Renewable energy and energy efficiency technologies for wastewater treatment works in South Africa

Technical fact sheet for **energy management and optimisation of wastewater treatment works**

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This factsheet on energy management and optimisation forms part of a series of ten (10) factsheets which highlight the renewable energy (RE) and energy efficiency (EE) technologies relevant to wastewater treatment works (WWTWs). The full list of technologies and factsheets can be found [here].

Wastewater treatment works WWTWs are large consumers of energy, with water supply and wastewater treatment constituting approximately 17% of the total energy consumed by South African municipalities.

Innovative approaches to efficient energy use in municipal WWTWs, specifically through increased energy efficiency EE and greater adoption of renewable energy RE technologies such as biogas, solar, wind power, thermal power and hydropower, can reduce spend on energy bills and enable sustainable delivery of water services. The adoption of EE and RE technologies supports climate change mitigation as it decreases the amount of electricity consumed and the associated greenhouse gas (GHG) emissions while improving resilience to disruptions such as planned power outages (loadshedding).

This factsheet is written for:

- Municipal officials interested in:
  - > Reducing electricity consumption and the overall energy bill at WWTWs.
  - > Reducing the carbon footprint of WWTWs.
- Funders and investors interested in supporting EE and RE projects at WWTWs.
- Businesses that are looking to identify potential market opportunities for EE wastewater treatment technologies.

This factsheet discusses:

- The activities that operators can undertake to determine the process efficiency of WWTWs.
- The business case and market assessment to determine and improve process efficiency.
- The parameters required to determine the eligibility of a wastewater treatment work for EE and RE interventions.

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Introduction

Conducting EE audits and optimising WWTWs is a crucial first step to identifying opportunities for energy savings, reducing energy demand, improving operational efficiency, minimising operational costs, and enhancing sustainability. Opportunities for EE in WWTWs represent ~48% of the known electricity efficiency opportunities within the overall operations of a municipality, particularly metropolitan municipalities (SACN, 2014). This fact sheet provides technical guidance to wastewater treatment practitioners[1] on how to conduct EE audits, identify inefficiencies, and optimise wastewater treatment processes to achieve energy savings and reduce GHG emissions.

1.1 Energy audits

A comprehensive preliminary energy audit (level 1 energy audit) of WWTWs involves collecting data (metering) on energy consumption, analysing energy usage patterns, and identifying areas of high energy demand. Practitioners can use utility bills, meter readings, and any other relevant energy usage records. A detailed guideline for EE audits at WWTWs can be found here. Particular attention must be paid to the typical energy intensive wastewater treatment process stages, such as pumping systems, aeration processes, and sludge management. The typical energy consumption of activated sludge processes is shown in **Table 1**:

Table 1: Typical distribution of energy consumption at a WWTW by technology

TECHNOLOGY	TYPICAL ENERGY CONSUMPTION
Aeration	13 - 80%
Sludge treatment	5 - 35%
Pumping	4 - 31%
Other	1 - 38%

Source: WRC Report No. TT866/21

The energy data must be analysed to understand specific energy consumption (SPC) patterns and identify areas of high energy demand based on international benchmarks (Table 2) or past performance.

Additionally, the efficiency of heating, ventilation, and air conditioning (HVAC) systems, as well as lighting fixtures and controls in buildings must be evaluated.

Process stages with significant energy-saving potential must be prioritised for optimisations and EE interventions while taking capital costs, timelines (short/long-term) measures, techno-economic feasibility and potential impact into consideration. International SPC benchmarks of wastewater treatment processes at different plant sizes are shown in Table 2.

1 The main focus is for the plant managers, sustainable energy managers and process controllers

Table 2: Benchmarks for specific power consumption of secondary treatment processes

PLANT SIZE (MLD)	<0.5	0.5 - 2	10 - 25	>25
TRICKLING FILTER (kWh/m³)	0.43	0.68	0.28	0.17
ACTIVATED SLUDGE (kWh/m³)	0.39	0.59	0.37	0.31

*Advanced treatment systems use 0.31 - 0.14 kWh/m^3 MLD = mega litres per day
Source: Feng 2012, NEWRI, 2010, Green Drop 2022

1.2 Process optimisation

As part of the audit process, on-site inspections should be performed to assess the physical infrastructure and treatment equipment related to high energy usage. Based on the findings of the audit, the following strategies can be implemented to optimise the different process stages to reduce their energy demand.

1.2.1 Process controls and automation

Implementing advanced process controls and automation systems can help optimise energy consumption in WWTWs. Real-time monitoring and control of pumps, blowers, aeration and dewatering systems can enable efficient operation, optimal performance and EE.

1.2.2 Peak shaving

Peak shaving techniques include:

a. **Loadshedding:** Temporarily reducing non-critical equipment operation during peak demand periods to manage energy consumption and avoid utility demand charges.

b. **Load shifting:** Adjusting the timing of energy-intensive processes to off-peak hours.

1.2.3 Aeration process optimisation

Optimise aeration rates, dissolved oxygen levels, and nutrient dosing to match process requirements:

- **a** Adjusting aeration rates based on real-time oxygen demand.
- **b** Install variable frequency/speed drives (VFDs/VSDs) in blowers to match airflow with actual oxygen demand.
- **c** Fine-bubble diffusers or alternative aeration technologies may offer improved oxygen transfer efficiency, reducing energy requirements.

1.2.4 Motor driven systems optimisation

Optimise motor driven systems (pumps, centrifuges and mixers) to reduce energy demand:

- **a** Install VSDs on motors (pumps, centrifuges and mechanical mixers) to match flow rates with actual process demand.
- **b** Regular maintenance of the piping system can improve system efficiency and reduce energy requirements.
- **c** Ensure efficient flow distribution, minimise pressure drops (leaks, excessive bends and rough pipes), and use proper pipe sizing to reduce pumping energy requirements.
- **d** Replace inefficient motors and pumps with EE ones. Consider factors such as SPC and pump curves during the selection process.

1.2.5 Sludge management

Optimising operating parameters can improve dewatering efficiency. Factors to consider include the flocculent and/or coagulant dosage, sludge feed rate, belt/screw speed, and pressure settings. Here are some strategies to achieve energy optimisation:

- **a** Gravity thickeners can be used to increase solids content and reduce the volume of sludge before dewatering, thereby reducing the energy needed for subsequent dewatering processes.
- **b** Optimise the dosage and selection of sludge conditioning agents (flocculants and coagulants). Conditioning agents can enhance the dewatering performance and reduce energy demand.
- **c** Implement heat recovery systems such as heat exchangers to utilise excess heat from the wastewater or other WWTWs processes for sludge dewatering.
- **d** Explore EE dewatering technologies such as belt/screw presses, and centrifuges. Selecting the appropriate equipment based on the characteristics of the sludge
- **e** Consider implementing thermal hydrolysis and/or anaerobic digestion of sludge to generate biogas that can be used for on-site electricity generation and/or as a heating fuel.

1.2.6 Renewable energy integration

If the above interventions have already been achieved, consider integrating RE sources such as solar power, wind energy, biogas, and mini hydro (turbine).

Business case

The implementation of different EE interventions presented above can yield potential energy savings of up to 75% with payback periods ranging from months to about 7 years (**Table 3**).

Table 3: Benchmarks for specific power consumption of secondary treatment processes

INTERVENTION	POTENTIAL OVERALL/ SECTIONAL ENERGY SAVINGS (%)	PAYBACK PERIOD (YEARS)
Energy audits and EE interventions implemented	10 – 50*	–
Process controls and automation	5 – 20*	–
Peak shaving	< 50	4 – 6
Aeration process optimisation Fine bubble diffusers VSDs in blowers and mechanical mixers Dissolved oxygen control	30 – 70 20 – 75 10 – 50 20 – 50	1 – 7 <1 2 – 7 2 – 3
Pumping system optimisation VSDs in motors Improve power factor of motors Eliminate pump throttling valves	15 – 30 10 – 40 5 – 10 Up to 50	<3 <5 <2
Optimisation of dosage and type of sludge conditioning agent	Up to 30	–
Optimisation of heating, ventilation, and air conditioning systems	15 – 65	–

Source: Feng et al. (2012); NERSYDA, (2010); SEA (2020) and SEA (2017)
*Overall energy savings

Financing mechanisms

Potential EE projects can be financed through various mechanisms, depending on the nature of the project, municipality's implementation capacity, financial strength, borrowing capacity, revenue base and commercial financing environment. Some examples are shown in Table 4.

Table 4: Financing mechanisms for energy efficiency projects

MECHANISM	DESCRIPTION	EXAMPLES
Municipal budget	EE projects funded from municipal revenues.	EE projects motivated and included in IDP, WSDP, SDBIP and Project business plans.
Grants	Non-repayable funds from government or donors to municipalities.	Conditional grants (MIG, RBIG, WSIG), Green Fund and EEDSM
Concessional loans (Dedicated credit lines)	Soft public loans to municipalities for EE projects from foreign funders. They usually have lower interest rates.	AFD, SEFA (AFDB), DBSA
Commercial bank loans	Commercial banks lend money to municipalities for EE projects or through Energy services companies (ESCos).	Most commercial banks fund sustainable projects.
Energy performance contracts (Vendor credits)	Financing of EE equipment/ services covered by the ESCos with repayments based on estimated future energy savings. Alternatively, the initial costs are paid by the municipality and the ESCo is required to guarantee energy savings and pay the difference if the expected savings are not achieved.	City of Cape Town SANEDI ESCo register
Climate financiers	Finance for activities aiming to mitigate or adapt to the impacts of climate change.	See: https://greencape.co.za/archives/green-finance-databases/

Source: ESMAP: Financing Municipal Energy Efficiency Projects; NBI: Private Sector Energy Efficiency Programme; and SALGA: Financing Energy Efficiency and Renewable Energy

AFD = French Development Bank, DBSA = The Development Bank of Southern Africa, ESCo = energy service companies, MIG = municipal infrastructure grant, RBIG = Regional bulk infrastructure grant; SEFA = Sustainable Energy Fund for Africa;

WSIG = water services infrastructure grant

Next steps

- Conduct a comprehensive preliminary level 1 energy audit of WWTWs. [A detailed guideline for EE audits at WWTWs can be found (here)].
- Identify areas of high energy demand and feasible interventions to promote EE.
- Conduct a financial pre-feasibility study and identify a feasible financing model/s.
- Explore other EE and RE interventions [biogas, hydro power, pre and post treatment, pumping, sludge management, solar PV, and thermal beneficiation].

Pipeline development to deploy **clean energy technology solutions in municipal wastewater treatment works of South Africa**

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