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Implemented by: giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

EXECUTIVE SUMMARY

BIOGAS FEASIBILITY STUDY
Kingstonvale Wastewater Treatment Works

Report for: Kingstonvale WWTW, City of Mbombela

Commissioned by: Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

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1. PROJECT SUMMARY

The detailed feasibility study on the production of power to reduce the electricity purchase of Kingstonvale WWTW Wastewater Treatment Works determined the technical and economical baselines for this specific case. Different scenarios of Biogas to Energy production have been evaluated. The study present recommendations for further consideration by Mbombela Local Municipality:

First step: Starting with a CHP-project of 250 $kW_{e,}$ using the sludge from WWTW only, requires a moderate investment 10 m ZAR, will replace 67% or 1.96 m kWh/yr of consumed power, the static payback period is shown with 13.7 years. A more detailed stochastic financial modelling shows a discounted payback period of 12.4 years, an IRR of 18.8%. The existing practice whereby methane is directly released to the atmosphere will be discontinued, which will safe 22 639 t CO_2 equivalents (reduction of 89 %).

Further steps: In addition to the sludge from the WWTW, additional agro-industrial wastes could be secured for co-digestion, utilizing of the full capacity of the existing digesters. Such an extended project would require an additional investment of 12 m ZAR, depending on type of waste available, creating a payback period of 9.2 years. The detailed stochastic analysis shows a discounted payback period of 9.67 years and an IRR of 21.9%. The electricity production will **exceed** the internal consumption by 88% and will amount to 5 509 000 kWh yearly. The study confirmed an existing potential of 26 ton/d waste, versus a demand of 63 ton/d.

A successive implementation is recommended whereby in Step 1 already an upgrading should be foreseen. This would include premature installation of some components (e.g. gas treatment, gas pipes), while the main investment in the CHP will be split into several units.

According to the recommended **Business Model,** Sembcorp will be responsible for Design, Build and Operation of the supplied plant and equipment. The precise exclusion of contractual obligations should be based on the existing contract and the financing possibilities or intentions.

The Feasibility Study provides sufficient information and data to enable the asset owner Mbombela Municipality and the operator Sembcorp Ltd. SA to make a sound decision regarding the future of a Biogas-to-Energy project at the Kingstonvale WWTW.

Three general recommendations are highlighted:

1. Abandon the draw and fill operation of the digester since this create an explosive atmosphere.
2. Optimise the operation of plant by increasing the feed sludge density and optimise the loading regime and operational configuration of the anaerobic digesters.
3. Combust and flare the produced biogas to reduce methane emissions and risk of explosion.
4. Currently, the Kingstonvale WWTW operates at 80% of its design capacity regarding COD reduction. A yearly increase of 2% in COD load will exhaust this reserve capacity within the next 9 years. The expansion of the plant should be considered at an early stage.

2. BACKGROUND

South Africa faces challenges in the security- and cost of supply of energy. In the subsector of biomass the usage of wet waste streams, next to solid waste and wood-based biomass, offers significant opportunities to produce biogas and generate electricity. Unlike foreign markets, this source of energy is under-represented in South Africa. Unlike other renewable energies, biogas can be stored and balance peak loads and support load management.

This project aims to develop a Feasibility Study for the generation of electricity and heat from the biogas produced during the anaerobic digestion (AD) of sewage sludge at the Kingstonvale WWTW. This project forms part of the initiatives under the SAGEN "Biogas Market Development" component implemented by GIZ and financed by BMZ German Federal Ministry for Economic Cooperation and Development.

3 STATUS QUO ASSESSMENT

3.1 Design Capacity, Flow Regimes and Loading

The City of Mbombela (former Nelspruit) is located within the Mbombela Local Municipality in the province of Mpumalanga, and has a population of approximately 54 181 people. The greater city is served by the larger of the Mbombela plants, i.e. the Kingstonvale WWTW, which is managed and operated by Sembcorp Silulumanzi as per a concession agreement of 30 years, ending in 2029. Additionally, industrial wastewater is treated.

The plant is registered as a Class B facility with the Department of Water and Sanitation (DWS). The plant's design capacity (ADWF) is 26 Ml/d, and consists of a 15 Ml/d conventional bio-filter and polishing module and 11 Ml/d activated sludge module.

The figure below shows the plant layout.

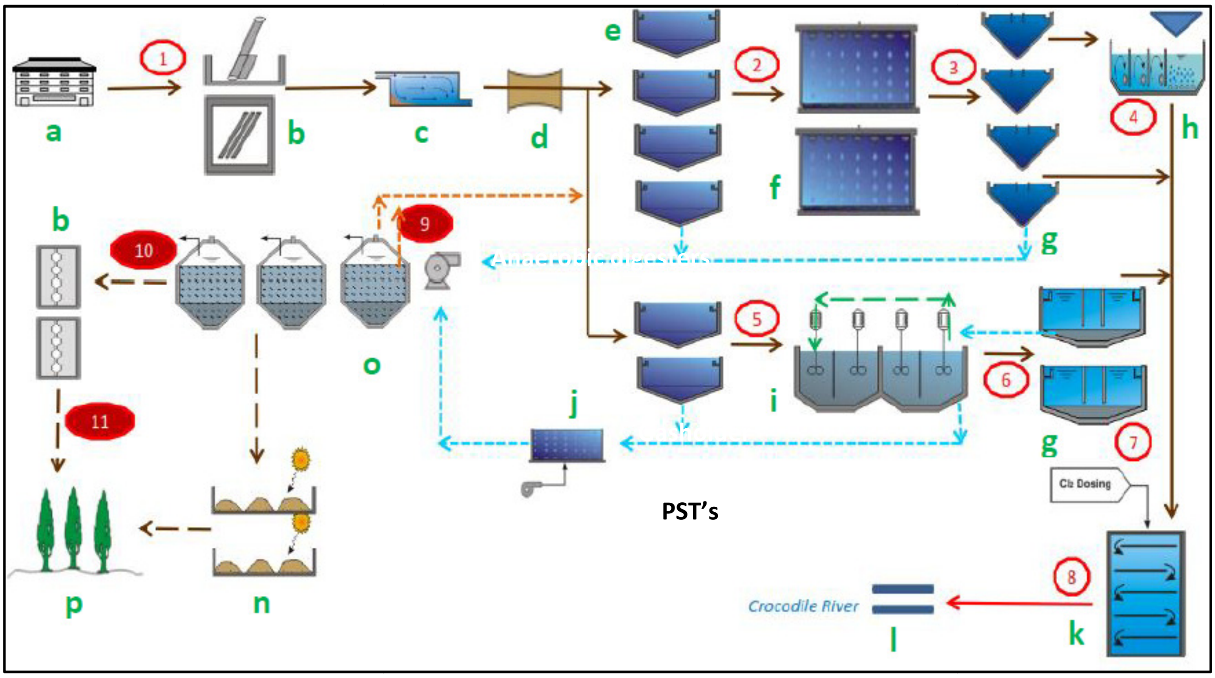


Figure 1: Simplified Kingstonvale process flow diagram

3.2 Flow and load dynamics

The inflow and COD load patterns are extracted from the data available (inflow data 2001 to 2017 and Analysis Data Kingstonvale WWTW Raw 2014 – 2017). The results are summarised in the following table.

Table 1: Comparison between actual load profile and the water use license specifications

Discharge License	Design capacity	ML/d	27
	spec. consumption	l/P,d	180
	P.E. licence, water		**150.000**
COD Analysis data 1/14 - 5/17 and Inflow data 8/2001 - 5/2017	Inflow COD	mg/l	886
	Inflow volume	ML/d	16,5
	Organic load COD	kg/d	14.619
	specific COD	g/P,d	120
	P.E. inflow, COD		**121.825**

Based on the COD load, the Kingstonvale WWTW operates at 80% of its design capacity (as per Water Use Licence). Based on treated effluent volume, the plant operates at 61.1% of its capacity.

For the Biogas Feasibility Study, the measured COD load was used as basis for further estimates, applying an average of 121 825 P.E. person equivalents.

3.3 Status of the Anaerobic Digesters

The three existing digesters were constructed in two stages and have a combined capacity of 7000 m^3:

- First stage: two conical bottom, 2000 m^3 units, mixed and unheated.
- Second stage: a single conical bottom 3000 m^3 unit, mixed and heated. At the time of this upgrade, the first two digesters were equipped for gas collection and upgraded to heated units as well.

A 350 m^3 gasholder was part of the 1999 upgrade, together with a boiler for steam generation and digester heating by steam injection. Gasholder is broken down, steam generation and heating system is not functional any more, gas flare and security devices are missing.

Due to a lack of piping and flaring equipment, the produced gas is currently escaping to the atmosphere.

Operational recommendations: The digesters are apparently operated on a fill and draw mode as well as on a sequential flow mode, i.e. raw sludge is fed into one digester and flows through the series of three digesters. Digested sludge is withdrawn from the last in the series of three. It is reported that 50% of one digester is withdrawn and replaced with a fresh batch of sludge. This approach is subject to likely process upsets resulting poor stabilisation, poor sludge quality and poor biogas production. The Feasibility Study (full report) contain recommendations to improve the process stability and efficiency.

Safety warning:
This modus operandi is highly dangerous. While drawing out the sludge the digester is filled with air. This practice is not inhibiting the anaerobic digestion and allows the creation of an explosive atmosphere. It is recommended to discontinue this procedure with immediate effect.

3.4 Energy Audit of Plant demand

Kingstonvale WWTW has provided several sources of data on energy consumption:

- Power bills (period 1st April 2015 to 8th April 2016) PB 2016 with daily readings
- Own data collection (May 2017).

The following data are based on these sources:

- Consumption of electricity: 245,034 kWh/month or 2,940,408 kWh/year
- Total costs for electricity: 3,430,000 ZAR/year
- Average specific cost 2016/17: 1.299 ZAR/kWh
- The daily power demand is fluctuating between 6500 kWh and 9500 kWh.

The provided data included readings for different tariffs. The tariffs are split between consumptive and fixed charges. All fixed charges have been split in the total consumption (0.2846 ZAR/kWh for the period 2015/16)) and added to the consumptive charges and resulting as "average tariff 2015". The new tariff costs have been applied to the consumption of 2015/16, which results in the average tariffs 2016/17. The feasibility study operates with these figures for each tariff as shown in the table 4 below (average tariffs 2016/17). The costs increase for the WWTW Kingstonvale is estimated at 7.9% p.a., fluctuations in diesel costs have been not considered.

Table 2: Average Tariffs based on Kingstonvale WWTW power consumption (source: ACC 778095924 Apr 15 to Apr 16; power bills

	power consumption	avr. Tariff 15	avr. Tariff 16/17
	[kWh/year]	[ZAR/kWh]	[ZAR/kWh]
Off-Peak	1 318 190	0.77548	0.863
On Peak	451 305	1.91653	2.03
Standard	1 167 942	1.09389	1.165
Stand-by	2 971	4.67	4.67
total	2 940 408	1.081	1.166

3.5 Feed-stock for Co-Digestion Case

As quantified, the existing anaerobic digesters are not fully utilised as result of the present load on the Kingstonvale plant. This excess capacity can utilised by importing suitable co-substrates.

A number of industries were identified as possible producers of waste streams that would be suitable as co-substrate (to enhance the power generation potential) and is located within a radius of up to 15 kilometres around Kingstonvale to limit possible transport costs. These industries included agro-processing, food, catering, soft drink, breweries and paper industries

Following six industries were identified and summarised as follows:

1. Dri-Froot
    - Comments: It appears that there is no formal arrangement in place and Dri-Froot could possibly serve as a source for co-substrate. Fruit waste is expected to have a VSS content in the order of 90%. Terpene oils associated with citrus waste is toxic to microorganisms (Garcin and Aucamp, 2007) and utilisation should be approached with care.

2. Joubert & Sons
    - Waste stream: solid waste consisting of fruit peels and pips, fruit type not specified.
    - Production rate: Not specified.
    - Comments: Situation is unclear but there could be some reluctance from the side of the game farm to give up this source.

3. Allwin Biodiesel
    - Waste stream: Glycerol, a water miscible liquid, a by-product from biodiesel production.
    - Production rate: 15 t/month, or 0.5 t/d (0.4 m^3/d at SG of 1.26)
    - Current disposal method: Glycerol currently used for manufacturing of soap.
    - Comments: Glycerol waste is presently used for the production soap products. Allwin Biodiesel however expressed an interest in this co-digestion disposal option. Glycerol waste is reported to be an excellent co-substrate to enhance methane production. Furthermore the disposal of glycerol waste from biodiesel production is over-supplying the present market in terms of glycerol demand (in general) to the extent that it is impacting the viability of biodiesel production. Disposal of glycerol as a co-substrate is therefore an excellent disposal solution because it also has positive impacts on the stabilisation of recalcitrant COD resulting in overall higher degree of stabilisation and an increase in methane production. Research has however indicated that glycerol should be limited because excessive volumes will result in process instability. This limit is expected to be in the order of 1% to 8% volumetrically. Considering the current Kingstonvale situation, the available glycerol would be well below the stated limit. It appears this waste stream is continuous and not related to seasons.

4. Cape Fruit Processors
    - Waste stream: solid waste consisting of mango, papaya banana and orange peels and pips
    - Comments: Could serve as a source of co-substrate if there is no formal arrangement with regard to present disposal method. Terpene oils associated with citrus waste is toxic to microorganisms (Garcin and Aucamp, 2007). Citrus waste should be approached with care.

5. JAB Fruit
    - Waste stream: solid waste consisting of persimmon, pineapple, banana, mango and papaya peels and pips
    - Comments: It appears that there is no formal arrangement in place and JAB could possibly serve as a source for co-substrate.

Recommendations with regard to co-substrate:

- The waste generator should be responsible for transport of waste product to Kingstonvale WWTW site. The survey should be extended to include the waste generators ability to terminate present disposal practices and to enter into a medium term agreement for the delivery of co-substrate to Kingstonvale site.
- Care should be taken with regard to citrus waste to ensure that the relative mix does not have any negative impact on the biology of the process due to the terpene oil content of the citrus peel. Test runs should be conducted, but require careful monitoring to give meaningful results. Relative flows of sludge and co-substrate should be measured and recorded. Biogas production rate should also be monitored.
- It should be relatively easy to receive and incorporate the glycerol waste stream into existing infrastructure and equipment. A test run could therefore be conducted with relative ease. In order to conduct a meaningful test run, it would be preferable to install biogas flow meters in order to determine the impact on gas production.

4. BIOGAS PLANT TECHNICAL DESIGN

4.1 Description of Possible Biogas Use

Biogas can be used in many different ways, including:

- decentralised combined heat and power production,
- direct heat utilisation or distribution via heating networks,
- application in gas-powered household appliances,
- processing and feeding into the natural gas grid, and
- utilization as fuel for cars, tractors and trucks.

Biogas can also be stored in the gas network, in decentralised gas storage facilities or by means of heat storage facilities over longer periods of time.

For Kingstonvale, the most viable option would be to use the gas in a combined heat and power (CHP) station for the following reasons:

- Value creation through production of electricity is higher than using biogas for heat production only
- Absence of a heat-consumer or gas-consumer in the vicinity to make it worthwhile to considera heating or gas distribution network

- To feed biogas into a gas grid or to use it as fuel in cars it has to be converted into CNG. This means that all components (except methane) such as CO_2, humidity and other substances have to be removed. The gas need to be pressurized up to 200 bar. The technology for this application is new and expensive.

4.2 Investigated CHP scenarios

Various alternatives were investigated with regard to economic feasibility of a combined heat and power installation with respect to the following reflections:

- **Substrate for biogas production:** WWTW solids only or additional substrates from 3rd party (co-digestion)
- **Energy use profile:** consistent supply throughout the day or focusing on peak-time-periods
- **Sizing:** CHP and biogas treatment equipment
- **Additional technologies:** equipment to heat and mix the sludge, devices to prepare co-substrate.

Options I include the use of sludge from the WWTW, whilst Options II consider the addition of co-substrates. Key characteristics and figures of the options are given below.

- **Option IA - unheated digester**: For this alternative the sludge production was based on a plant loading of 16.5 Ml/d (design average dry weather flow) and a sludge production of 174 m^3/d (at 2.1% solids) primary and 131 m^3/d (at 2.8% solids) thickened secondary sludge. For this option the digesters are operated unheated. Therefore, a lower specific biogas-production is expected. A biogas yield of 1 890 m^3/d was estimated and a 200 kW generator is proposed.
- **Option IB - heated digester**: For this alternative the sludge production was the same as for option IA. But here the digesters are heated and therefore resulting in a higher specific biogas yield. A biogas yield of 2 226 m^3/d was estimated and a 250 kW generator proposed. An additional heating system has to be installed consisting of pump station, pipes and external heat-exchanger. Internal power consumption for pumps is taken into account.
- **Option ID - unheated digester, optimized sludge thickening:** The sludge production in means of dry matter was the same as for option IA. The digesters are operated unheated. In contrast to option IA, an improvement in sludge thickening was postulated with a slight increase of dry matter content which leads to less wet mass. Therefore, a higher hydraulic retention time within the digester could be achieved to get a better biogas production. A biogas yield of 1 965 m3/d was estimated which will provide a 250 kW generator the whole day.
- **Option IIA – maximum co-substrate, unheated digester:** For this alternative option, the sludge production through WWTW was based on the estimations of Option ID. In addition to the normal wastewater sludge, it was assumed that co-substrate was available to the extent that the anaerobic digesters could be loaded to 2.7 kgVSS/m^3 and day. This leads to an additional wet mass of co-substrate of about 63 m3/d. For this option the digesters are operated unheated. A biogas yield of 7 628 m3/d was estimated and a 750 kW generator proposed. Organic substrate from outside has to be prepared to fit the requirements of existing digestion

technology. Therefore, devices like shredder, grinder and feeding pumps are added to investment. Internal power consumption for these devices is taken into account.

- **Option IIB – JAB Fruit co-substrate, unheated digester:** For this alternative option, the sludge production through WWTW was based on the estimations of Option ID. In addition to the normal wastewater sludge, it was assumed that co-substrate from JAB Fruit in the order of 18.7 t/d (dry solids 3.2 tDS/d and VSS 2.5 tVSS/d) was available to maintain the required loading. For this option the digesters are operated unheated. A biogas yield of 2 945 m3/d was estimated and a 350 kW generator proposed. Fruit waste has to be prepared to fit the requirements of existing digestion technology. Therefore devices like shredder, grinder and feeding pumps are added to investment. Internal power consumption for these devices is taken into account.

4.3 Summary of discussed scenarios

Key figures for the evaluated scenarios are reflected in the Table below:

Table 3: Summary of quantified option parameters

Kingstonvale		Option IA	Option IB	Option IC	Option ID	Option IIA	Option IIB
Description		Unheated Digester Size of generator according to consistent supply throughout the day	Heated digester Size of generator according to consistent supply throughout the day	Unheated Digester Size of generator optimised to peak-tariff	Unheated Digester Optimized sludge thickening Size of generator according to consistent supply throughout the day	Unheated digester High load Digester Size of generator according to consistent supply throughout the day	Unheated digester JAB-Waste as Co-Substrate Size of generator according to consistent supply throughout the day
Input	m³/d	**Sludge PST**: 174 with DM: 2.1 % **Sludge from DAF**: 131 with DM: 2.8%	**Sludge PST**: 174 with DM: 2.1 % **Sludge from DAF**: 131 with DM: 2.8%	**Sludge PST**: 174 with DM: 2.1 % **Sludge from DAF**: 131 with DM: 2.8%	**Sludge PST**: 104 with DM: 3,5 % **Sludge from DAF**: 104 with DM: 3,5%	**Sludge PST**: 104 with DM: 3.5 % **Sludge from DAF**: 104 with DM: 3.5% **Organic Waste**: 63 with DM: 23.1%	**Sludge PST:** 104 with DM: 3.5 % **Sludge from DAF:** 104 with DM: 3.5% **JAB Waste:** 18.7 with DM: 17%
Digester load	kg oDM/ m³,d	0,7	0,7	0,7	0,7	2,7	1,1
HRT	d	23,1	23	23	33,6	25,8	30,8
Biogas-yield	m³/d	1.890	2.226	1.890	2.224	7.628	2.945
Size of CHPS	kW	200	250	600	250	750	350
Net Electricity produced	kWh/a	1.669.851	1.743.237	1.671.754	1.964.538	5.509.559	2.229.216
Net Electricity produced ratio to own consumption	%	57%	59%	57%	67%	188%	76%

Depending on the scenario, CHP sizes of 200 up to 750 KW_{el} would be applicable. Net electricity ranges between 1.67 M kWh and 5.5 M kWh per year.

Approximately 67 % of the total electricity demand of the WWTW could be produced in-house using only own sludge. If digesters are loaded to full capacity, an excess electricity of about 88 % above total demand are available to feed into the grid.

4.4 Connection point of CHP

The total operating load of the two plants is **362 kW**, i.e. **215 kW** (Polishing Plant) plus **147 kW** (Activated Sludge Plant). A CHP generator up to this size could be connected to the low voltage side of the supply point of activated sludge and polishing plant, powering both of the two plants or only one of them.

The proposed position to install the CHP generator is identified as follows:

Figure 2: Proposed location of the CHP plant

5. FINANCIAL MODELLING AND COST BENEFIT ANALYSIS

5.1 Estimation of Investment Costs CAPEX, Running Costs OPEX and Benefits

The Estimation of Investment Costs has been done with varying degrees of accuracy. The accuracy varies with depth of the present preliminary designs of the discussed options. The table below summarizes the various types of used cost estimates.

Table 4: Types of Cost Estimates

Item	Kind of estimate
Digester Equipment, including gas pipes connections, gas pipes, trenches, earth work	Price estimates
Gas treatment, including civil work, engineering, installation, put in operation and shipment from Germany if necessary	Guiding price quotations
CHPS, Gas-engine, generator, gas mixer, gas control path, voltage and Cos-Phi regulator, synchronization, control system with remote monitoring, silencer, heat-exchanger, emergency cooler, preinstalled in container, engineering, installation, put in operation and shipment from Germany if	Guiding price quotations

necessary	
Substrate preparation unit in option II, including civil work, engineering, installation, put in operation and shipment from Germany if necessary	Guiding price quotations and price estimates
Electrical connection, incl. cabling, control systems, security systems, junction boxes, possible modification of connection point	Price estimates

The CAPEX is split into Technical and Constructive Devices to allow different depreciation rates. Most items include both types of cost groups.

The operational expenditures summarize the reoccurring costs of an investment. These include in particular costs for operation of gas-treatment, effluent handling, wages of employees, maintenance and annual inspection cost of the CHPS, insurance policy for the CAPEX. We did not include effluent handling, and wages of employees involved in sludge handling, because these costs are inevitable cost even when there is no CHP running. Maintenance costs of the CHP are determined as percentage of the CHPS´s CAPEX. Additionally a capital interest rate (14%) of the total CAPEX has been included into the OPEX.

In options II, operational cost respective power consumption for substrate preparation was taken into account.

The depreciation has been determined using three depreciation rates:

- 16.6 % (life span 6 years) for the CHPS
- 12.5 % (life span 8 years) for other technical equipment and accessories
- 5 % (life span 20 years) for structural investments.

In general, a biogas plant with added CHP has three main outputs:

- Electrical Energy
- Thermal Energy
- Effluent.

In all options, the produced power is solely used to satisfy the in-house power consumption of the WWTW. The benefits are calculated as saving on costs of electricity provided and in-house produced power through diesel generators.

One has to note that this biogas system is **not** creating any monetary income but savings on energy. Economically these savings are regarded as income although not creating any physical cash-flow.

The one exception here is Scenario Option IIA were excess electricity will be produced and sold to the grid. The regulatory environment are still under development to accommodate these opportunities and new developments need to be followed in future if Mbombela wishes to explore this avenue.

5.2 Economic modelling and economic evaluation

This study considered two approaches for economic evaluation: Static economic evaluation and Dynamic economic modelling.

5.2.1 Static economical evaluation

Approach: This calculation uses static, single point values to show the feasibility of discussed options in terms of Payback time period. PBT-Period was calculated using surplus versus investment costs when surplus will be calculated being total benefit minus OPEX minus depreciation. Main question here is: Will there be a payback of invested capital within life span of implemented technology. Results are shown in the following table.

Table 5: Results static economical evaluation

Kingstonvale		Option IA	Option IB	Option IC	Option ID	Option IIA	Option IIB
Description		Unheated Digester Size of generator according to consistent supply throughout the day	Heated digester Size of generator according to consistent supply throughout the day	Unheated Digester Size of generator optimised to peak-tariff	Unheated Digester Optimized sludge thickening Size of generator according to consistent supply throughout the day	Unheated digester High load Digester Size of generator according to consistent supply throughout the day	Unheated digester JAB-Waste as Co-Substrate Size of generator according to consistent supply throughout the day
Measurements to be implemented		Renew digester equipment New CHP 200 kWel Gas cleaning 80 m³/h Gas connection Digester-CHP Electrical connection CHP-internal grid	Renew digester equipment Installation of external heating system New CHP 250 kWel Gas cleaning 96 m³/h Gas connection Digester-CHP Electrical connection CHP-internal grid	Renew digester equipment New CHP 600 kWel Gas cleaning 260/96 m³/h Gas connection Digester-CHP Electrical connection CHP-internal grid	Renew digester equipment New CHP 250 kWel Gas cleaning 96 m³/h Gas connection Digester-CHP Electrical connection CHP-internal grid	Renew digester equipment New CHP 750 kWel Gas cleaning 330 m³/h Gas connection Digester-CHP Electrical connection CHP-internal grid Installation of devices for substrate preparation	Renew digester equipment New CHP 350 kWel Gas cleaning 130 m³/h Gas connection Digester-CHP Electrical connection CHP-internal grid Installation of devices for substrate preparation
Investment costs, incl. VAT 14 %	ZAR	8.520.000	12.665.000	14.633.000	9.742.000	21.875.000	15.573.000
Depreciation	ZAR/a	1.167.475	1.628.050	2.058.900	1.360.850	3.049.825	2.111.625
Operational cost	ZAR/a	1.348.692	1.819.023	2.157.039	1.549.186	3.113.665	2.069.123
Income	ZAR/a	1.922.649	2.007.149	2.348.386	2.261.949	5.483.595	2.598.875
Surplus	ZAR/a	-593.518	-1.439.925	-1.867.553	-648.087	-679.895	-1.581.872
Cash Flow	ZAR/a	573.957	188.125	191.347	712.763	2.369.930	529.753
PBT	a	14,8	no	no	13,7	9,2	29,4

According to the table above the Options which represent the best business case and benefit are Options IA, ID and IIA.

Further results are:

- **Option IB has no PBT-Period:**
  Even if more biogas is produced, additional CAPEX for heating system is too high for being viable.
- **Option IC has no PBT-Period:**
  Focusing on peak-time period is not viable due to high CAPEX of large CHP.

- **Option ID is slightly better than Option IA:**
  Operational changes can results in a higher DM-content of sludge which leads to higher HRT and higher biogas production.
- **Best option is IIA:**
  The use of a co-substrate ensures that the anaerobic digester capacity is used effectively. Any surplus of electricity could be fed to the grid. Depending on kind of co-substrate, CAPEX for substrate preparation devices could be less and should be adapted when co-substrate is defined.

Note: In work funded by the WRC, the University of Kwa-Zulu Natal has developed a protocol to screen potential wastewater streams for co-digestion with sludge. The methodology is designed to test the biodegradability of the waste, optimal ratio of wastewater to sludge and identify any potential inhibitory effects

Options ID and IIA were selected for further detailed calculations.

5.2.2 Dynamic economical modelling

The modelling details are presented shown in the full study report. A total of 4 scenarios were evaluated to determine the most economically feasible configuration. As noted above, for each main scenario defined, an additional sensitivity scenario was compiled to evaluate the effect of adding revenue streams, additional to the baseline assumption of electricity only.

Table 5: Summary of the main economic factors for the project's different scenarios:

Scenario:	ID EXCL	ID INCL	IIA EXCL	IIA INCL
Variables:				
IRR	18.80%	20.40%	21.90%	24.60%
MIRR	17.10%	17.70%	18.10%	18.90%
NPV_20	R3.9m	R5.4m	R15.4m	R22.8m
Discounted Payback Period	12.4 yr	10.7 yr	9.7 yr	7.3 yr
Estimated Capital cost incl. VAT & duties	R10.1m	R10.1m	R22.4m	R22.4m
DSCR debt service coverage ratio	1.65	1.77	1.87	2.27
NPV / CAPEX	38.8 %	53.2 %	68.9 %	101.8 %

From the summary, the most economically feasible project option, by most metrics (CAPEX restrictions ignored) is Option IIA, with significant opportunity to optimize on income potential by adding additional revenue streams, such as selling waste sludge as fertilizer (Options INCL). An IRR between 19.5% and 23.8% can realistically be expected for the base case scenario for Option IIA, with an expected NPV range of between R11.7mil and R21.7mil. The discounted payback period for Option IIA is between 7.3 and 9.7 years. Option IIA INCL provides the highest earnings per Rand spent with a median value of R1.02 NPV per R1.00 CAPEX. When assuming a 50% loan for the project with interest rate equal to the assumed WACC of 14%, the Net DSCR is between 1.61 and 2.50 for the base case.

6. ENVIRONMENTAL CONSIDERATIONS AND ROLEPLAYERS

6.1 Overview of the South African Legislative Environment

Policy: The framework set out for the energy sector is implemented by the Department of Energy which is primarily commanded by the National Development Plan (2011), the 2003 White Paper on Renewable Energy; the Electricity Regulation Act (2006), the Integrated Resource Plan (2010), and the Integrated Energy Plan (2013).

Legislation: In the absence of a dedicated legislative framework for biogas, a number of Acts and Regulations need to be consulted prior to the approval for the development of a biogas project. These include:

- National Environmental Management Act (NEMA)
- National Environmental Waste Act (NEM;WA)
- National Environmental Air Quality Act (NEM:AQA)
- National Environmental Biodiversity Act (NEM:BA)
- National Environmental Protected Areas Act (NEM:PAA)
- National Heritage Act
- National Gas Act
- National Water Act
- Spatial Planning and Land Use Management Act
- Municipal planning regulations.

The relevant national government departments include the Department of Environmental Affairs (DEA), Department of Water and Sanitation (DWS), Department of Agriculture and Fisheries (DAFF), and the Department of Energy, and the National Energy Regulator of South Africa, NERSA. Facilities are also subject to local municipal bylaws and strategic planning documents that have jurisdiction.

The main activities that are regulated include:

1. Environmental authorisation for establishment, construction and/or upgrading;
2. Waste licence for treatment of sewage sludge;
3. Atmospheric emission licence;
4. Water use licence authorising the management and disposal of wastewater;
5. Registration of energy generation facility;
6. Licensing of energy generation connected to the grid;
7. Storage of biogas; and
8. Beneficial use of digested sludge as a fertiliser.

6.2 Status Quo of Kingstonvale Wastewater Treatment Plant

The draft IDP for 2017 to 2022 for the City of Mbombela sets out the development objectives of the municipality. Development objective 25 is "An environmentally friendly and tourism centre region", which comprises a two pronged approach. One approach is described as:

"Developing the municipality into an environmentally friendly municipality means that the municipality creates a favourable environment for recycling and waste management activities, encourages sustainable production practices and promotes the use of alternative energy sources".

One potential project that has been identified is energy production from waste. It is identified as an anchor project aimed at medium to long-term implementation. Renewable energy is identified in Strategy 4: Economic nodes in the Mbombela Vision 2030.

The Kingstonvale WWTW has a valid water use licence dated 2 June 2009, which was submitted for review by the Inkomati Catchment Management Agency in January 2017. The current authorisation allows the disposal of 1,500m^3/d of sludge to drying beds which must be classified and disposed of in accordance with the WRC sludge guidelines. Currently, 150m^3/day of sludge (2.9% solids) is disposed to the drying beds and is characterised as A2c sludge type.

The current municipal electricity bylaws do not include provisions for the renewable energy projects connected to the grid.

Based on the status quo with regard to authorisation of the existing plant and the proposed biogas project, the processes that will be required to fully comply with the environmental legislative framework are summarised in the following table.

Table 6: Additional legislative processes for biogas project

Activity	Legal Framework	Legislative Requirement	Process Required	Action Required
Sludge treatment	National Waste Management Act (No. 59 of 2008)	Category B listed waste activity Waste licence required	Scoping and EIR process Waste licence application	Waste license required
Biogas utilisation	Electricity Regulation Act (No. 4 of 2006) National Gas Act (No. 48 of 2001)	Registration with NERSA Registration with NERSA	Register electricity generation and on-site use Register biogas project and on-site use	Yes, registration required
Biogas combustion	Air Quality Act (No. 39 of 2004)	Gas combustion listed activity Air quality licence required	Scoping and EIR process Air quality licence application	No No, but need to be confirmed
Water	National Water	Discharge of	Notification of amendment	No, covered in

Activity	Legal Framework	Legislative Requirement	Process Required	Action Required
management	Act, 1998 (No. 36 of 1998)	waste that may impact on water resource Water use licence required	to sludge management and disposal to DWS	existing authorisation Review process currently busy with IUCMA
Beneficial use of sludge	Fertilisers, Farm feeds, Agricultural remedies and Stock Remedies (No. 36 of 1947). WRC Guidelines for utilisation and disposal of wastewater sludge	Sale and disposal of fertiliser to be registered Sludge disposal methodology guided by classification of sludge	Determine ultimate disposal of digested sludge and register with DAFF is product is to be sold as a fertiliser Classify digested sludge and confirm disposal route is appropriate	No, unless biosolid is to be sold as fertiliser, etc. Yes, but this is covered under existing Authorisation
Municipal framework	Strategic planning frameworks Bylaws	Project to align with municipal strategic direction Conditions for biogas projects defined	Include project in strategic planning and budgeting framework Existing bylaws do not make provision for renewable projects and will be updated for future application	Yes Yes
Institutional Arrangements	Water Services Act 108 of 1997	Contractual requirements between WSA and WSP	Formal service level agreement between WSA and any service provider appointed to support with service delivery	Yes, depending on business model and use of PSP. In this case, it could be an addendum to the existing contract between Mbombela and Sembcorp.

TBC = to be confirmed by regulating authorities

6.3 Role-Players in the Biomass/Biogas Environment

The *Municipality* is pivotal in project implementation. The municipality will be implementing the project from project preparation to operation phase. The municipality will own the infrastructure, will contract out and manage service contracts for operation of the facilities. The municipality contribute significantly to the project by making available existing wastewater facilities and fixed assets to the projects where possible, while taking responsibility for the long-term financial commitment associated with the operation and maintenance of the projects. The municipality is also responsible for sludge management and is the owner of the sludge and its end destination.

In the case of Kingstonvale WWTWs, the *Service Provider* (Sembcorp Silulumanzi) is a key role player as Water Services Provider. This arrangement is covered by a long term concession, whereby the operational and maintenance duties are the responsibility of Sembcorp.

The *Department of Energy* (DoE) is a key driver in both the development and the implementation of Renewable Energy programmes.

Financing Agencies has a role to consider and fund projects under their Renewable Energy units, and if required, to management, monitor and evaluate. A comprehensive list of financing institutions is available from GIZ on request. In the case of municipal infrastructure financing, the Department of Cooperative Governance and Traditional Affairs (CoGTA) and National Treasury may have defined roles to (co)fund the CHP project.

The *SA Local Government Association* (SALGA) is responsible for representing municipal interests in parliament, comment on legislation, facilitate knowledge exchange between municipalities and in general facilitate the improvement of waste management services at municipalities.

Various *Government Departments* have a role biogas projects which may be from the perspective of regulation, monitoring or as synergies with their own Renewable Energy initiatives. These may include Provincial Government Departments, the Department of Environmental Affairs (DEA), Department of Trade and Industry (DTI), Department of Science and Technology (DST), Department of Agriculture (DoA), Department of Water and Sanitation (DWS).

Organised Business and *Private Service Providers* (PSPs) such as SABIA and project developers will have commercial interest and expertise to offer. PSPs will be invited to bid and will be contracted to operate facilities. PSPs will contribute to the monitoring and evaluation of the programme, taking on responsibilities with regard to reporting on different technologies.

Third party consultants will be invited to bid and will take on responsibilities in technical assistance for due-diligence and business plan development, project preparation, transaction advisory services, construction service supervision and technical assistance during operation.

Parastatals such as ESKOM will have an interest from a strategic supply point of view and taking note of the need for pricing strategies and incentives to municipalities on biogas projects in future.
Research, Technology, Development and Innovation Institutions has a role to play in terms of sourcing, developing, and communicating technologies and performance achieved via the treatment of sludge, the use of biosolids and generating information that inform the sustainable futures of Renewable Energy and Sludge Treatment in future.

Institutions and agencies such as GIZ, SANEDI, SABIA, etc. are involved in the development and support of various project, depending on their respective mandates.

Industrial partners, such as the industries identified for possible supply of organic substrates for co-digestion. An agreement between the supply and receipt of organic waste to co-feed the anaerobic digesters would be paramount to optimise the biogas production and instrumental in the success of the CHP project.

Research and technology partners, such as the Water Research Commission, universities and technical colleges, who are responsible to advance and disseminate research and emerging technologies in the water sector.

7. INSTITUTIONAL AND BUSINESS MODELS

7.1 Background for the Business Model

The asset ownership and project execution strategy is an important consideration and will ultimately depend on financing model, the appetite for risk, business strategy, responsibility allocation, contract period, skills base, regulatory requirements and governmental factors and drivers. Different preferential models which suit the specific needs of the municipality and the WWTWs should be considered.

In the table and figure following, different business models are explored. These models may not be exhaustive, but may serve as springboard for more discussion within the municipality on the suitability of the models or hybrids thereof.

For the purpose of this section, it is assumed that a proposed CHP facility may include aspects such as feed sludge thickening and rehabilitation/upgrading of the anaerobic digesters. The illustrative table below shows a range of management options whereby business model number 1 renders the highest level of ownership and operational responsibility to the municipality (WSA) or a Professional Service Provider (as WSP), in contrast to the higher number options which leans towards lesser ownership by the WSA and/or more outsourcing of operation and maintenance responsibilities to a PSP (as WSP).

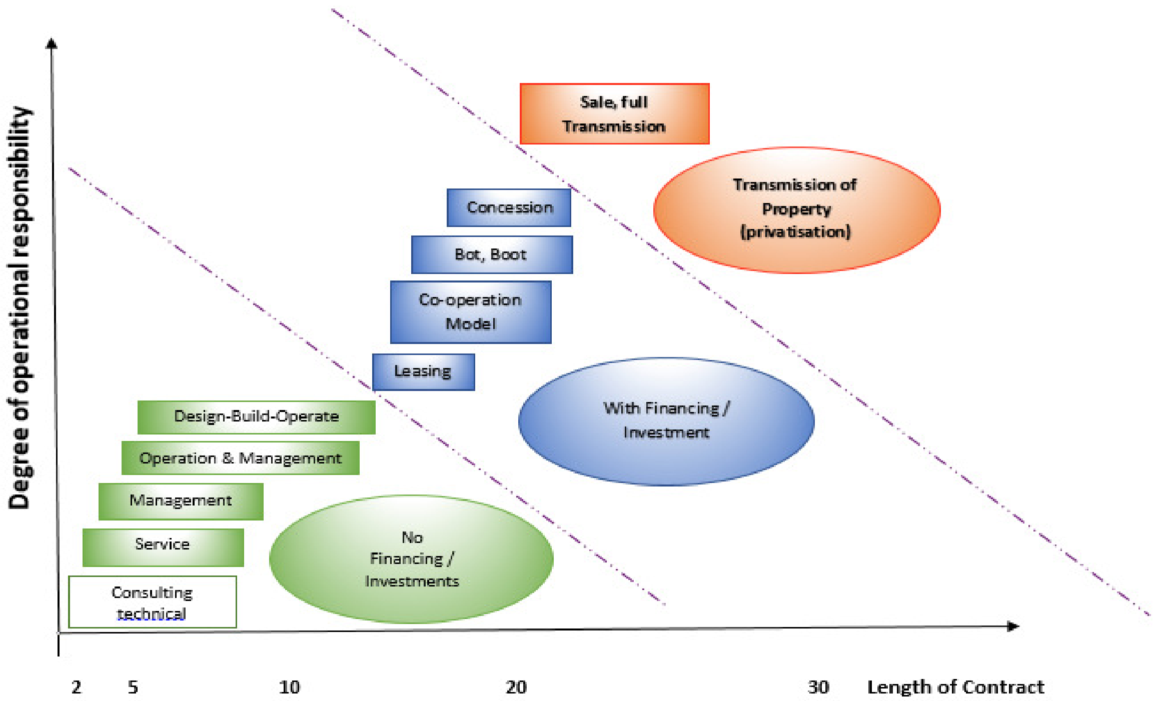
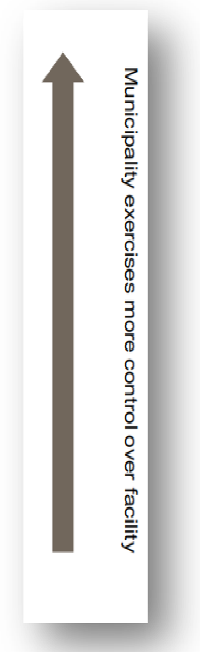


Figure 2: A schematic representation of business models versus responsibility and contract period (GIZ, 2017)

Possible models are:

1. Investment and operation by the municipality with maximal participation.
2. Outsourcing of the energy production, based on a monthly operation fee and a tariff per kWh. Thermal energy used for digester heating and electricity for the on-site use.
3. Outsourcing the sludge treatment from post thickening process steps, anaerobic digestion and energy production, based on a monthly operation fee and a tariff per kWh. Thermal energy used for digester heating and electricity for the on-site use. Digested sludge returned to WSA.
4. BOT/BOOT* model for the proposed CHP system while WSA remains responsible for the balance of the WWTW.
5. Outsourcing the total sludge treatment from post thickening process steps, anaerobic digestion and energy production, based on a monthly operation fee and a tariff per kWh. Thermal energy used for digester heating and electricity for the on-site use. Digested sludge dewatered and disposed by PSP (as WSP).
6. Outsourcing of operation of the complete plant.
7. Transfer of ownership/privatisation with complete take-over by PSP.



7.2 Potential business model for Kingstonvale WWTW/CHP

A 1st order SWOT analysis, present the following strengths and weaknesses for the City of Mbombela / Sembcorp. The City is the WSA and Sembcorp is the PSP/WSP in the treatment of wastewater, as outlined in a long-term concession agreement:

Mbombela - Kingstonvale WWTW: Strengths	**Mbombela - Kingstonvale WWTW: Weaknesses**
1. Competent and experienced staff 2. Strong skills/experience base in wastewater treatment 3. High level of commitment to green technologies 4. Reasonable appetite for CHP, if bankable 5. Open to CHP, if various benefits can be motivated to Council 6. Ability to conceive, procure, manage CHP project 7. Possibility of internal funding 8. Limitation on existing (rural) Eskom supply line	1. No CHP skills/experience 2. Limited knowledge of the technology in field 3. Difficulty to attract skilled CHP resources 4. Procurement response time for maintenance repair services 5. Funding uncertain 6. Viability of CHP may depend on co-digestion for a good business case 7. Various other priorities may compete more successfully for funding, (eg meeting stricter effluent quality standards).

The recommended business models for the WWTW are as follows:

Business Model 3: If Mbombela takes a decision to extend its competency to include CHP technology, and Sembcorp takes a decision to remain in current battery limits, business model 3 is the preferred model:

- Capital investment funded by WSP, grant funding, or a combination.
- Sembcorp as PSP remains responsible for the complete WWTW, excluding CHP and directly related aspects.
- Successful DBO-PSP2 be responsible for design, build and operation of the CHP supplied plant and equipment.
- PSP2 is responsible for all aspects related to biogas collection, treatment, conditioning, analysis, flow measurement, boosting and utilization as fuel, power generation and control, heat recovery and distribution to digesters.
- PSP2 responsible for skills transfer during operating period. Option to renew the operational period should the WSP prefer this option at the time.

According present contractual situation between Mbombela and Sembcorp possible contractual combinations have to be clarified:

- Contractual partner for PSP2?
- Payment to PSP2: Agreed amount per month for plant management and O&M of infrastructure and equipment for which the PSP assumes responsibility?

- Payment to PSP2: Agreed tariff per kWh generated and supplied into the site reticulation for consumption by the WSP on site? Tariff depending on contribution to capital investment.
- Payment for site utility services?
- Agreement on mass of sludge at agreed solids content with responsibility for further thickening, anaerobic digestion and related equipment, returning supernatant and digested sludge to the WWTW?

Business Model 6: If Mbombela in association with Sembcorp takes decision to extend its current competency to include CHP technology by extending contract with Sembcorp, business model 6 is the preferred model:.

- Existing contract between Mbombela and Sembcorp should be extended.
- Capital investment funded (or channelled) by Mbombela; or Sembcorp fund the CHP; or a combination thereof.
- Sembcorp be responsible for Design, Build and Operation of the supplied plant and equipment.
- If the PSP fund project, the PSP retain ownership of plant and equipment installed
- Transfer plant to WSP according to agreed residual value
- WSA continue to pay Sembcorp (as WSP) the agreed amount per month for plant management and O&M of existing infrastructure and equipment, plus an agreed amount for the new plant
- Possible compensation of new CHP plant
    - All benefit of savings to Sembcorp when funded through Sembcorp
    - If funding through WSP, payment of interest through Sembcorp, benefits for saving to Sembcorp
    - Selling of electricity to WSA with tariff according source of funding

In comparison with the two models, preference should be given to **model 6**, as this is less complex, especially with regard to the interfaces. The precise exclusion of contractual obligations should be based on the existing contract and the financing possibilities or intentions.

8. RECOMMENDATIONS

The recommendations aim to target aspects that would assist the municipality to advance the project by addressing gaps or sensitivities identified during the feasibility phase of this project.

8.1 Opportunity Roadmap and Recommendations

According to the structure of a SWOT-Analysis, the impact or possible impact of implementing a CHP project can be summarized as follows:

Strengths	**Weakness**
• Reduction of operational costs • PBT-period within life cycle • Reliable source of energy • About 90 % reduction of CO_2 emissions • Improvement of Green Footprint • Reduction of peak demand in ESKOM grid	• Investment in additional technology • Increased requirements on operations of biogas treatment and CHP • Pressure on existing human resource capacity
Opportunities	**Risk**
• Positive effects on efficiency of operation of whole WWTW • Knowledge Hub for RE Renewable Energy and EE Energy Efficiency within SEMBCORP and RSA • Gain from FiT • Set-up of center for treatment of organic waste through co-digestion	• Permanently low electricity price • Long decision-making processes

Figure 3: Possible impact of CHP project

Reduction of operational costs: Using only own sludge the total demand of the plant could be covered up to 67 % with own production of electricity. Savings will lead to a payback time period for CAPEX between 10 and 13 years. If sufficient co-substrate become available to feed the digester to full capacity, then about 2.7 M kWh could be fed into the grid generating additional income.

Improved sludge quality: In order to produce as much as possible electrical and heat energy, the PSP will need to stabilise the sludge. Stabilising is essentially the destruction of volatile suspended mass. The degree of stabilisation required to produce biogas implies that the digested sludge will comply with the Sludge Guideline stabilisation requirement, allowing classification as a Class 1 in terms of stability. This will reduce restrictions in terms of disposal with positive cost implications for the WSP. Well-digested sludge will also lead to a better microbiological quality, although the improvement may not be as well defined as in the case of stability. This will result in a further improved sludge classification, reduced restrictions and reduction in disposal costs.

Reduced sludge mass and related disposal cost: As described above the stabilisation of sludge implies the destruction of volatile solids. Typical solids destruction expected for well controlled anaerobic digesters is in the order of 37% to 44% resulting in a significant mass reduction for Kingstonvale WWTW. This implies a considerable reduction in sludge disposal cost based on mass to be disposed only.

Freeing up of Eskom generating capacity: The generation of electrical energy on the proposed sites implies that energy produced on site displaces the energy consumption by the WWTW resulting in the freeing up of Eskom generating capacity, thus delaying capital investment in power generating capacity.

Opportunity for additional revenue streams: A CHP project will serve as trigger to explore additional revenue streams that will further boost the economics of the energy generation project.

- The identification of organic sources for co-digestion will imply that the surplus capacity of the anaerobic digesters are productively used to increase biogas and energy generation. These waste streams will likely originate from an industrial and agricultural sources, which may see benefit in paying gate fees to the municipalities in exchange for their 'waste' problem.
- Different levels of refinement of the generated biosolids offers economic opportunities, i.e. soil enrichment, composting, and production of fertiliser. Technologies for the precipitation of struvite (MAP), brick making, etc. are available and documented.

Optimisation opportunities: The Kingstonvale site presents opportunities to optimise certain inefficiencies which would contribute to a sustainable CHP future, if addressed.

- The generation of electricity coupled with the reduction in energy demand of the plant will have benefits it terms of the economics and the carbon footprint of the plant.
- Correction of extraneous flows, i.e. water losses, excessive stormwater- and groundwater infiltration to the sewer system will free up capacity at the plant
- Correction to the water losses will reduce Non-Revenue Water, improve the revenue stream, improve the COD loading to the plant, and thereby, improve sludge quality and AD loading for optimal CHP generation.

Reputational value: The City of Mbombela and Sembcorp consider their good name, reputation and brand as important. A CHP project which is rooted in good economics, job creation and environmental consciousness, will benefit the municipal brand and reputation up to being the Knowledge Hub for RE Renewable Energy and EE Energy Efficiency within RSA.

Climate impact potential: Current practice at the WWTW does use the biogas and the methane is released (un-flared) to the atmosphere. The replacement of methane by CO_2 by combustion in a CHP generator is associated with a positive effect concerning avoided greenhouse gas (GHG) emissions, as methane has a significantly higher (factor 25) global warming potential (GWP) than CO_2. The use of biogas as a fuel would substitute the baseline methane emissions (today) by CO_2 emissions in the CHP plant (future).

8.2 Recommendations according to the installation of CHP:

- From economic evaluation, Option IIA seems to suggest a shorter payback period if the assumed availability of co-substrate can be achieved and maintained and a feasible feed-in tariff could be achieved.
- Until co-substrate will be available Option ID should be focussed. Sludge process should be improved to increase DM of sludge to higher retention time in the digester.
- The implementation can be phased in a modular fashion as the co-substrate supply is firmed up:
    - starting with 250 kWe CHP,
    - upgrade with 250 / 350 kWe generator on demand / when co-substrate and funds available, preferably with similarly sized modules.
- The total operating load of the two plants is 362 kW (215 kW - Polishing Plant and 147 kW - Activated Sludge Plant), which is above the potential CHP size of 250 kWe. The CHP generator will power either of the two plants at any one time. Connection point could be activated sludge plant mini-sub.
- It is recommended that the CHP generator primarily supply the Activate Sludge Plant of 215 kW operating load as this operating load falls within the capacity of the potential CHP generator.
- When the Activate Sludge Plant is out of service for any particular reason, the CHP generator will then feed the Polishing Plant of 147 kW operating load.
- Refer to the diagrams to follow for the suggested connection point of the CHP generator.
- Further studies on co-digestion sources and optimized CHP configurations would be required to confirm this arrangement.
- Gas treatment plant should be situated nearby the digesters while CHP should be situated nearby of the connection point. Gas from Gas treatment could easily be conducted to the CHP via gas pipes.

8.3 Recommendations according to the business model:

- Sembcorp should take decision to extend competency to include CHP technology by extending existing contract. Responsibility and operation of all technology steps of the WWTW being in one hand is much less complex, especially with regard to the interfaces as when there is another PSP2 involved.
- The precise exclusion of contractual obligations should be based on the existing contract and the financing possibilities or intentions.

8.4 Recommendations according to anaerobic process stability and efficiency:

- The digesters are currently operated on a fill and draw mode as well as on a sequential flow mode, i.e. raw sludge is fed into one digester and flows through the series of three digesters. Digested sludge is withdrawn from the last in the series of three. It is further reported that 50% of one digester is withdrawn and replaced with a fresh batch of sludge. This approach is subject to likely process upsets resulting poor stabilisation, poor sludge quality and poor biogas production.

- The digesters should preferably be operated on a feed and displace approach. The volume of feed sludge should be as small and continuous as possible (as opposed to infrequent large volumes). This will have a significant positive impact on process stability and efficiency.
- It is strongly recommended that the sludge distribution chamber on the digesters are adjusted and set up to split incoming sludge proportionally to each of the digesters proportional to the digester volumes. This will reduce the volume of fresh sludge with each feed relative to the digester volume and will allow operation of each digester on an individual basis.
- The feed sludge should be managed to ensure the highest solids concentration achievable by the existing process units.
- The temperature of the digester content should be kept as stable as possible and a temperature variation of more than 1°C per day should be avoided.
- The installation of a gas flow meter and recorders/loggers on each anaerobic digester will assist the operator to understand the condition of the digesters and under what conditions high biogas production rates can be expected. High biogas production will coincide with good stabilisation, mass reduction and high quality final solids for disposal.
- There will not be enough energy in the produced biogas to dry the dewatered sludge cake (at present or future full capacity loading), even if the biogas thermal energy was used directly to dry the dewatered sludge cake. In the case where the biogas is directly used for sludge drying, there will also be no remaining energy to heat the digester contents to the operating mesophilic temperature range (which will drastically reduce biogas production).

8.5 Recommendations with regard to the application of co-substrate:

- Further evaluations and test runs of the organic (industrial and agricultural) waste streams which has been identify as potential co-digestion sources is required. A possible (negative) impact of citrus peels, ammonia from chicken waste, fats from abattoir, etc. must be established before a source is confirmed as a suitable co-digestion source. Care should be taken with regard to citrus waste to ensure that the relative mix does not have any negative impact on the biology of the process due to the terpene oil content of the citrus peel. Test runs should be conducted, but require careful monitoring to give meaningful results. Relative flows of sludge and co-substrate should be measured and recorded. Biogas production rate should also be monitored

- The waste generator should be responsible for transport of waste product to Kingstonvale WWTW site. The survey should be extended to include the waste generators ability to terminate present disposal practices and to enter into a medium term agreement for the delivery of co-substrate to Kingstonvale site.

- It should be relatively easy to receive and incorporate the glycerol waste stream into existing infrastructure and equipment. A test run could therefore be conducted with relative ease. In order to conduct a meaningful test run, it would be preferable to install biogas flow meters in order to determine the impact on gas production.

- The co-digestion source material could be utilised effectively (depending on process stability and response times) to boost biogas production during Eskom peak rate periods.

8.6 Recommendation in order to improve the energy efficiency of the plant:

- Implement the current plans to install Variable Speed Drives, etc.
- Replace old non-functional PLC's with new PLC's.
- Replace old non-functional instruments.
- Install solid state smart drives (VSD's and Soft Starters) in all the motor starters from 22 kW and above.
- Supply and install in the control room a modern SCADA system for the overall system for performance monitoring and control.
- Supply and install a fibre Ethernet data communication ring network between all the new PLC's, and between the PLC's and the SCADA system.

8.7 Recommendations according additional value creation

The following additional streams of revenue need to be considered to optimise the returns on this project:

- Selling digested and prepared sludge as fertilizer to agriculture
- Waste gate fees for domestic, industrial, agricultural waste and landfill leachate from non-hazardous waste sites.
- Sale of effluent as compost for its Nitrate and Phosphate properties.
- Struvite recovery and precipitation processes could be investigated to recover MAP (Magnesium, ammonia, phosphate) from the sludge.
- Carbon credit trading (not common in SA yet but a strong economy internationally).
- Other tax incentives that could apply towards renewable energy projects.

9. WAY FORWARD

The Feasibility Study provides the basis for further actions to be taken by Mbombela Local Municipality. The following high-level steps are recommended:

1. Council to take a decision to implement a CHP project, and add this project to the IDP and capital projects list (if positive decision taken)
2. The decision may be supported by the recommended Business Model
3. Set a detailed Project Plan with responsibilities, timeframes, target dates to administer the project
4. Source and secure funds
5. Design, tender and adjudication Construction and commissioning
6. Optimisation of operation as per the recommendations from the Feasibility Study
7. Commence with sourcing of co-digestion phase, and explore fertilizer production

Note: GIZ will remain available in a support and facilitation role after close out of the Feasibility Study. The GIZ network may offer valuable opportunities to facilitate meetings between Mbombela, Sembcorp and financing institutions, government departments, etc.

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