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

Technical factsheet for **biogas combined heat and power (CHP)**

01 Energy management and optimisation
02 Pumps and motors
03 Primary and tertiary treatment
04 Sludge management
05 Secondary treatment
06 Solar photovoltaic (PV) technology
07 Biogas combined heat and power
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09 Thermal beneficiation and treatment of wastewater sludge
10 Energy storage systems

This factsheet on biogas combined heat and power (CHP) forms part of a series of ten (10) factsheets that highlight the renewable energy and energy efficiency technologies relevant to wastewater treatment works (WWTWs). The full lists 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 aiming to:
  - > Offset electrical and heating demands of WWTWs by generating heat and/or electricity at their WWTWs.
  - > Reduce the carbon footprint of WWTWs.
- Private developers and engineering, procurement and construction companies looking for opportunities to explore the WWTW market.
- Funders and investors interested in supporting RE projects at WWTWs.

This factsheet discusses:

- The feasibility of integrating a CHP system with existing or planned biogas installations at WWTWs.
- The potential energy savings and business case of biogas projects in municipal WWTWs.
- Financing mechanisms for biogas projects in municipal WWTWs.

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01 Introduction

Anaerobic digestion (AD) is a widely used technology in WWTWs to break down organic waste in wastewater and/or sewage sludge using microorganisms in an oxygen-free environment. The process produces biogas as a by-product. This biogas primarily consists of methane (CH_4) and carbon dioxide (CO_2), along with trace amounts of other gases such as nitrogen (N_2), ammonia (NH_3), and hydrogen sulphide (H_2S). Biogas is combustible due to its high methane content and can be used to power a combined heat and power system (CHP) to co-produce heat and electricity.

AD is mainly used for wastewater sludge (primary and secondary) treatment as it stabilises the sludge, and reduces pathogens, odour, organic content, and ultimately the volume of sludge to be disposed.

About 50 WWTWs in South Africa use AD as part of the sludge treatment process. However, the biogas produced at WWTWs is typically flared or released into the atmosphere. Although flaring decreases the GHG emissions in comparison to release, there is still an opportunity to also recover energy from about 1 900 tonnes of wastewater sludge produced each day from South African WWTWs[1].

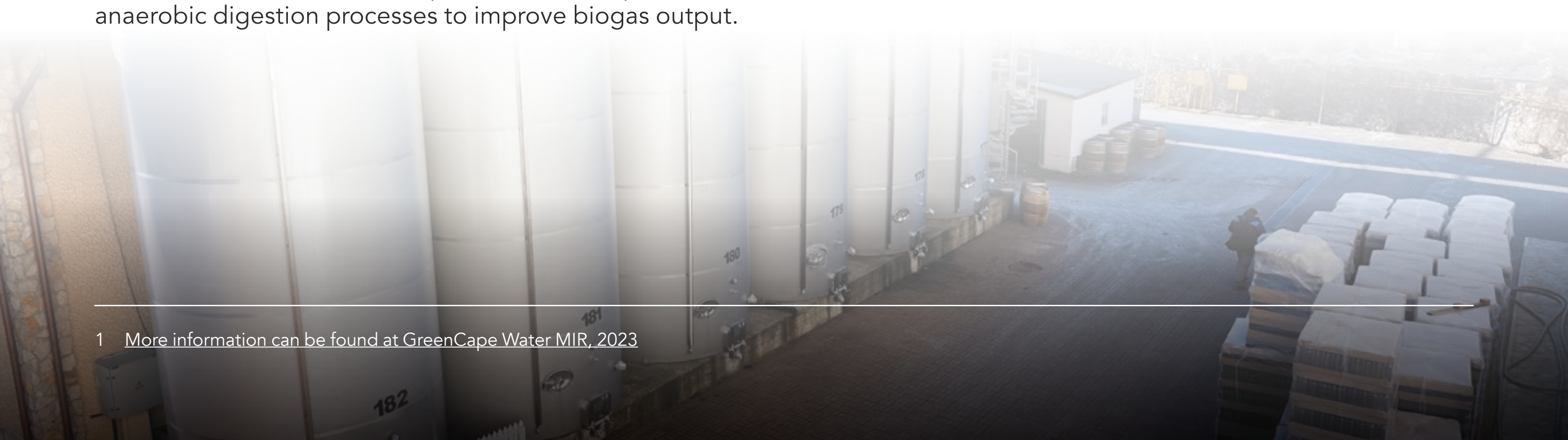
1.1 Wastewater sludge

The specific wastewater treatment process employed by the WWTWs influences the quantity and quality of wastewater sludge produced. Generally, WWTWs in SA use the conventional activated sludge process and its variants (biological nutrient removal and extended aeration), and trickling filters. The primary sludge produced in primary settling tanks possesses the highest nutrient content and is the best feedstock for biogas generation. In contrast, humus from trickling filters and secondary/ waste activated sludge (WAS) has lower nutrient levels and is more stabilised than primary sludge and therefore has less biogas potential.

1.2 Anaerobic digestion technology

The process of anaerobic digestion is a series of chemical reactions carried out by microbes breaking down organic material under oxygen-free conditions resulting in the production of biogas. There are a variety of factors that determine biogas production rates and yields such as digester temperature, mixing and throughput. The composition and digestibility of the organic feedstock is also a determining factor in biogas yields. Digesters with increased temperatures (~38°C) and mixing, as well as longer residence times, are associated with increased biogas production. However, digesters without heating or mixing are also commonly used due to their decreased capital and operating costs. Furthermore, in order to improve the digestibility of feedstocks, additional thermal, mechanical and/or chemical treatment steps are often incorporated into anaerobic digestion processes to improve biogas output.

One such treatment that has increased in popularity in WWTW sludge applications is thermal hydrolysis, a process which uses high pressures and steam to break down the feedstock prior to anaerobic digestion (refer to the fact sheet on thermal beneficiation and treatment of sludge). The optimum process configuration for a given biogas installation will depend on the nature of the existing plant and waste stream. Aspects which improve digester performance or biogas output need to be weighed against their associated capital and operating costs.



1 More information can be found at GreenCape Water MIR, 2023

1.3 Biogas to energy using combined heat and power system

The coupling of a biogas installation with a CHP system, which typically consists of an internal combustion engine, gas turbine and a heat recovery unit, helps to recover electrical and thermal energy in a single process. During the combustion of biogas, the energy released drives a generator, producing electricity and waste heat. The generated electricity can be used to power the WWTWs, offsetting its electricity consumption from the grid and indirectly its GHG emissions. Additionally, the waste heat can be captured and used for various purposes, such as heating the WWTWs' anaerobic digesters, sludge drying, heating, ventilation, and air conditioning (HVAC) of onsite buildings. This significantly increases the overall energy efficiency of the CHP system.

The following are key performance metrics for biogas CHP systems, **per tonne** of wastewater sludge digested on average[2]:

- Biogas yield: 35m^3 (approximately 60% methane content)
- Overall conversion efficiency: 60 - 80%
- Electrical energy yield: 70kWh of electricity
- Thermal energy yield: 75 kWhJ

Figure 1 below shows the general process of an anaerobic digester fitted with a CHP system.

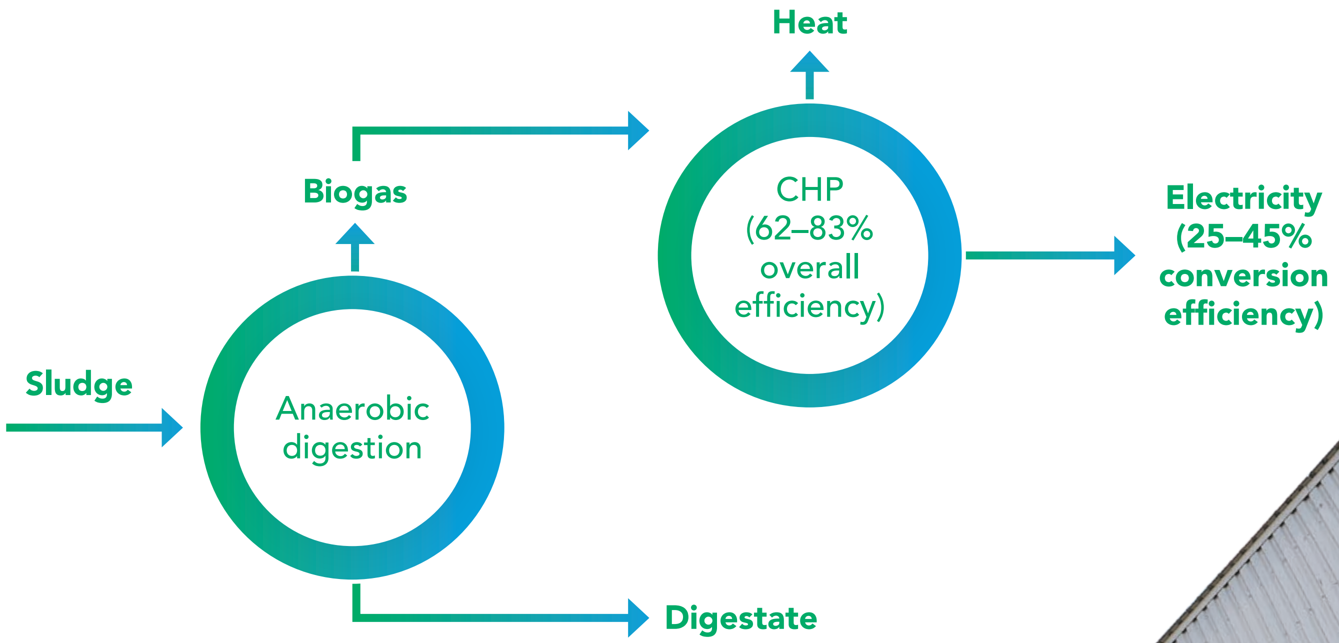


Figure 1: Process flow diagram for conversion of biogas from WWTW sludge into heat and electricity using CHP

2 More information can be found at: Biogas Potential: A Survey of South African Wastewater Treatment Works

3 More information can be found at: Biogas to Energy at Municipal Waste Water Treatment Works

Business case

The key criteria that should be taken into account when considering implementing CHP at a WWTWs is provided in **Table 1**. The installation of a biogas-CHP system can improve the operation of WWTWs by addressing:

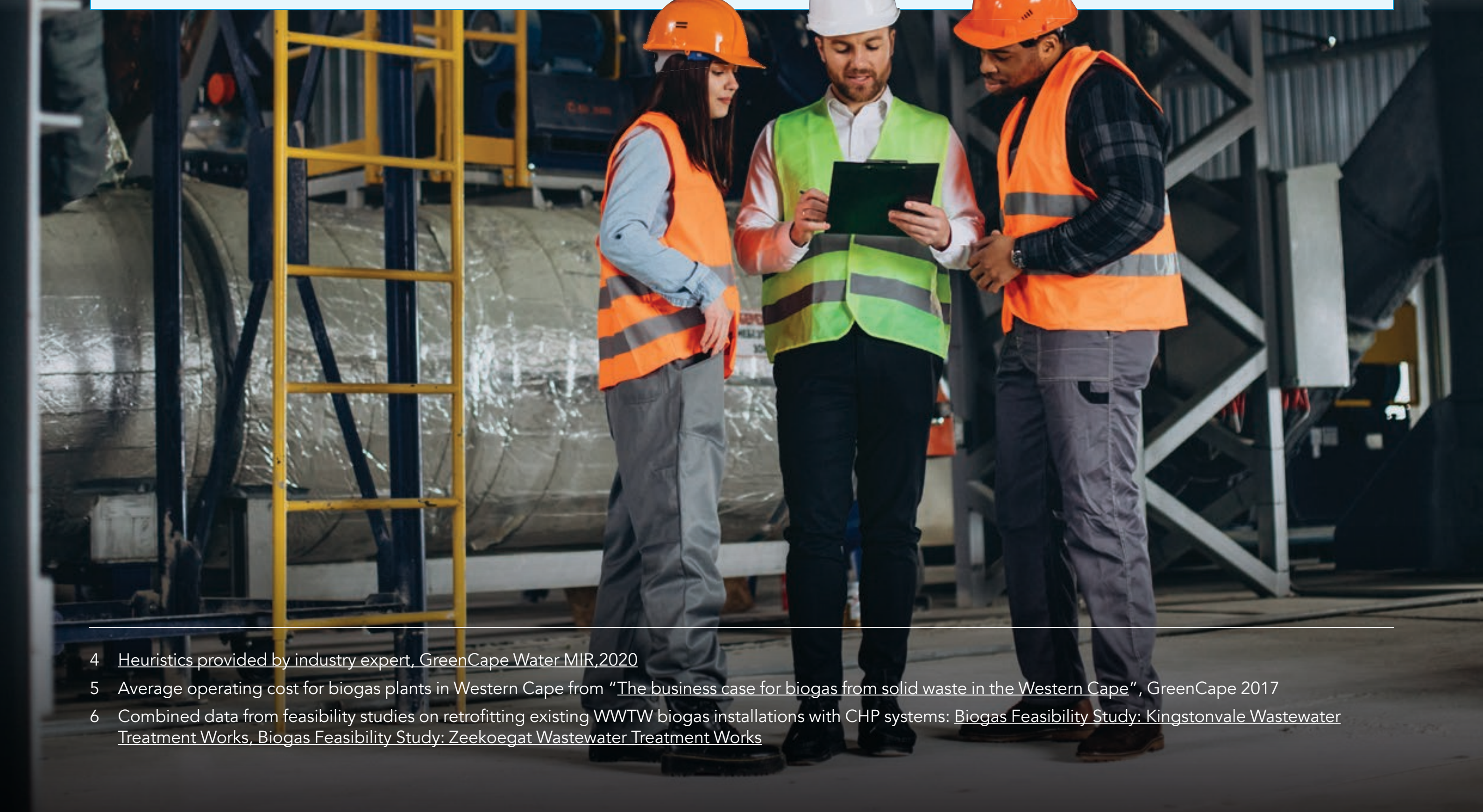
- The costs incurred and regulatory barriers around transporting and disposing of large volumes of sludge.
- Load shedding impacts and the need for additional sustainable energy (heat or electrical) to aid the WWTWs process.
- The hazard posed by the production and storage of large volumes of organic-rich, biologically activated sludge.
- The release or flaring of biogas being produced in WWTWs.

Consider this technology if:

- The WWTW has an existing AD system that can be updated or modified to include a CHP system.
- If a pre-feasibility/feasibility study has been completed and it dertermined that your WWTWs can implement anaerobic digestion.
- The WWTWs has an inflow capacity of >15 MLD (MLD = million litres per day) if aiming for the project to be financially feasible.

Table 1: Decision-making criteria for installation of biogas-CHP at WWTWs

BUSINESS CASE:	
Anaerobic digester + CHP[4]:	**CHP only (existing anaerobic digester)[6]:**
Capital cost: ~ R40 million/ MW (electrical capacity)	Capital cost R20-45 million/ MW (electrical capacity)
Operating cost: R 1700/kW (per annum, electrical)[5]	Operating cost: ~16% of the capital cost
Payback period: ~15 years	Payback period: 5-15 years
	IRR: 18-30%
Potential benefits: • Offsetting of heating requirements for AD • Treatment of WWTW sludge using AD • Prevention of biogas release to atmosphere	



4 Heuristics provided by industry expert, GreenCape Water MIR,2020

5 Average operating cost for biogas plants in Western Cape from "The business case for biogas from solid waste in the Western Cape", GreenCape 2017

6 Combined data from feasibility studies on retrofitting existing WWTW biogas installations with CHP systems: Biogas Feasibility Study: Kingstonvale Wastewater Treatment Works, Biogas Feasibility Study: Zeekoegat Wastewater Treatment Works

Financing mechanisms

Potential EE and RE 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 2.

Table 2: 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 pre-feasibility/feasibility studies to determine the expected techno-economic performance of the addition of biogas CHP system to WWTWs[7].
- Determine a suitable financing mechanism for the project.
- Investigate requirements for authorisation and permits around activities such as gas emissions, construction, energy generation, biogas storage, and waste treatment.
- Begin the process of planning, technical design, procurement, risk management etc. of biogas-CHP installation.

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

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> Department of Cooperative Governance and Traditional Affairs
> Department of Science and Innovation
> Development Bank of Southern Africa
> National Treasury
> South African Local Government Association
> Municipal Infrastructure Support Agent
> South African National Energy Development Institute

7 More information can be found at: Biogas to Energy at Municipal Waste Water Treatment Works

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