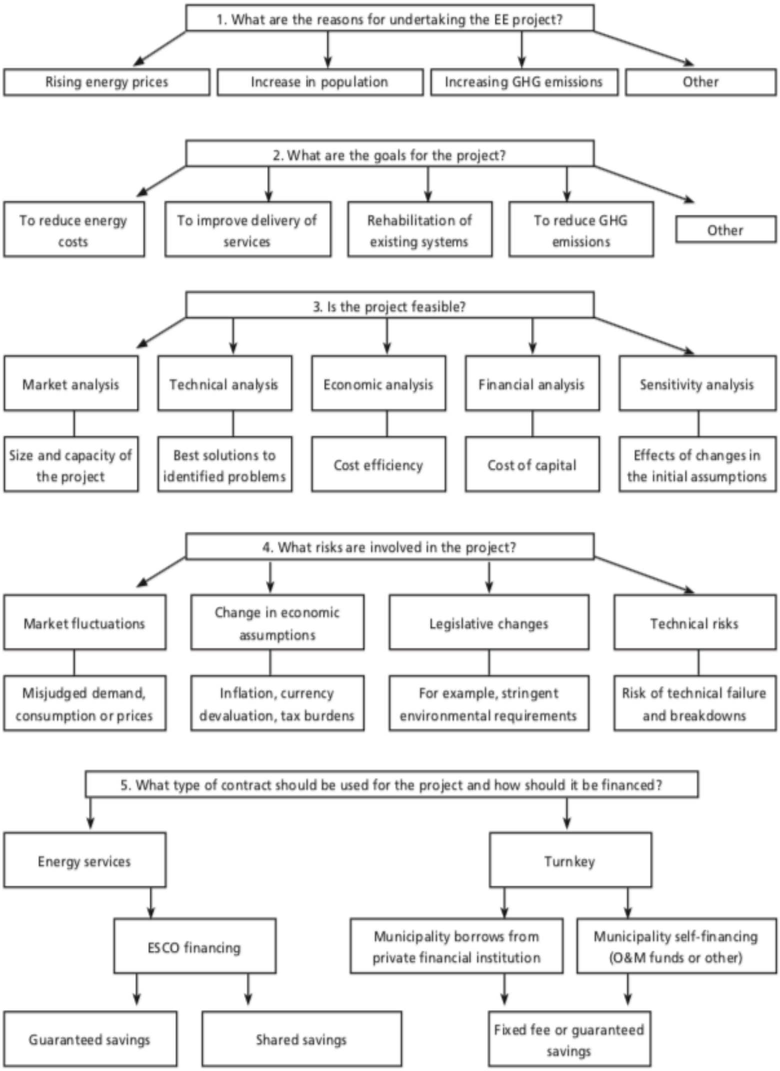
This indicator aims to quantify the use and reduction of energy (per MLD of wastewater generation and treatment) using different options and solutions used/implemented by the city. The performance is assessed based on the trend of reduction in energy consumption per MLD. Progression levels are evaluated based on progress made on an energy consumption reduction per MLD of treated water compared to baseline data. Thus, carrying out energy audit is the fundamental step to move forward.

Even before going for an energy audit, ULB authorities (or any agency that wants to perform an energy audit) must brainstorm the purpose, process and sequential steps to determine the course of action for achieving energy efficiency. This is shown in Figure 4 as a flow diagram to assess the energy efficiency project needs, risks and feasibility.

Figure 3 Performance Evaluation Levels

	1	2	3	4	5
Progression levels	Energy audit for wastewater pumping stations and treatment plants not conducted	City has conducted energy audit for wastewater pumping stations and treatment plants. Most recent energy reduction reported per MLD by the city during 2016-20 is <10% of baseline dat	Most recent energy reduction reported per MLD by the city during 2016-20 is >10% to 15% of baseline data	Most recent energy reduction reported per MLD by the city during 2016-20 is >15% to 20% of baseline data	Most recent energy reduction reported per MLD by the city during 2016-20 is >20% of baseline data
Evidence/ Data sources		Energy Audit Report (2016-20)			
Responsible Department/ Agency	ULB/ Water Utility/ Water Boards/ Flood and Irrigation Department/ Any SPV and or any other relevant implementation agency				
Reference	Manual for the Development of Municipal Energy Efficiency Projects. BEE (2008) https://tinyurl.com/w6omgtt A Primer on Energy Efficiency for Municipal Water and Wastewater Utilities (ESMAP; 2012) https://tinyurl.com/sw6qja5				
Score	0	25	50	75	100

Figure 4 Energy Efficiency Assessment Flow[8]



[8]*Source: International Finance Corporation, India- Manual for Development of Municipal Energy Efficiency Projects, 2017*

2

Energy Audit

An Energy audit is an official report on energy consumption by an organisation/process/plant/equipment aimed at reducing energy consumption and energy costs without affecting productivity and comforts and suggesting the methods for energy saving and reduction in energy cost. Every energy-intensive organisation/plant management carries an energy audit in a planned, official manner.[1]

An energy audit's primary purpose is to quickly and reliably establish the basic relative costs of the various forms of energy purchased, and their main use and identify locations where losses, wastages, or inefficiency occurs.

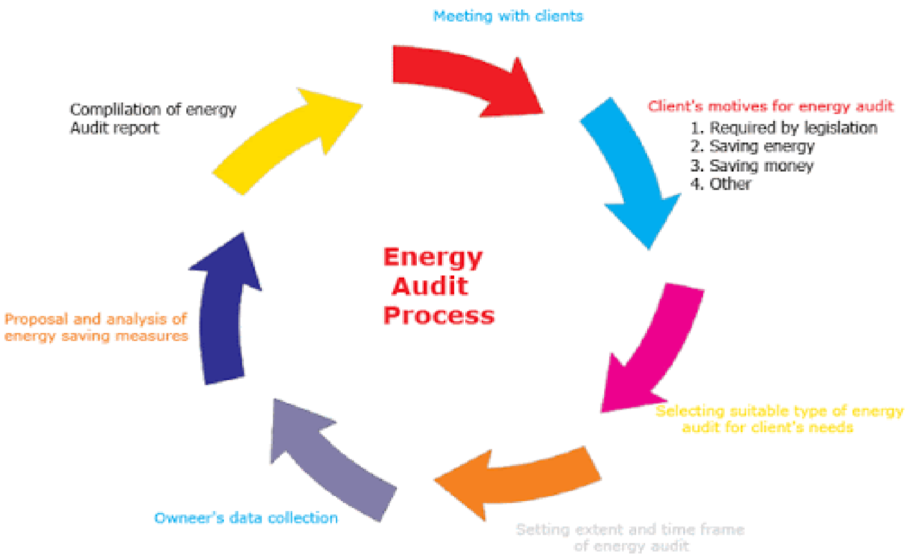
In simple language, we can say that an energy audit helps to understand more about the ways different energy sources are used in the industry and helps identify areas where waste can occur and where the scope for improvement may be possible. Thus, an energy audit is one of the concepts used in energy management, and it involves methodological examination and a comprehensive review of energy use in industries.

2.1. Energy Audit Process

- Collect and analyse historical energy usage.
- Study pumping systems and their operational characteristics.
- Identify potential modifications that will reduce the energy usage and or cost
- Perform an engineering and economic analysis of potential modifications.
- Prepare a rank-ordered list of appropriate modifications

[1] *ENERGY MANAGEMENT AND AUDIT. BEE. available here: https://beeindia.gov.in/sites/default/files/1Ch3.pdf*

Figure 5 Energy Audit Process[2]



The energy audit identifies the cost of energy and where and how it is used. It will specify the amount of energy expended in a process with the help of mass and energy balance for each method. The energy flow diagram is then prepared to show the quantity, form, source and quality (i.e., temperature) of the energy required for various processes.

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[2]*Source: https://nhenergygeek.org/blog-post/what-is-an-energy-audit/*

The next step is to critically analyse energy used, and energy wasted, then identify potential areas for energy saving.[3] The preparation of the energy audit report can also be broken down into components, as shown in figure 5, which includes;

a) Determining objectives/ goals of energy audit,
b) Selecting type of energy audit process,
c) Working out timeframe and methodology,
d) Data collection,
e) Data analysis and identifying measures for energy saving, and
f) Compilation of reports and buying in of staff.

2.2. Types of Energy Audit

Generally, two approaches are adopted in Energy Audit, often sequentially :

Preliminary Audit

- Prelimnary audit is generally completed within 5-10 days
- It highlights the energy cost and wastages in the significant equipment's and processes
- Recommendations in Preliminary audit are generally low tech and low cost

Comprehensive Audit

- Comprehensive audit may take 1-10 weeks to complete
- It involves detailed engineering measures for options to reduce energy consumption and energy costs
- The action plan is divided into short term, medium-term and long term actions

Preliminary audit:

A preliminary audit is carried out in a limited time, say within 10 days, and it highlights the energy cost and wastages in the significant equipment and processes. It also gives the primary energy supplies and demands an accounting. The questionnaire containing the industrial details of the energy consumption process carried out, energy needs to the unit product, such as load data etc. must be completed before the pre-audit visit.

The pre-audit visit is done, by the audit team/audit consultant, in the plant area with the attention focused on the energy inputs, spots of wastage and available energy conservation opportunities. The items for waste recycling opportunities are identified.

[3] *Energy efficiency in wastewater facilities. Tongyan Li (2016) Online. Available here: https://www.slideshare.net/TongyanLi/energy-efficiency-in-wastewater-facilities*

The data regarding energy inputs and outputs are collected during the preliminary audit.

During the visit, discussions with line supervisors and line technicians and joint brain storming may be necessary to acquire creative ideas and to know the practical difficulties in carrying out the proposed energy conservation measures (ECMs).

After the pre-audit visit, the work-energy audit is undertaken. In the preliminary audit, low tech recommendations are preferred. High tech solutions are given under detailed energy audit. Some of the low-cost recommendations may be: Switching off lights when not required, replacing incandescent lamps with fluorescent lamps, automatic thermostat control, use of solar water heating panels etc.

The preliminary audit spots energy waste spots and recommends short, intermediate and long term solutions. It should adopt a step by step and cautious approach for improvements and new energy management and control system techniques.

Comprehensive Audit

A comprehensive audit involves detailed engineering for options to reduce energy consumption and cost. It is completed within a 1-10 weeks period. The action plan is divided into short term, medium-term and long term actions. The comprehensive audit is quite exhaustive, and it is convenient to split it into the following subparts:

a) **Overall system audit:**
   It accounts for energy leakage/loss through the total system to the atmosphere. Energy conservation measures to eliminate such leakages/losses are recommended.
b) **Functional audit:**
   It identifies the energy conservation measures in operation and maintenance of each main plant and its subsystems and suggests ECOs is operation and maintenance.
c) **Utility Audit:**
   It identifies yearly/monthly/daily consumption of commercial secondary energy (electricity/petroleum products/fuel etc.) and suggests ECOs.
d) **Modernization audit:**
   It recommends significant changes in the process requiring retrofitting.
e) **Report of Energy Audit:**
   The comprehensive energy audit report generally converts the following:
   (i) Energy conservation opportunities (ECOs)
   (ii) Energy conservation measures (ECMs)
   (iii) Projected investments for ECMs.
   (iv) Projected annual savings of ECMs and pay-back period.
   (v) Feasibility studies for retrofitting/modification work.

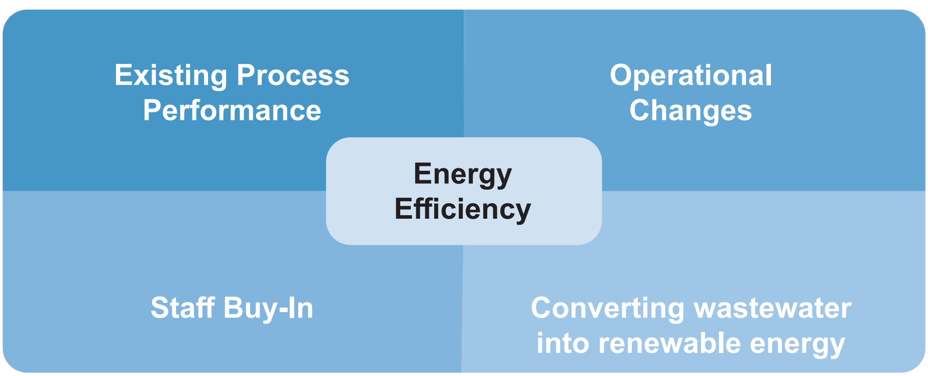
3

Approach to achieve energy efficiency

3.1. Common Approaches

Common Approaches to achieving energy efficiency include supply-side interventions like policy decisions, regulatory framework etc. and demand-side interventions, which are explained here:

Figure 6 Approaches to achieve Energy Efficiency



3.1.1. Existing Process Performance

Evaluate energy consumption and efficiency through an on-site survey to identify operational needs, maintenance and faulty equipment. Use energy consumption information to understand usage patterns and evaluate potentials for energy efficiencies. Implement audit recommendations through operational changes.

3.1.2. Operational Changes

Facilities should regularly evaluate the condition, performance and remaining useful life of process equipment. Ageing equipment is inefficient, expensive to repair, and typically requires more energy than newer models. The process that consumes the most power in a wastewater treatment plant is the aeration step, and this should be a starting point for efficiencies.

3.1.3. Converting wastewater into renewable energy

Converting wastewater into renewable energy with the help of anaerobic digesters can help to increase energy efficiency. An anaerobic digester produces methane that can be then utilised in a system to supply energy to the facility at significantly lower costs. The overall cuts on energy costs can enable the facility to become more self-sufficient.

3.1.4. Staff Buy-In

Educating treatment system operators in the relationship between energy efficiency and facility operations is key to meeting energy targets and finding new opportunities for efficiency. Engaging operators in the process by asking for input results in efficiency measures being suggested and embraced. After all stages in the facility, the staff are dealing with the processes every day, which is invaluable insight.

3.2. Energy Conservation Measures and Energy Management

The below table gives an overview of energy conservation measures in different areas of interventions.

Table 1 Energy Conservation measures[1]

Area of Interventions	Energy Conservation measure
Electricity Rates	Reduce demand during periods of peak electricity rates
Electric installations	Power factor optimization with capacitors Reduction in voltage imbalance
Operations and maintenance	Routine pump maintenance
Production and Distribution	Use automation (such as telemetry, SCADA, and electronic controllers on modulating valves) to optimize the operation of pumping equipment New efficient pump New efficient motor Replace Impeller
End Use	Incentive program for the use of efficiency technologies

Thus, there is a range of options and combinations of processes to optimise energy efficiency. Therefore, knowing where to maximise benefit becomes imperative, and an energy audit helps identify these opportunities.

Moreover, an approach to comprehensive 'Energy Management' may also enhance energy efficiency throughout the life cycle of wastewater management. The components of this approach are shown in Figure 7 as given by Environment Protection Agency (EPA), USA. This approach can apply to many processes, including wastewater treatment and management.

It encompasses stage-wise steps to improve energy efficiency, including 'Planning, Implementing, Checking/ Monitoring and Actions' for improvement.

Four simple steps denote it: 'Act, Plan, Do and Check.'

[1] *Source: Judith A. Barry, WATERGY: Energy and Water Efficiency in Water Supply and Wastewater Treatment, The Alliance to Save Energy, February 2007*

Figure 7 Lifetime cycle of energy management[2]

Plan	***Step 1. Get Ready*** • Establish the facility's energy policy and overall energy improvement goals • Secure and maintain management commitment, involvement and visibility • Choose an energy "fenceline" • Establish energy improvement program leadership • Secure and maintain employee and management buy-in ***Step 2. Assess Current Energy Baseline Status*** • Establish a baseline and benchmark facilities • Perform an energy audit • Identify activities and operations that consume the most energy or are inefficient ***Step 3. Establish an Energy Vision and Priorities for Improvement*** • Identify, evaluate, and prioritize potential energy improvement projects and activities ***Step 4. Identify Energy Objectives and Targets*** • Establish energy objectives and targets for priority improvement areas • Define performance indicators
Do	***Step 5. Implement Energy Improvement Programs and Build a Management System to Support Them*** • Develop action plans to implement energy improvements • Get top management's commitment and approval • Develop management system "operating controls" to support energy improvements • Begin implementation once approvals and systems are in place
Check	***Step 6. Monitor and Measure Results of the Energy Improvement Management Program*** • Review what the facility currently monitors and measures to track energy use • Determine what else the facility needs to monitor and measure its priority energy improvement operations • Develop a plan for maintaining the efficiency of energy equipment • Review the facility's progress toward energy targets • Take corrective action or make adjustment when the facility is not progressing toward its energy goals • Monitor/reassess compliance status
Act	***Step 7. Maintain the Energy Improvement Program*** • Continually align energy goals with business/operation goals • Apply lessons learned • Expand involvement of management and staff • Communicate success

[2]*Source: Energy Efficiency in Water and Wastewater Facilities, U.S. Environmental Protection Agency, 2013*

3.3. Specific opportunities and measures to improve EE

Specific opportunities to achieve energy efficiency is given in the table. Typical Energy efficiency interventions include:[3]

1. **Improve pump system efficiency**
   a. Replace inefficient (and often over-sized) pumps with efficient and adequately sized ones
   b. Install variable speed drives
   c. Carry out regular preventive inspection and maintenance,
   d. including cleaning or replacing impellers and checking lubrication of bearings
   e. Re-wind pump motors (when insufficient funds exist to replace them)
   f. Trim impellers where pumps are too large for the application but otherwise suitable

Table 2 Key Energy Saving Opportunities[4]

Functions and components	Potential energy saving
Pumps and Pumping	**5-30%**
Improving existing pumps	5-10%
Adopting new pumping technologies	3-17%
Closer matching of pumps (VSD etc)	Upto 30%
Aerobic Sewage Treatment	**Upto 50%**
Aligning control parameters with discharge standards	**Upto 50% in aerobic treatment** **Upto 25% in activated sludge process**
Other	
Improving building services	**Upto 15%**

b) 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

c) Metering and monitoring

- Create a system for regular monitoring of system components and performance
- Install and maintain water meters regularly (after about every 10 years)

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[3] *Suresh Kumar Rohilla, et al; 2017, Mainstreaming energy efficiency in urban water and wastewater management in the wake of climate change, Centre for Science and Environment, New Delhi*

[4] *Source: World Bank Group, A Primer on Energy Efficiency for Municipal Water and Wastewater Utilities, February 2012*

- 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)

d) Use of energy generated in the process

WW&S contains a lot of energy and resources, should be used reasonably. Nutrients (N and P) and energy (C) are feasible recycling components. Table 3 shows some available energy and utilization ways in WW&S. Most of the recovered; For example, biogas can be used to maintain the system temperature at 35 °C or 55 °C, which is energy is used in many processes of WWTPs, which makes energy self-sufficiency possible. For example, biogas can be used to maintain the system temperature at 35 ◦C or 55 ◦C, conducive to medium temperature digestion or high-temperature digestion.[5]

Table 3 Use of generated energy in treatment process

Energy in WW&S	Technologies	Applications
Heat energy	Wastewater source heat pump	Sludge drying, Heating
Biomass energy	Microalgae culture, Anaerobicdigestion, Microbial fuel cell	Fuel production, Power generation
Chemical energy	Thermochemistry	Fuel production, Power generation

e. Green energy and energy optimisation methods

Green energy and optimization technologies are used in modern WWTPs to bring energy efficiency to operations. Many factors, such as processes, scale, and water quality, significantly impact energy consumption, and hence each method has its pros and cons. Table 4 summarises the various green technologies and processes and their potential to reduce energy demands.

Table 4 Use of green energy in treatment processes[6]

Types	Technologies	Achievement
Biomass Energy	Anerobic digestion Microbial Fuel Cell	Provide 50% energy needs Achieve 0.360 kWh/Kg COD
Equipment	Use the direct drive turbine Use variable frequency driver	Save more than 35% energy Reducing energy consumption by upto 50%

[5] *Source: Yongteng Sun et al; Application and Evaluation of Energy Conservation Technologies in Wastewater Treatment Plants, Applied Sciences*

[6] *Source: Yongteng Sun et al; Application and Evaluation of Energy Conservation Technologies in Wastewater Treatment Plants, Applied Sciences*

Types	Technologies	Achievement
Algorithms	Fuzzy Algorithm Model Predictive Control	Save about 40% of the energy Reduce over 25% in power usage
Chemical Energy	Pyrolysis Incineration	Recover 59.2- 79.3% sludge energy Provide 20% energy needs
Solar Energy	PV Generation	Provide 10% energy needs
Control Strategy	ASM2d[7] Model	Save 2.2 to 3.3% of energy
Heat Energy	Wastewater source heat pump	Electricity equivalent 2.18 kWh/m3

f. Use of low-energy intensive wastewater treatment systems

The below table gives a comparative analysis of area and power requirements in a few standard wastewater treatment systems in India.

Table 5 Energy requirement in various treatment technologies[8]

Technology	Whether Natural or Built	Aerobic/ Anaerobic/ Mixed	Expected effluent quality (low, medium, high)	Area Requirement (m^2/person)	Power requirement kWh/ person/ year	Prevalence in India
Waste Stabilisation Pond System	Natural	Mixed	Medium to High	2.0–3.0	Nil	All over India
Duckweed Pond System	Natural	Aerobic	Medium to High	2.5–6.0	Nil	Greater number in the state of Punjab
Constructed Wetland	Natural	Aerobic	Medium	1.5–2.5	Nil	Less Implementation experience in India
Upflow Anaerobic Sludge Blanket	Built	Anaerobic	Low	0.1–0.2	Only for pumping	All over India in urban areas, but very less experience in rural areas
Anaerobic Baffled Filter	Built	Anaerobic	Low	0.2–0.4	Nil	All over India
Package Aeration System	Built	Mixed	High	0.1–0.15	20–30	All over India
Extended Aeration System	Built	Aerobic	High	0.1–0.2	15–25	All over India
Sequencing Batch Reactor System	Built	Aerobic	Very High	0.05–0.1	10–20	All over India
Soil Bio Technology	Natural	Aerobic	Very High	0.021	40–50 kWh/MLD to pump wastewater for distribution across the reactor bed	All over India

[7]The Activated Sludge Model No. 2d (ASM2d) presents a model for biological phosphorus removal with simultaneous nitrification-denitrification in activated sludge systems

[8]Source: https://jalshakti-ddws.gov.in/sites/default/files/Primer%20SLWM.pdf

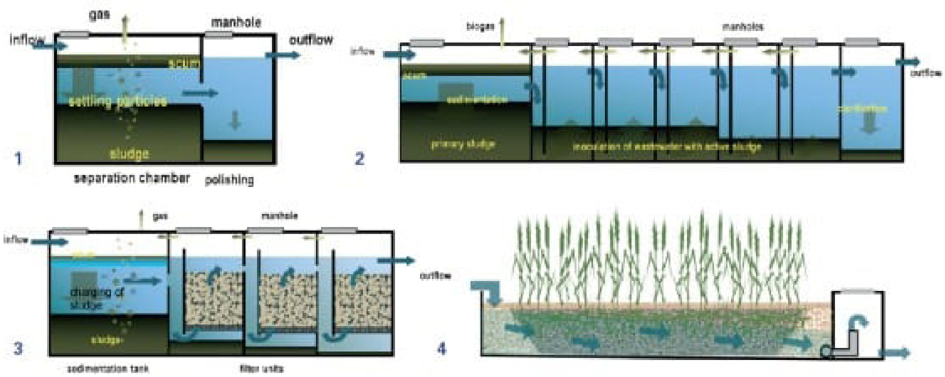
3.4. Low Energy Intensive Wastewater Treatment Systems

Below are three examples of India'a low maintenance and low energy wastewater treatment system:

a. DEWATS

DEWATS is a technical approach to decentralized wastewater treatment in developing communities. The passive design uses physical and biological treatment mechanisms such as sedimentation, floatation, aerobic and anaerobic treatment to treat domestic and industrial wastewater sources. DEWATS is designed to be affordable, low maintenance, use local materials, and meet environmental laws and regulations. DEWATS has service packages available for the sanitation needs of small and medium-sized enterprises, including communities, schools, municipalities, agro-industry, emergency settlements, hospitals, hotels, and prisons.

Figure 8 Schematic Diagram of DEWATS[9]



b. Soil Bio Technology (SBT)

Soil Biotechnology is a terrestrial system for wastewater treatment that is based on the principle of trickling filters. In this system, a combination of physical processes like sedimentation, infiltration and the biochemical process is carried out to remove the wastewater's suspended solids and organic and inorganic contents10.

The system's key components are the suitability of mineral constitution, culture containing native micro-flora and bio-indicator plants. It is also known as Constructed Soil Filter (CSF). SBT systems are constructed from RCC, stone-masonry or soil bunds. It consists of a raw water tank, bioreactor containment, treated water tank, piping and pumps.

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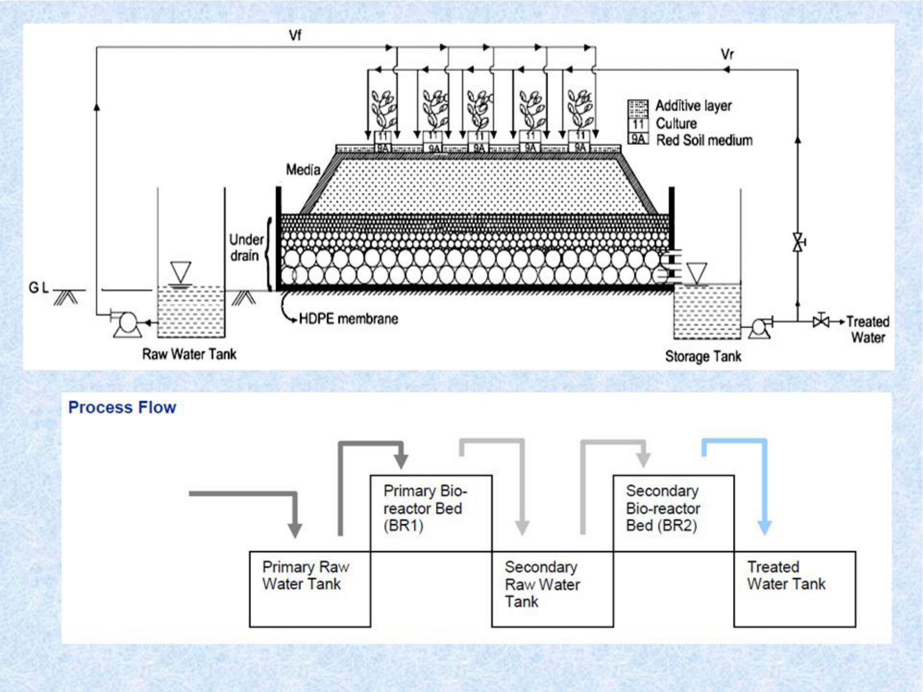
[9]*Image source: Consortium for DEWATS Dissemination (CDD) Society- www.cddindia.org*

[10]*Soil Bio Technology. CSE India 2022. https://www.cseindia.org/soil-bio-technology-sbt-3774*

Salient features

- The process run on batch or continuous mode.
- No sludge production
- Mechanical aeration is not required.
- The overall time of operation is 6-7 hours per day. The soil biotechnology system bed is dried before the next cycle of use.

Figure 9 Schematic Diagram of Soil Bio Technology[11]



[11]*Image Source: Sergio Thyng, 3 R's of water Recharge, Reuse & Recycling. Capture / Reuse Volume Control Reduced potable water consumption Cost savings (https://slideplayer.com/slide/3501084/)*

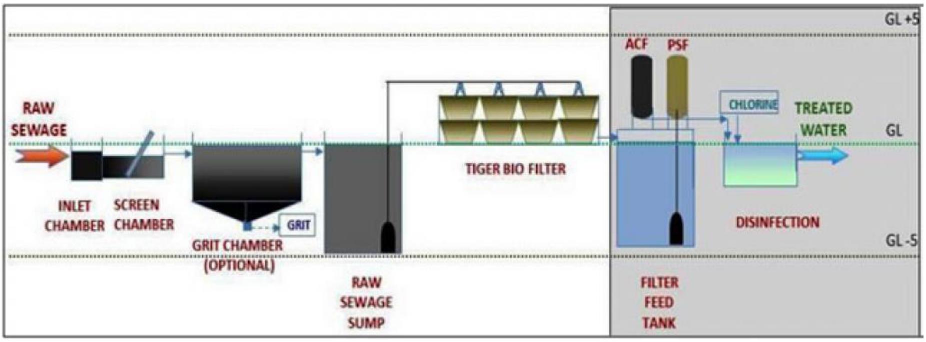
c. Tiger Bio Filter

(A Verm-filtration based sewage treatment technology)[12]

Vermi-filtration is widely recognised as a superior form of sanitation compared to septic tanks and pit latrines. Earthworms are well known to promote the digestion of organic waste, which results in vermicompost production. In vermifilters, this behaviour is combined with filtration to digest organic matter present in sewage. The Tiger Biodigester is made of layers of natural media that treat faeces. The media provides bedding for waste consuming microorganisms and composting earthworms. The faecal matter is consumed in the Biodigester, and producing the highly fertile humus.

Biomedia induces "passive aeration" to the faecal wastewater, which dissolves oxygen into it. Waste matter is thus purified by assimilation and digestion of organic matter in the bodies of worms and microorganisms, leaving behind clean, fertile, and odour-free vermicompost.

Figure 10 Schematic Diagram of Tiger Bio Filter, CSE India



[12]*TBF Environmental Solutions Pvt. Ltd. Online. https://www.tbfenvironmental.in/about-us.html*

4

Institutional framework

Water and wastewater are contemporary issues, requiring co-legislation of central and state levels. The National Urban Sanitation Policy of 2008 provides an overarching framework for states and cities, outlining general policy goals (such as awareness-raising and open defecation-free cities) and providing elements of draft state and city sanitation plans. It recommends a minimum of 20% reuse of wastewater in every city. The National Advisory Manual complements this policy on Septage Management and the Manual on Sewerage and Sewage Treatment Systems (both from 2013), giving more concrete suggestions and guidelines on technologies, operation and management procedures. The National Water Policy of 2012 encourages recycling and reuse of water after treatment to specified standards (CPHEEO guidelines) as well as preferential tariffs that incentivize the reuse of treated wastewater in general).[1]

4.1. Stakeholders in Energy Efficiency in WTP

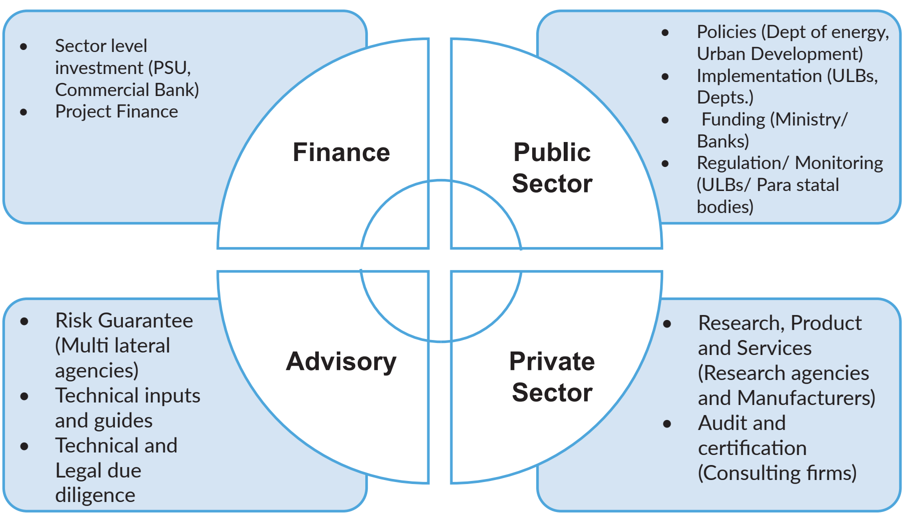
Figure 11 outlines the roles and responsibilities of various stakeholders in achieving energy efficiency in wastewater management. The figure includes government agencies, regulatory authorities, consultants, professionals, specialised agencies and even national and international finance agencies.

4.2. Contracting and Services

Contracting services like ESCO plays an essential role in achieving energy efficiency in the system. The table below gives various contracting options that can be applied by ULBs when determining how WTPs are operated.

[1] *A Primer on Energy Efficiency for Municipal Water and Wastewater Utilities*

Figure 11 Stakeholder in energy efficient wastewater management systems



Energy Service Companies (ESCOs) is a company that offers energy services, usually designing, retrofitting and implementation of energy efficiency projects after identifying energy-saving opportunities through energy audits of existing facilities.[2]

Energy Performance Contracting (EPC) means a contractual arrangement between the beneficiary and the provider of an energy efficiency improvement measure, verified and monitored during the entire term of the contract, where investment in that measure are

[2] *BEE, 2020. Available here: https://beeindia.gov.in/content/escos-0*

paid for in relation to a contractually agreed level of energy efficiency improvement or other agreed energy performance criteria, such as financial savings.

Thus, ESCO is related to the company offering energy efficiency services, and EPC is the contractual model that governs the relationship between the ESCO and the client.

4.2.1. Advantages of an ESCO project

Usually, the service offered by an ESCO integrates all energy services for all the phases of the project through a single contract. Furthermore, the ESCO, grounding its benefits in energy savings, guarantees rational solutions consistent with the customer needs. Thus hiring an ESCO enables customers to renew their technology and improve competitiveness and productive assets.[3]

4.3. Energy Performance Contract

An Energy Performance Contract is a form of 'creative financing' for capital improvements which allows funding energy upgrades from cost reductions. Under an Energy Performance Contract arrangement, an external organisation (ESCO) implements a project to deliver energy efficiency. The cost savings achieved from the energy-saving initiative are then used to repay the project's costs. Essentially the ESCO will not receive payment unless the project delivers the targeted energy savings.[4]

There are three main types of Energy Performance Contract:

Shared savings: Under a shared savings contract, the investment is assumed entirely by the ESCO, including investment financing, management and control of energy consumption.

Guaranteed savings: Under a guaranteed savings contract, the client assumes the required investments

Mixed savings: This contracting is a high-bred combination of the two previous models.

The contract adopted will depend on the type of project being implemented and the appetite for risk on both sides. Either way, an Energy Performance Contract is based on some element of the ESCO achieving the targeted energy savings.

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[3] *Concept of ESCO and EPC. Leonardo Energy. 2020. Available here: https://help.leonardo-energy.org/hc/en-us/articles/202552562-What-is-the-difference-between-an-ESCO-and-an-EPC-*

[4] *Types of energy performance. ETS. Available here: contracts. https://energy-ts.com/energy-performance-contracts/*

In recent years the implementing agencies are moving away from long term contracts because of uncertainty in political and financial conditions. Taking into account commercial risk has become vital for private sector participation.

Table 6 Types of contracting in wastewater sector

Table 1: Types of contracting in the wastewater sector

	Service contract	Management contract	Lease	Concession	Design, build, operate and transfer (DBOT)*	Divestiture
Asset ownership	Public	Public	Public	Public	Public or private	Private
Capital investment	Public	Public	Public	Private	Private	Private
Commercial risk	Public	Public	Shared	Private	Private	Private
Operations/ maintenance	Private/ public	Private	Private	Private	Private	Private
Usual contract duration	1-2 years	3-5 years	8-15 years	25 years	20-30 years	indefinite

*Variations: Build, own, operate; Build, own, train, transfer.

Source: Budds & McGranahan (2003)

5

Interactive Exercise

The exercise aims to understand various tasks and activities of energy audit at different stages of the audit process.

The columns depict three stages of the process- Pre Audit, During Audit and Post Audit, while the rows depict broad categories of activities related to management decisions, technical assessment, process evaluation, Monitoring outcomes and changes in approach or system itself. Various tasks, activities are given in the list separately.

	Pre-Audit	During Audit	Post Audit
Management decision/ staff commitment			
Technical assessment			
Process evaluation			
Monitoring outcomes			
Changes in approach/ system technology			

List of activities:

- Automation
- Realign with standards
- Energy improvement goals
- Staff training
- Identify energy drain points
- Bill analysis
- Improve algorithm
- Check compliance
- Choose leadership
- Commitment from staff
- Establishment baseline data

- Management changes required
- Establish maintenance alerts
- Efficient pumps
- Note energy costs
- Check peak hour loads
- Use VFD
- Decentralization
- Check operation and timings
- Routine maintenance
- Optimize wasted energy
- Explore new technology
- Record peak demand
- Note operational timings
- Compare results
- Energy consumption
- Use of solar energy
- Check compliance with standards
- Management commitment
- Site audit
- Use efficient motors
- Process changes required
- Technology upgradation
- Reuse heat energy
- Improve management
- Monitor changes
- Identify priority areas
- Note device level energy usage
- Optimize wasted energy
- Phased improvement

There are two sequential steps in the exercise. First step focuses on segregating the audit activities according to phases of audit process and task categories, and the second step focuses on prioritising the activities across the phases and categories.

Step 1

Objective:

To identify audit activities according to phases of audit and categories of the task.

Process:

Select tasks from yellow sticky notes and place them (drag and drop) in appropriate cells corresponding to phases of energy audit and broad categories of activities.

For Example, 'Setting Energy improvement goal' is Pre-audit activity in management decisions and hence may be placed in the first cell (top left).

Likewise, participants may arrange all listed activities appropriate cells of the Energy Audit frame. It will give a clear idea of essential activities that need to be done under during different energy audit phases under various categories.

Step 2

Objective:

To prioritise audit activities according to phases of audit and categories of the task.

Process:

After completing the exercise, a discussion on essential activities in all three phases of energy audit and challenges in identifying and monitoring these activities may be initiated. Participants may be encouraged to share their views and experiences regarding enabling and hindering factors from carrying out energy audits and implementing its recommendations in their respective cities.

Take away for participants from the exercise:

The final board with segregated and prioritised phase-wise activities on the board may act as a ready reckoner to plan energy audit activities for participants. It is the takeaway for participants to work on further detailing as required in their respective cities.

Additional offline exercise for participants
Participants may also work again with their city teams to identify and prioritise energy audit activities and tasks for different projects using the given table.

Fill in the black cells of the table with appropriate and relevant activities in a city.

Categories	Pre-Audit	During Audit	Post Audit
Management decisions			
Technical aspects			
Process			
Outcomes			
System related			

6

Case Study

6.1. One stop shop sewage treatment plant – Jaipur

Benefits of project

This WWTP transforms sewage to water for farming, harnesses alternative energy, while saving valuable electricity.

- The facility treats and cleans nearly 62.5 million liters of sewage a day.
- The treated water is released into channels and farmers use it free of cost to irrigate their farm fields.
- Methane captured from the plant is also used to generate clean electricity to run the entire facility.
- This will save more than Rs. 2 Crore a year in electricity cost.

Project and its need

With increased population, deficient rainfall and deteriorating water sources, Jaipur faced severe stress on water supply and sanitation services every year. Untreated sewage-contaminated groundwater in the city become a health hazard for Jaipur citizens. On the other hand, farmers in the city's vicinity used untreated sewage water to grow crops and vegetables, as irrigation water was scarce. In 1998, the government of Rajasthan established the Rajasthan Urban Infrastructure Development Project or RUIDP-1 as an entity under the Urban Development and Housing Department. The Asian Development Bank gave financial assistance to the endeavour, which provided investments in the water supply and sewage sectors across six major cities in Rajasthan. As part of the project, RUIDP-1 built a state of the art sewage treatment plant in Jaipur. The facility treats and cleans nearly 62.5 million litres of sewage a day. The treated water is released into channels, and farmers use it free of cost to irrigate their farm fields.

WWTP at Jaipur

Opportunities created for ULBs

Jaipur Municipality saves more than Rs. 2 Crore, a year in electricity cost of operating the plant as methane captured from the plant, is used to generate clean electricity to run the entire facility. Health hazards due to the open flow of sewage water, breeding of mosquitoes and contamination of land and water resources were also checked by this project. The institutional and financial mechanism for setting up the plan ensured that the work on the project was completed on time with desired quality, without burden on ULB.

6.2. State of the art energy efficient Waste Water Treatment plant at Kodungaiyur, Chennai

Benefits of project

- The plant treats 110,000 m3 of Wastewater from various parts of Chennai every day.
- The 1MW gas Engine works on the Bio-Gas produced from the incoming sludge and generated power which is used to run the plant.
- The plant boasts 98% self-sufficiency, thus saving on power for operation.

WWTP at Chennai1

6.2.1. Project

With the growing population of the Chennai Metropolitan region, water and sanitation services were under severe stress. In 2003, a state of the art STP was established at Kodungaiyur on 'Design-Build Operate' mode under the Chennai City River conservation project. The plant was commissioned in 2006 with the capacity of treating 110,000 cubic meters of sewage every day. The plant is equipped with an advanced sludge management process capable of producing an adequate amount of electricity to run the entire plant and hence converting the waste to wealth.

[1]*Image source: https://english.newstrack.com/india-news/mld-sewage-treatment-plant-inaugurated-in-chennai-304496.html*

Figure 12 Wastewater Treatment

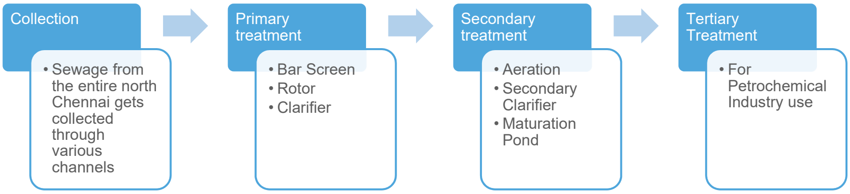
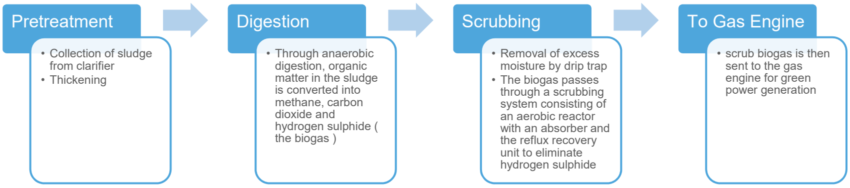


Figure 18 Sludge Treatment



The entire plant operates using the electrical energy that is generated through biogas. However, the facility is also equipped with the provision to extract power from the grid and also has a DG set that acts as the backup power supply. The digested sludge then moves to the sludge balancing tank, where it is dewatered and reused as fertilizer in agriculture.

6.2.2. Opportunities created for ULBs

This neutral power plant is the precursor to the government's MNRE ministry for a new and renewable energy subsidy program in line with India's ratification at the Paris climate convention (forty per cent of India's power requirement is to be met through non-fossil sources). It can work as a model project of ClimateSmart Cities for planning, designing and commissioning these types of projects. Reuse of treated wastewater reduces the burden on freshwater, especially in a city like Chennai, which depends on groundwater.[2]

The '*Design-Build Operate*' mechanism ensures that ULB does not bear the financial burden for large infrastructure in this sector without compromising the quality of operations by involving Private sector expertise and capital. This mode can be used to upgrade the infrastructure and set up new infrastructure quickly and increase coverage of sanitation services.

[2] *Source: VA Tech WABAG. Video link: https://www.youtube.com/watch?v=tMJ-L407QGU*

7

List of additional materials

7.1. Documents

- ✓ *Sam Azimi, Energy Consumption Reduction in Wastewater Treatment Plant, Researchgate, March 2017*
- ✓ *Renan Barroso Soares, Comparative Analysis of Energy Consumption of different Wastewater treatment plants, Researchgate, January 2017*
- ✓ *Status Of Water Treatment Plants In India, Central Pollution Control Board*
- ✓ *Suresh Kumar Rohilla, Pradeep Kumar, Mahreen Matto and Chhavi Sharda, Mainstreaming energy efficiency in urban water and wastewater management in the wake of climate change, Centre for Science and Environment, 2017*
- ✓ *Pratima Singh, Arun Kansal, Cynthia Mary Carliell-Marquet, Energy Pattern Analysis in Wastewater treatment plant, Researchgate, September 2012*
- ✓ *Judith A. Barry, WATERGY: Energy and Water Efficiency in Water Supply and Wastewater Treatment, The Alliance to Save Energy, February 2007*
- ✓ *Yongteng Sun et al, Application and Evaluation of Energy Conservation Technologies in Wastewater Treatment Plants, Applied Science, October 2019*
- ✓ *Michael Schäfer et.al., The Possible Roles of Wastewater Treatment Plants in Sector Coupling*
- ✓ *World Bank Group, A Primer on Energy Efficiency for Municipal Water and Wastewater Utilities, February 2012*
- ✓ *Marta Gandiglio et.al, Enhancing the Energy Efficiency of Wastewater Treatment Plants through Co-digestion and Fuel Cell Systems, Frontiers, October 2017*
- ✓ *International Finance Corporation, India- Manual for Development of Municipal Energy Efficiency Projects, 2017*
- ✓ *J. Daw and K. Hallett et. Al, Energy Efficiency Strategies for Municipal Wastewater Treatment Facilities, NREL, January 2012*

- ✓ *Energy Efficiency in Water and Wastewater Facilities, U.S. Environmental Protection Agency, 2013*
- ✓ *Babette Never, Wastewater Systems and Energy Saving in Urban India, Governing the Water-Energy-Food Nexus Series, German Development Institute (DIE), Discussion Paper December 2016*

7.2. Webpages

- ✓ *https://www.businessmanagementideas.com/energy-management/energy-audit-and-its-types-energy-management/6346*
- ✓ *https://www.oxymem.com/blog/4-ways-to-create-a-more-energy-efficient-wastewater-treatment-plant*
- ✓ *https://tataandhoward.com/importance-energy-efficiency-water-wastewater-treatment-case-studies/*
- ✓ *https://iopscience.iop.org/article/10.1088/1755-1315/16/1/012033*

Notes:

सत्यमेव जयते

Ministry of Housing and Urban Affairs
Government of India