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City of Johannesburg Organic Waste to Biomethane for Bus Fuel Plant

Process Description

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1 ABBREVIATIONS

AD Anaerobic Digestion
BA Basic Assessment
barg bar-gauge
C: N Carbon - Nitrogen ratio
CBM Compressed Biomethane
CH_4 Methane
CHP Combined Heat and Power
CNG Compressed Natural Gas
CO_2 Carbon Dioxide
COD Chemical Oxygen Demand
COJ City of Johannesburg
CSTR Continuous Stirred Tank Reactor
CV Calorific Value
DDF Dual Diesel Fuel
EIA Environmental Impact Assessment
EISD Environment and Infrastructure Services Department
$FeCl_3$ Ferric Chloride
FEL Front End Loader
g/ton gram per tonne
GCMS Gas Chromatograph Mass Spectrometer
GJ Giga Joule
H_2S Hydrogen Sulphide
HHV Higher Heating Value
JCPZ Johannesburg City Parks and Zoo
JFPM Johannesburg Fresh Produce Market
kg/kmol kilogram per kilomole
kL kilo litres
kWh kilowatt-hour
kWp kilowatt Peak
L/h Litres per hour

LHV	Lower Heating Value
MCC	Motor Control Centre
MSW	Municipal Solid Waste
NH_3	Ammonia
Nm^3	Normal Cubic Meters
OEM	Original Equipment Manufacturer
P&ID	Process & Instrumentation Diagram
PFD	Process Flow Diagram
PLC	Programmable Logic Controller
ppm	parts per million
PSA	Pressure Swing Adsorption
REL	Rear End Loader
RoRo	Roll-on-Roll-off
SCADA	Supervisory Control and Data Acquisition
SG	Specific Gravity
SSO	Source Separated Organics
tpd	tonnes per day
TS	Total Solids
VFA	Volatile Fatty Acids
VOCs	Volatile Organic Compounds
VS	Volatile Solids
VSD	Variable Speed Drive
WWTW	Waste Water Treatment Works
BMP	Biomethane Potential
UPS	Uninterruptable Power Supply
kPa	kilopascal
mA.	mili amperes
FOSTAC	Food Safety Training and Certification
PPE	Personal Protective Equipment
HAZOP	Hazard and Operability Study
EPC	Engineering Procurement and Construction

City of Johannesburg Organic Waste to Biomethane for Bus Fuel Plant

2 INTRODUCTION

The City of Johannesburg (COJ) Biomethane project aims to produce biomethane as bus fuel from clean organic waste produced by the Johannesburg Fresh Produce Market (JFPM). Other sources of organic waste can also be digested with this waste stream, but this should only be allowed once approved by the plant operator and management. This project will act as a pilot demonstration project for the Municipality. The initial plant size is a nominal 50 tons of clean organic waste per day. This can be increased to 100 tons per day (tpd) by expanding the plant. Spatial allowance has been made for this in the design. An equivalent gas to natural gas can be obtained by upgrading and purifying biogas, which is typically 60 vol.% methane (CH_4) and 40 vol.% carbon dioxide (CO_2). The removal of CO_2 and other impurities leads to an increase in the CH_4 concentration to above 95 vol.% with an associated calorific value (CV) increase. This upgraded gas is called biomethane, which can be compressed to high pressures to obtain energy densities that allow it to be used as fuel. In this project the gas will be compressed and filled into cylinders which act as fuel tanks on the Metrobus Busses. Currently the CoJ has approximately 148 dual diesel fuel (DDF) busses in their Metrobus fleet that can take this renewable fuel. It is foreseen that this project can fill approximately 10-30 busses per day with this compressed natural gas (CNG) equivalent, called compressed biomethane (CBM).

Biogas is produced by microbial degradation of putrescible organic waste in a process called Anaerobic Digestion (AD). The process employed in this project is mesophilic anaerobic digestion with two Continuously Stirred Tank Reactors (CSTR) in series. The temperature will be controlled at 38 °C to 40 °C. It requires careful feed preparation and control in large tanks called digesters. The waste feedstock is then processed mechanically to feed it into the digesters. The residual sludge after bio-digestion will be processed into both a liquid and solid fractions that are high in organic nutrients and have fertilizer nutrient value as liquid and solid compost respectively. The gas will be purified to allow for upgrading and fueling busses. Carbon dioxide and other trace gas impurities removed from the biomethane is vented to atmosphere.

The plant will be a net consumer of electricity as the energy from the biogas is produced in the form of vehicle fuel. However, the project will be acquiring it's electricity from an expansion to the neighboring Joburg Landfill Gas project which will produce electricity from waste heat. Low grade waste heat from this same site will be procured by the project to heat the digester in the form of hot water. This is the most viable option as it gleans the highest value as an energy source for the municipality. 20 kWp Solar rooftop power generation will be incorporated into the project. All power generation will be synchronized either with the grid or a backup generator.

This document sets out the process description for the plant. The process is divided into the following sections:

- Waste receiving, sorting and pre-processing;
- Biogas production;
- Biogas upgrading, compression and filling;
- Digestate treatment and utilization;
- Offsite composting (digestate maturation) and storage;

- Heat supply;
  - Waste heat hot water.
  - Backup hot water from natural gas boiler.
- Electricity supply for net exportation of power from site and energy independence;
  - Rooftop solar PV.
  - Baseload waste heat to electricity.
  - Backup generator (diesel or natural gas).
- Utilities;
  - Natural gas (Egoli Gas)
  - Water
  - Effluent
  - Grid connection
  - Stormwater
- Site Development and Infrastructure.
  - Management offices (existing)
    - Meeting room
    - Boardroom/visitors room for up to 20 people
    - Ablutions (male and female)
    - Kitchenette
    - Infirmary
  - Plant building (new)
    - Mess room
    - Ablutions including showers and changeroom (male and female)
    - Laboratory
    - Control room
    - Server closet
  - Boiler house (existing)
  - Pump room (new)
  - Weighbridge office (new)
    - Office (with view of weighbridge and gate)
    - Induction room
    - Single toilet accessible from both outside and inside independently
  - Waste processing building (existing)
  - Digestate dewatering sheds (existing)
  - Workshop (existing)
  - Spares and chemical store (existing)

This process description is for the Phase 1 part of the project, namely for 50 tpd organic feedstock processing capacity. Reference is also made to the potential Phase 2 expansion capacity of up to 100 tpd for planning purposes but is only indicative.

3 DESIGN BASIS

3.1 Location

The site is located next to the Robinson Deep Landfill and on the same erf, or plot of land. The erf number is Robinson Deep RE/81IR. As with many properties in that area, it started out as farmland. This was subsequently zoned as demarcated mining. The specific area is in the process of being rezoned for green infrastructure. Most of the area used for the project was used initially as a brick quarry. Later, the city constructed a workshop for waste trucks, which subsequently was converted into a hazardous waste incineration facility. The incinerator was later shut down as it did not meet the air emissions specifications within the COJ. The tasks of removal of the old incineration plant and disposal thereof as well as the rehabilitation of the existing buildings for use in the biomethane production process, are part of this project. Most of the existing buildings will be repurposed for the biomethane plant.

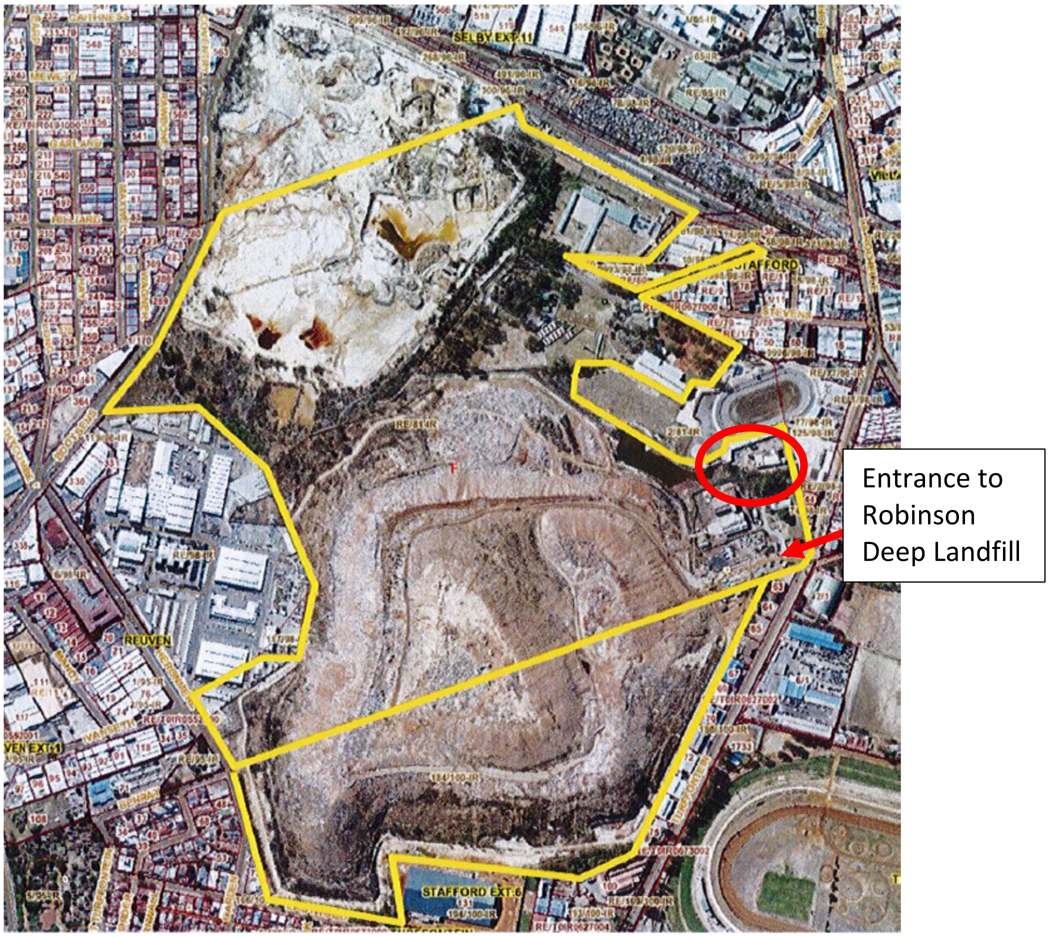

Figure 1: Location of the biomethane plant.

Access to the facility is on Turffontein road and is shared with the main Robinson Deep landfill entrance as well as the entrance to the Pikitup offices on site. A traffic impact note was done by JG Afrika (Pty) Ltd for the development of this project. The traffic impact note is available on request.

3.2 Climate

The climate in Johannesburg is semi-arid as it receives an average of only 604 mm of water per year. Water should therefore be used conservatively in the design of the plant.

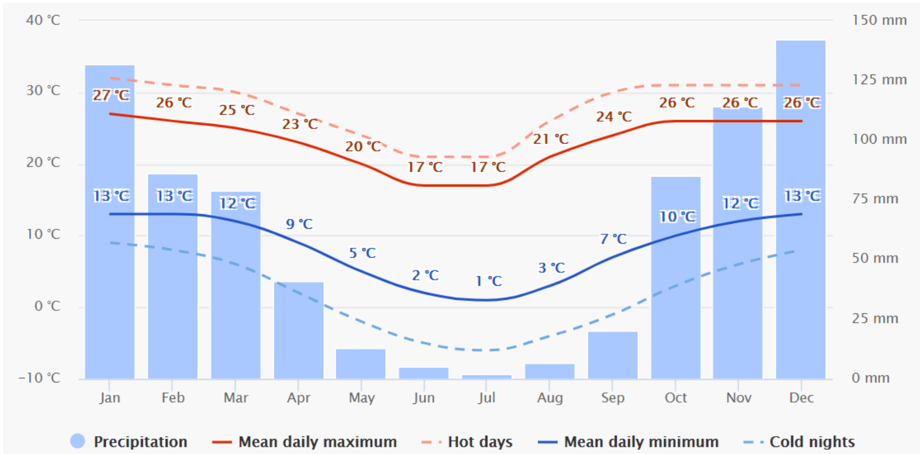

Figure 2: Precipitation and temperatures in Johannesburg throughout the year.

The predominant wind direction is Northernly and seldomly exceeds 28 km/hr. Due to the high solar irradiation in the area allowance has been made for roof mounted solar on the north facing side of the main warehouse roof wherein the waste presorting will be kept. It is estimated that this will be able to facilitate 20 kWp of solar capacity that can be grid tied for offsetting some of the parasitic electrical load requirements.

3.3 Geotechnical information

A geotechnical study was done by JG Afrika in the development of this project. The report is available on request. Ground water levels are quite low towards the leachate pond for the Robinson Deep landfill to the west.

3.4 Function

The facility will function as a commercially operated demonstration plant for organic waste processing, biogas production, upgrading of this to biomethane and from there filling it into busses. Table 1 sets out the main functional parameters:

Table 1: Functional parameters for the plant.

Design Life	The design life of the plant is to be >20 years.
Uptime	The plant is expected to have a biomethane producing uptime of 95% at full design capacity.
Feedstock	Source separated organic waste with minimal packaging contamination.
Biomethane filling	The project will allow for scheduled offtake of biomethane at dispensing points at a fenced off area on the same site as the biogas plant.

Residual waste treatment	Removed packaging and contaminants will be collected in a RoRo bin on site and disposed of periodically to Robinson Deep Landfill.
Digestate utilisation	The digestate will be tested for use or sale as solid and liquid compost to Johannesburg City Parks and Zoo (JCPZ). Digestate liquor may also be treated for sewer disposal or treated to industrial discharge limits for possible use a landfill site dust suppression media.
Operator	The operator will be contracted to manage the site, operations, maintenance, waste collection and vetting, pre-sorting, product sales, invoicing, accounting, human resources, managing statutory checks and responsibilities, waste disposal and the day-to-day activities involved with running the Biomethane project. Monthly reports will be submitted to University of Johannesburg and the CoJ EISD. The University of Johannesburg will be involved in a supervisory capacity to do tests on feedstock, the digestate and non-critical process parameters. Optimisation suggestions from these activities may be accepted by the operator. The site will also be used for training activities and field trips arranged with consent of the operator and with advanced notice.
Odour	The plant will have odour control systems installed to prevent discomfort due to bad smells. Fortunately, the site is located at the current landfill and on an informal recycling centre. The additional impact of the biogas process should be minimal. The source of odours is typically the raw waste collection point, which is housed in an enclosed warehouse in this instance. If upgrading is done by water scrubbing, the vented off-gas may also have a smell if the hydrogen sulphide levels are high in the biogas. This may need to be treated in an additional biofilter if the problem persists.
Power generation	Backup power generation will be allowed for in phase 1 of the project. In the future power generation from biogas may also be included if excess biogas is available. Since diesel storage would require additional permits it is suggested that a gas backup generator be installed that can run off the Egoli gas pipeline. Electricity will be generated on site by the project in the form of 20 kW roof mounted PV. The project will also procure electricity for itself and the site from Energy System's new waste heat to electricity system.
Heat supply	Hot water will be purchased from a neighbouring landfill gas combined heat and power plant operated by Energy Systems (Pty) Ltd. This is the least cost heat energy supply to the biogas plant. Backup heat supply will be from a natural gas hot water boiler. In final design it may be considered to implement this as a dual fuel boiler system to allow for use of biogas also. Currently this has been excluded as the boiler is only a start-up and backup requirement.

Gas flaring	Excess on specification biogas can be utilised elsewhere if the upgrading plant or busses aren't available. This specification is to align with the inlet specifications of the landfill gas generators. The gas can therefore be piped to the Joburg Landfill Gas project intake. Otherwise excess biogas will be sent to a flare where it will be combusted to $CO_{2(g)}$ and $H_2O_{(g)}$. The amount of gas generated by the plant equals the same amount of gas generated by >1000 cows in the field per day. Utilising or flaring the gas before release to atmosphere is both safer and more ecologically friendly as methane gas is 21 times greater global warming potential (GWP) as a greenhouse gas than CO_2.

3.5 Input Parameters

A summary of the input design parameters is provided in Table 2 .

Table 2: Parameters of the design basis for the Phase 1 of the biomethane plant

Parameter	**Normal Operating Value**	**Maximum Value**	**Notes**
Feed rate of waste (ton/week)	350	700	Depending on type of waste fed as well as the phase of the project.
TS content of feed (%)	17%	25%	Higher than 20 % becomes difficult to pump and dilution liquid (water, digestate or centrate) is needed.
VS content of feed (% of TS)	90%	99%	Pure sugar wastes are almost entirely volatile solids.
Expected biomethane yield ($Nm^3/kgVS$)	0.55	0.7	Some vegetables, fruit, sugary and fatty food wastes have very high gas yields.
C:N ratio of feed	25	-	Co-feeding can be employed to get feedstock in the right ratio. Proteinaceous wastes such as animal wastes are high in nitrogen and need to be balanced with wastes with a high carbon content.
Biogas production (Nm^3/hr)	149.3	200	Depending on type of waste blend and loading of digester. Standard modular plant used as reference. Phase 2 may produce even more gas and require increase of biogas processing capacity. The upgrading plant can turndown to 50% of rated maximum throughput flow.

Biomethane production (Nm^3/hr)	93.3	125.0	Directly linked to biogas production.
Solid digestate cake production (t/day)	10.7	21.4	Depending on whether polymer is used or not. This also impacts the moisture content of the final sludge.
Digestate solids maturation to compost (t/day)	7	14	Offsite composting at JMPD academy provides an enclosed shed for turning and stacking the digestate and blending it with suitable manure from the onsite horse stables and other green waste that can be obtained from JCPZ and chipped on site. Digestate liquor can be used for any required water addition. Compost is to be produced in both bulk and bagged form. Compost screening, weighing and bagging is therefore allowed for.
Liquid digestate production (kL/day)	42.7	85.5	Depending on whether polymer is used or not.
Parasitic load (kW)	140 (average)	341 (peak)	During start-up and during the waste processing hours the parasitic load reaches its maximum. Units can be started in series to prevent too high load.
Parasitic load (kWh_e/day)	3600	5400	Extending the operational shifts of the MRF will increase power consumption proportionally. (excluding dryer)
Heat requirement per day (kWh_t/day)	1920	2942	The peak heat demand will be in the winter season and will be used in the form of hot water. (excluding dryer)
Water consumption (kL/day)	17.3	34.6	Actual consumption depends on feedstock, whether polymer is used and how much centrate or treated effluent is used for dilution or cleaning.
Design delivery pressure for biomethane (barg)	250	270	As per the requirements of the OEM for the Metrobus fleet
Biomethane storage on site (Nm^3)	2319	4638	The maximum storage is assumed when the storage has doubled for the application where the biogas production has doubled and where the pressure is at 300 in all the high-pressure storage units.

Biomethane composition	Please refer to the CoJ Biomethane Specification (ED002-COJ-CNG-SPEC-002-RA.pdf) for details.

3.6 Operational hours

Currently the landfill is open to the public for 24 hours 7 days a week. This means that the biomethane plant will need its own fencing, access control and security to ensure that prohibited persons do not have access to the plant after hours. The bus filling terminals can be outside of this controlled area if buses need to be filled during the evening shifts.

The biogas facility will be receiving waste 5-7 days a week and will be consuming organic waste and generating biogas and other products continually (24 hours, 7 days a week). Buffer capacity on the inlet and outlets of the plant are therefore required.

For residual waste, solid digestate cake and digestate liquor, the collection will be during business hours (06:00 to 17:00) from Monday to Friday. Special arrangements need to be made on weekends or public holidays as it is essential that these products and residues are removed to ensure that the process can continue operating.

Depending on the scheduling of supply and offtakes, a 1 or 2 shift operation can be run on site at the facility.

Since the gaseous product, compressed biomethane, will be produced on a continual basis, the offtake needs to be 7 days a week. This needs to be ensured by scheduling the correct number of buses per day from Metrobus. The Metrobus bus fueling will be done by shunters that fill the parked buses at Village Main depot from 9:00 am to 13:00 am and from 18:00 pm to 21:00 pm every day. The schedule for filling is given in figure 3.

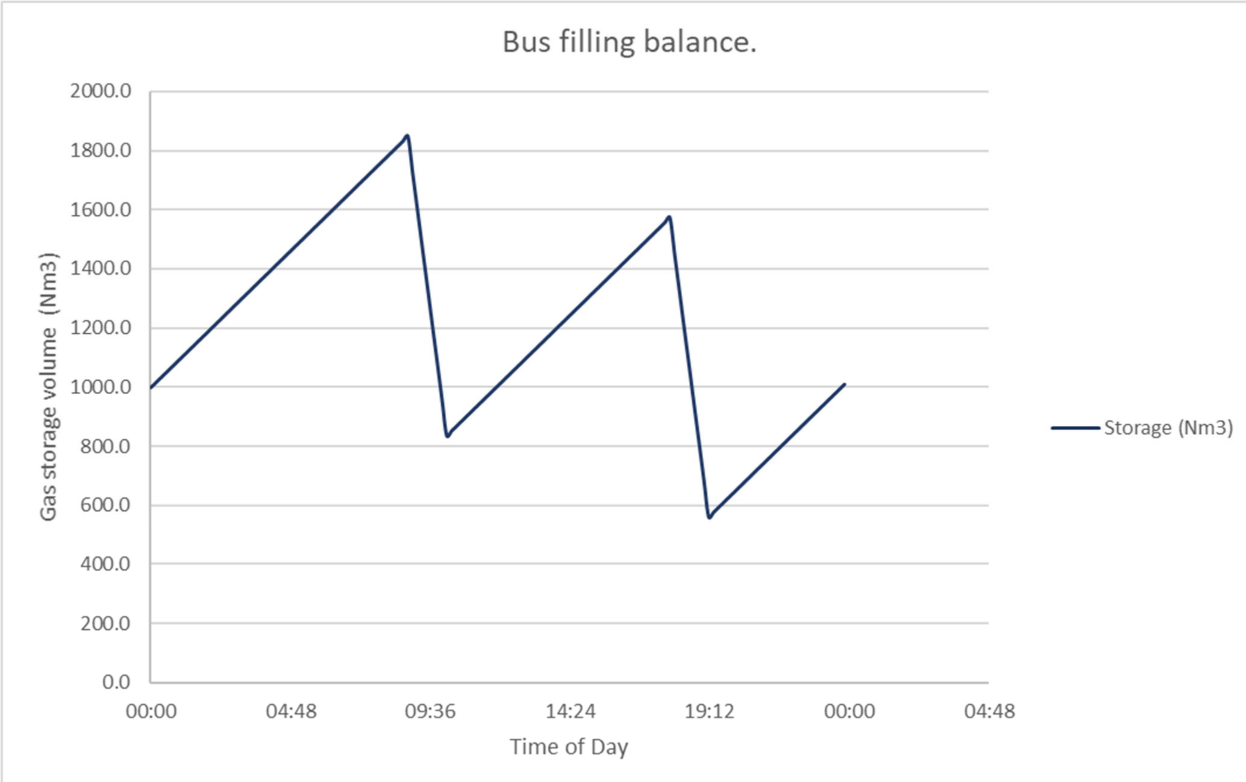

Figure 3: Biomethane inventory and bus filling.

3.7 Assumptions

The following assumptions where made in the design of the biomethane plant:

#	Assumption	Value	Units
1	Grit, glass and soil contamination in feedstock is less than	negligible	
2	Methane concentration in biogas	60%	
3	Electricity cost	1	R/kWh
4	Water cost	25	R/kL
5	Gate fee for waste	213	R/ton
6	Storm water run-off is into a bioswale	NA	
7	Heat cost	9.5	R/GJ
8	Egoli gas cost	300	R/GJ
9	Frequency of digestate liquor offtake is daily	NA	
10	Capacity of digestate liquor offtake per load	20	kL
11	Coupling for digestate liquor offtake is from the top for top loading	NA	
12	Frequency of digestate cake offtake is daily during the week and once over weekends	NA	
13	Capacity of digestate cake offtake	30	m^3
14	Bin type for digestate cake offtake are roro's		

15	CNG trailer max pressure	300	barg
16	CNG trailer water volume	2000	m^3
17	Min operating pressure in trailer	35	barg
18	Max operating pressure in trailer	250	barg
19	Bus fuel tank size	400	L Water content
20	Bus Normal filling qty	80	Nm^3
21	Bus filling time	10	min
22	Bus min operating pressure	35	barg
23	Bus max operating pressure	250	barg
24	Digestate separator efficiency	90%	
25	Solids in digestate cake	27%	
26	VS destruction in digester	62%	
27	Polymer addition in g/tonTS	4	g/tonTS
28	Polymer dilution water	12.80	t/day
30	Dilution rate of polymer	0.001	kg poly/L
31	Max HS in biogas generated	2000	ppm
32	Density of reject waste	250	kg/m^3
33	Recovery rate of a picker picking plastic	0.5	ton per day
34	Bulk contamination in feedstock	5%	
35	Average TS of fruit and veg waste	17%	
36	Average VS of fruit and veg waste	90%	
37	Receipt of waste	5	days per week
38	Bus fuelling days	7	days per week
39	Operational weeks per year	52	Weeks per year
40	Target solids concentration in feed to digester	15%	
41	Extraction efficiency of organics from waste	90%	
42	Biogas yield from Fruit and vegetable waste	550	Nm^3 biogas per ton VS
43	Biogas yield from digestate liquor solids	0	Nm^3 biogas per kg VS
44	TS % in recirculate	1.10%	
45	VS % in recirculate	60%	
46	Capacity of reject waste bins	30	m^3
47	Upgraded biomethane CH4 concentration	96%	
48	Water consumption of upgrading	20	L/hr operating
49	Effluent generation from upgrading	20	L/hr operating
50	Maximum biogas feed to upgrading	200	Nm^3/hr
51	Minimum biogas feed to upgrading	100	Nm^3/hr
52	Waste density (tipped)	350	kg/m^3
53	Loader bucket size	2	m^3
54	In feed hopper	2.2	m^3
55	Number of high-pressure gas storage skids	4	
56	Volume of high-pressure gas storage skid	1958	L (Water Content)
57	Max pressure of high-pressure gas storage skid	300	barg
58	Min pressure of high pressure gas storage skip	35	barg
59	Operating pressure of gas storage skid	270	barg

60	Max bus filling pressure	240	barg
61	Molar mass of biomethane	16.8	kg/kmol
63	Excess raw waste storage in external RoRo bins	90	m^3

In general, the following must always be assured as these assumptions are critical to this type of process and relate to the management and selection of the waste feedstock:

- Sufficient biodegradability of the organic matter in feedstock.
- Potentially toxic, harmful or inhibiting products are not present in concentrations that can disturb the microbial activity.
- Inorganic impurities such as, sand/grit, metal, wood, bones etc. are not present in excessive quantities.

3.8 Standards and Regulations

The following standards and regulations are to be complied with:

- SANS 329
- SANS 347
- SANS208
- SANS10142-1
- SANS10019
- SANS13631
- OSH Act
- Pressure Equipment Regulation (PER)
- National Environmental Management Act (NEMA)
- Major Hazardous Installation (MHI) risk assessment and Department of Labor reporting
- NERSA Requirements
- Fire Chief approval
- Building plan approvals and requirements.
- Local Joburg Water waste water disposal bylaws
- All applicable provincial and municipal bylaws.

4 PROCESS DESIGN DESCRIPTION

4.1 Concept

The City of Johannesburg has embarked on the design and development of the demonstration organic waste digestion plant to produce biogas for productive energy use. Initially, a feasibility study was done by the University of Johannesburg and Pikitup, the municipal owned waste management company and operator of the Robinson Deep Landfill. This involved waste characterization, biomethane potential analysis, and a study to understand the potential technologies that can be used to produce the biogas required.

The main targets of this project is to:

- Reduce waste to landfill to extend the landfill site air space life.
- Divert organic waste from landfill to productive utilization so as to minimize methane generation in the landfills.
- Produce products in the most cost beneficial manner using the current infrastructure to a high degree.
- Provide a demonstration plant that can be scaled up for additional source separated organic (SSO) waste to be utilized as biomethane production feedstock as the City of Johannesburg improves its separated waste collection mechanisms.
- Provide a plant that is a showcase for the municipality and a research and visitor center for students and the public in general.
- Collect adequate data to enable the improvement of the process and inputs to the decision-making process for building a larger waste to energy complex within the municipality.

The above goals where considered and an Options Analysis was performed, looking at high level cost structures for different types of Anaerobic Digestion plants. The output from this exercise was clear that a simple system is to be designed to integrate with the old incinerator site on Robinson Deep Landfill to utilize much of the old redundant infrastructure and to produce biomethane as a CNG alternative and equivalent for some of the DDF Metrobus fleet buses.

The decision to have the biogas plant provide CNG for an onsite bus filling station was made as tube trailers would be a very expensive and complex option with lower revenue or cost savings potential to the city.

4.2 Description

The old incinerator site is located at the back of the Pikitup offices on Robinson Deep Landfill. Access to the site is through the main gate on Turffontein road. Immediately after entering the site, drivers of buses, waste delivery trucks, and other vehicles will turn into a turning bay to turn right. There is a 200 m paved road that will lead to the fenced off areas for:

1. The biogas plant;
2. The CNG filling station for the buses.

As far as possible the waste delivery and removal vehicles are to be kept separate from the buses as they will come to site at different times. Waste trucks will need to reverse into the Waste Receiving area, while buses are never required to reverse.

The plant is designed to receive waste delivered in rear-end loader (REL) compactor trucks and Rollon-Rolloff (RoRo) hooklift skips. Both these types of vehicles will be weighed upon entry and exit from the facility. If the bin numbers of the trucks are recorded and the tare weights noted by the weighbridge operator, a system may be used where the truck is only weighed once when arriving with its full load. At this point the registered weight of the vehicle will also be noted and can be used to determine the net weight of the load. The vehicles will reverse into open bays in the waste presorting building. This building is the repurposed incinerator building. The building roof will be raised to increase the overhead space to safely tip and discharge the types of loads envisaged.

The waste will be tipped onto a floor that is ever so slanted with a screed towards a central collection trough for leachate. Waste delivery vehicles are never brought into contact with the waste on the floor. A curb wall prevents the trucks to reverse all the way into the building. Once the waste has been tipped, a picker and the loader operator inspect the waste on a cursory level to ensure that the bulk is processable in the plant. If excessive contamination is noted, then the truck details are reported to management and corrective action taken. Bulky contaminants are taken out by workers on the tipping hall floor in the bays.

A wheel loader or similar vehicle will scoop up this organic waste and feed it into a receiving hopper of a screw conveyor system that lifts the material onto a picking conveyor belt that is raised on an existing platform.

The waste will pass over a sorting conveyor where 4 pickers will screen the waste going to the pulping mill. On this same conveyor a magnetic cross rotational conveyor belt will act as an automated metal removal unit. All chutes discharge to the bottom of the platform into rocker bins. These bins are discharged into a central RoRo bin for daily removal once full and disposal to the adjacent landfill.

Waste picked off the elevated belt and platform is dropped down chutes into rocker bins. These bins are tipped into a main skip once full for bulk removal of contaminating wastes. This is done by using a forklift and tipping the rocker bin into the main waste skip. Allowance is made for an additional picking line and a de-packaging unit once more SSO is available. A liquid waste receiving pit is integrated with the leachate sump.

The yellow metal (forklift and loader) on site will all be fueled with CNG. These vehicles will drive around the entrance to the CNG fueling station to fill up at the same locations as where the buses fill up.

From the picking conveyor, the waste is dropped into a high speed pulper hammermill for reducing the organic material to a slurry with a thick "soup" consistency. This pulper mill is located above a 2 m^3 hopper that acts as the inlet and hopper of a high solids progressive cavity pump. This hopper has level control that allows for the addition of digestate and/or water for controlling the pumpability and solids concentration in the feed sludge.

The feed pump pumps the substrate through an inline macerator to further reduce the particle size of the waste to <5 mm to increase the surface area of the waste and thereby the biodegradability thereof. This increases the gas yield from the organic material as better access to fresh organic material and good mixing with recycled digestate is ensured.

With the addition of dailies, supermarket wastes and other SSO, a de-gritting system and pasteurization may be installed. Adequate space allowance is made for this, but this is not currently included in the design.

This prepared slurry is pumped into the feed buffer tank. This allows for up to a week of feedstock storage and allows the organic waste to acidify. In this process of hydrolysis and acidogenises, the feedstock breaks down to ensure a easily digestible and constant feed to the main digester. The feed buffer tank is stirred with two submersible stirrers to keep solids in suspension. It is insulated with a solid roof. It is gas tight and the headspace is connected to the gas headspace of the main digestor system.

The main and post digesters are identically sized tanks located next to each other. They can be operated in series or in parallel but are typically run in series. The total digester capacity is slightly oversized at 35-day retention time. The digesters will have at least one of the tanks with a double membrane gas holder. The digesters are to have removable or serviceable submersible mixers. Allowance is also made for a gas mixing system. The aim would be to compare the performance of the paddle and gas mixing systems. The gas mixing blower will be situated on top of the pumphouse that is adjacent to the digesters to minimize piping. The piping from the gas blowers has to be such that a water seal is formed and so that digestate cannot flow back into the biogas recirculation system. The blower will be a sliding vane rotary blower that can deliver a head at 2 barg.

The tanks are insulated and clad and heated with a hot water circuit. The higher heating load (>70%) is in the main digester, while the post digester just requires heating for making up heat loss to the ambient environment. Hot water is supplied at ~82 ^{o}C from a circuit that can be supplied by hot water from a plate frame heat exchanger integrated into the CHP system of Energy Systems or by running the backup natural gas boiler that is placed in an existing building that was used for flue gas treatment on the old incinerator plant. Return hot water is expected to be ~ 55 ^{o}C A natural gas backup generator is also located close to the boiler as this minimizes natural gas piping from the Egoli gas mains.

An emergency multifuel flare will be located close to the digesters and upgrading plant but far enough to maintain safe working distances. This can take biomethane or biogas and flare it if and when required.

Biogas will be collected in the head space of two digesters and the buffer tank, this will be drawn off and condensate removed. Next the biogas will pass through the external biological desulphurization where the H2S is removed by converting it to elemental Sulphur, facilitated by thiobacillus. This process requires oxygen which is typically supplied by introducing air into the system. For this specific plant, enriched or pure oxygen is required and therefore the air is pretreated through a PSA system that removes the nitrogen. The pure oxygen is fed to the biological de-sulphurisation reactor. The oxygen is also introduced into the main digester headspace for in-digester desulphurization. This reduces the need for Ferric Chloride addition. The main digester and feed buffer tank have the possibility of adding nutrients, lime, or other additives through a multipurpose dosing system.

Siloxanes and other non-methane VOCs can be removed with activated carbon filters due to the simple nature of the feed, this is not included in this current design, but allowance is made to add this at a later stage before the upgrading section if other wastes from municipal solid waste (MSW) or waste water treatment sources is fed into the system.

For upgrading two technologies are preferred. Either membrane upgrading or water scrubbing technology. Both have certain benefits and disadvantages. It is to be noted that biogas drying, and activated carbon filtering is essential if the membrane separation process is to be followed. For this design upgrading technology selected is water scrubbing as it is less sensitive to H_2S content and moisture content of the gas. This component is also stripped out further to some extent with the water washing process. Water is recycled in the process and usage is minimal. The process involves compression to 8 barg, n absorption column, a stripping column and a flash tank with water recirculation and chilling. This is done to increase the methane concentration by stripping out the carbon dioxide. The stripping column vent air rejects the CO_2, any residual H_2S, and a small amount of methane called methane slip. This is ~1% of the methane feed to the plant and is safely diluted below any explosive limit. The upgraded biogas is dried over a dual batch zeolite dryer before compression.

The upgraded biomethane is compressed as it is produced through a second, high pressure 4 stage compressor to a maximum of 270 barg. This is compressed into a cylinder buffer storage bank that can store production of up to 12 hours production from the biomethane plant. From the high-pressure buffer storage gas is reticulated to 2 filling posts that can fill 2 buses simultaneously. A hydraulic booster compressor helps to fill the buses for quick filling when they arrive. The filling of the bus should take 10 min from the time of connection until it is full.

The digestate residue after digestion is pumped from the post digester by one of two pumps. The digestate pump pumps the digestate to a decanter centrifuge separator that recovers the solids from the digestate into a cake that is 22-27% solids. The centrifuge is located in a building at an elevated height so that the cake discharges through a moving conveyor system into a roro bin that is periodically removed. When the roro bin is removed the digestate discharge is diverted or production halted. The solids recovery from this system is dependent on whether or not polymer is added.

Without polymer addition the water consumption and centrate production of the plant is considerably less. But the solids recovery and centrate quality is lower as only 70% of the solids are recovered into the digestate cake. The mass balance and process design allow for the addition of polymer but both scenarios are possible. A main impact on this would be how Johannesburg City Parks and Zoo (JCPZ) intend to manage the liquid and solid digestate streams.

The centrate runs from the centrifuge by gravity into a centrate tank, this is a closed roof tank, fitted with two stirrers to ensure that solids can be resuspended if settled. It allows for 3-5 days storage of centrate before discharge is required from the system. A centrate discharge pump can either pump this to an onsite water treatment plant, to recycling use, to a tanker filling point, or to the landfill leachate pond. It is suggested that this centrate be used for dust suppression on the landfill instead of using fresh municipal water for the same purpose. It will save substantial cost for running an onsite water treatment plant for disposal to sewer.

It was requested to also look into additional alternatives for using the digestate if JCPZ can't take the digestate cake or liquor. A dryer can be used to dry the cake fraction and also the unseparated digestate (diverted before the centrifuge). The design therefore includes the option for installing a digestate dryer utilizing additional hot water supply from the Energy Systems CHP plant. The limitation to this drying process would be the availability of heat from Energy Systems considering the plans to provide steam to a neighboring client. Drying requires around 1 MW of thermal energy per ton of water evaporated per hour from the wet digestate. The drying technology used is a belt dryer that can dry digestate from ~25% solids to 80% or alternatively ~6% to 80% with the addition of a recycle line. As the heat is from a low grade hot water energy source this is not optimal.

Drying is also an expensive process with additional heat exchange capacity required, and electrical costs. It is advised that for optimal economic performance a drier be excluded from the design and rather that both the digestate fractions (Solid cake and liquid fractions) be utilized as organic compost and liquid fertilizer respectively on a sustainable and secured basis.

5 PLANT SECTIONS

5.1 Waste Receiving and Processing

An operator will open motorised rolling doors on the 7 bays on the south side of the waste building for receipt or removal of waste from the tipping hall. Trucks will reverse into the open bay and discharge the waste onto the bay that is empty. Moveable concrete barriers will separate the batches of waste that arrive. A small push wall will prevent trucks from reversing all the way into the building and prevents the tires of the trucks to contact the waste. Doors are closed after the departure of a truck to ensure that odors do not cause a nuisance.

De-odourisation sprays located in the tipping hall ensure that odors are not released through the ventilation system.

Since the waste will be pre-sorted at the Johannesburg Fresh Produce Market and consist of minimal contamination, pickers are employed to focus on only removing the final residual contaminants. If this contamination increases with different organic waste sources a paddle de-packaging unit will be required.

A typical pulper is shown in the figure 4:

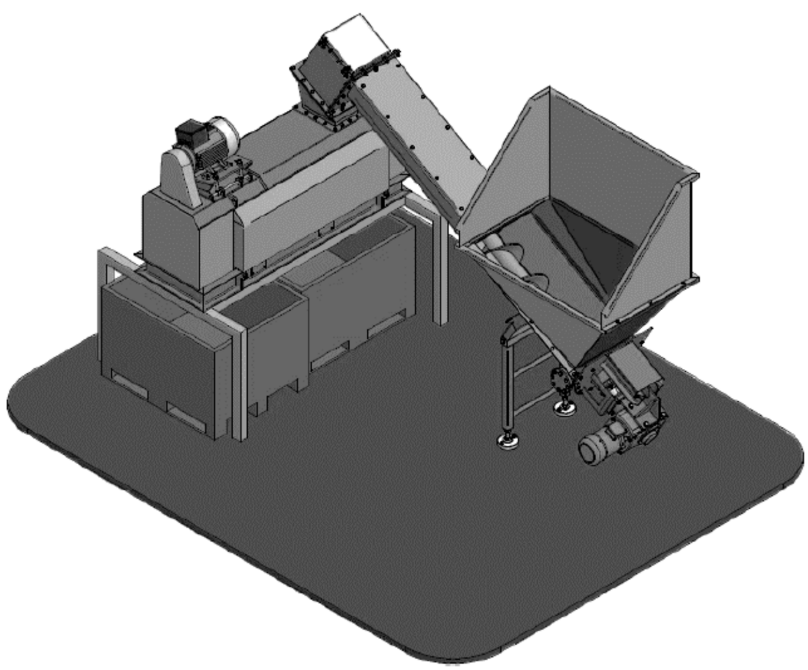

Figure 4: De-packaging and pulper wit hopper.

The pulper hammermill has a 10-20 mm screen that ensures only pumpable particles pass through. Soft organic fruit and vegetable wastes are easily cut up by this system. The pump that follows the pulper is a high-solids pump as shown in figure 5. The maximum solids concentration for such a pump is typically <20%.

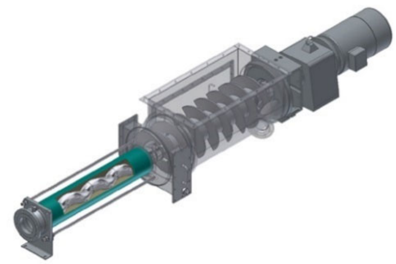

Figure 5: High solids progressive cavity pump.

5.2 Biogas Production

The biogas production is done in a 2-stage mesophilic anaerobic digestion process. The biogas production is directly related to the feed into the digester and prediction of production can be done based on the trailing 5-day average of the VS loading measured.

Biogas composition can vary slightly through the process but an average for 55% to 60 % methane is expected. The pH of the digesters is to be maintained between 6.5 and 8. Monitoring of the VFA's (especially relative to Total Alkalinity) and ammonia will give an indication if the feeding rate should be adjusted to prevent stalling of the digesters. This talks to a "pull" control philosophy, rather than "push". By calculating what the absorbable COD or VS load is in the digester based on the health indicators mentioned, the stability of the system is improved, whereas if a set amount of feedstock is "dumped" indiscriminately into the digester, the reactive control may lead to instabilities. The wetted parts of the biogas process that are in contact with the biogas needs to be either stainless steel or it needs to be made of a polymer or coating that is resistant to microbial and acidic corrosion.

Each tank requires a manhole for construction and maintenance purposes.

5.3 Upgrading, compression and filling

The upgrading section is preferably a packaged unit. A typical filling station is showed below in figure 6. A card reader system is used in conjunction with a cariolis flow meter for the accounting of the gas.

Figure 6: Example filling station for bioCNG.

5.4 Digestate Treatment

The elevated centrifuge will be fed with digestate from the post digester. Polymer addition and mixing is done at floor level and dosed into the feed line of the centrifuge. The operation of this is optional based on the requirements for the digestate solids content and the final disposal to land or utilization of compost or drying. Polymer is typically a grudge purchase as it is costly and also represents a large part of the plant's water requirement. However, it is necessary to produce a relatively high solids concentration in the digestate cake and a lower solids concentration liquid digestate fraction.

Splash covers are required next to and over the RoRo bin below the centrifuge for the dewatered sludge, as this falls from a height and may cause a spillage. The door to this facility will be permanently open to ensure good ventilation. The bins are removed when full and replaced with an empty one.

The liquid digestate can be utilized from the centrate tank, into which it flows by gravity directly after dewatering. This tank has submersible stirrers to prevent fine sediment from settling and accumulating in the tank. The tank is open to the atmosphere but vent points are considered hazardous areas as there are chances for methane concentrations to develop that may be flammable in close proximity. A tanker filling point with pump is available on the tank to load tankers from the top or through a bottom valve. These tankers can utilize the digestate liquid for dust suppression on the landfill, land irrigation, golf course irrigation, racecourse irrigation, rehabilitation of marginal mining land, or grass feed growing areas for the Johannesburg Zoo.

The digestate cake produced from the facility will be collected in a rorobin. This will need to be matured either at a local composter or at a dedicated site owned by the municipality. Panorama composting site waste initially earmarked but Pikitup have requested that this site should not be used due to health and safety concerns. It also ads a 40 km round trip to the project operations.

The current solution is to utilize the digestate cake as an additive to onsite horse manure composting at the Johannesburg Metro Police Department (JMPD) Academy, the property adjacent to the landfill. This site has dog kennels and horse stables for the. The manures from these animals are currently disposed of at a high cost. It is therefore an ideal scenario to utilize a large 120 by 26 m shed with open sides for the maturation of the digestate solids and the screening, weighing and packaging thereof for the users within and without the municipality. The figure below sets out a typical 10 ton per day composting layout.

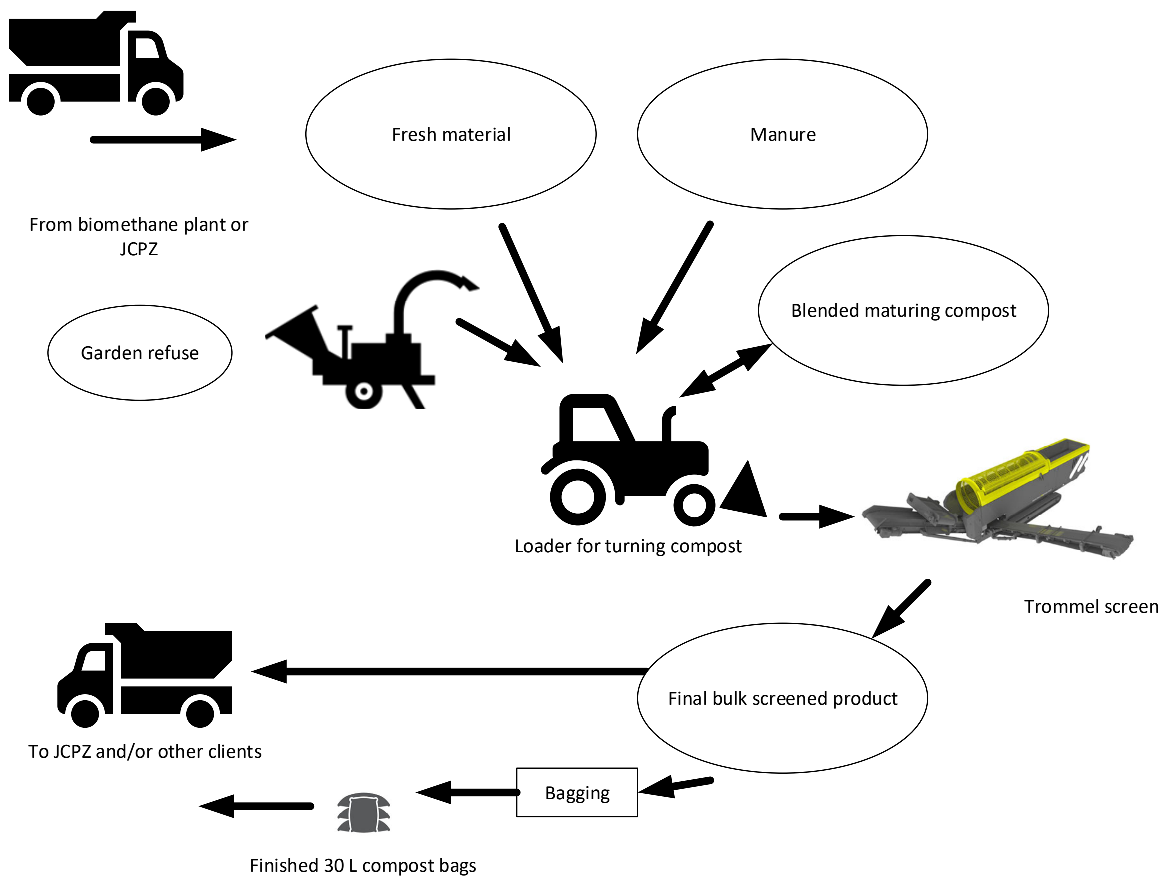

Figure 7: Composting and maturing of digestate solids (circles represent heaps).

Water treatment of the liquid fraction is costly and was considered in the initial design of the plant. It requires, floatation, biological reactions with addition of air and use of electricity to do so. The space requirement is also large and not optimal for a plant with so little space to work with. There are however better ways to utilize the digestate water in the arid Johannesburg environment and should therefor rather be used as such.

For water treatment a sequential batch reactor (SBR) or Membrane Bioreactor (MBR) system is envisaged as a package waste water treatment plant for reducing the COD load of the digestate liquor (centrate) if disposal to sewer is required. Final design of this section is to be done based on the actual centrate composition and the waste water disposal standards of Joburg Water. Currently

Joburg water has no additional capacity to take high strength effluent into their system. An area was allocated to the north east corner of the plant for this infrastructure but the ideal would be for this to not be needed if the contractual offtake of digestate can be found to be foolproof and sustainable.

5.5 Heat supply

A plate frame heat exchanger provides hot water from Energy systems (Pty) Ltd and an insulated piping circuit from the plant about 240 m away is allowed for on a pipe rack. This same pipe rack is used for cabling power to the plant. Figure 7 below shows a plate frame heat exchanger for a CT 3250 genset as used by Energy Systems (Pty) Ltd. A dual, running/standby, configuration for the het exchangers and hot water pump are required.

Additional plate frame heat exchangers would be required if the drying option is to be included due to the high demand for hot water. Up to 3 units can be installed on the current Combined Heat and Power gensets at Energy Systems with an unknown additional number on the steam plant they are in the process of developing for another neighboring application.

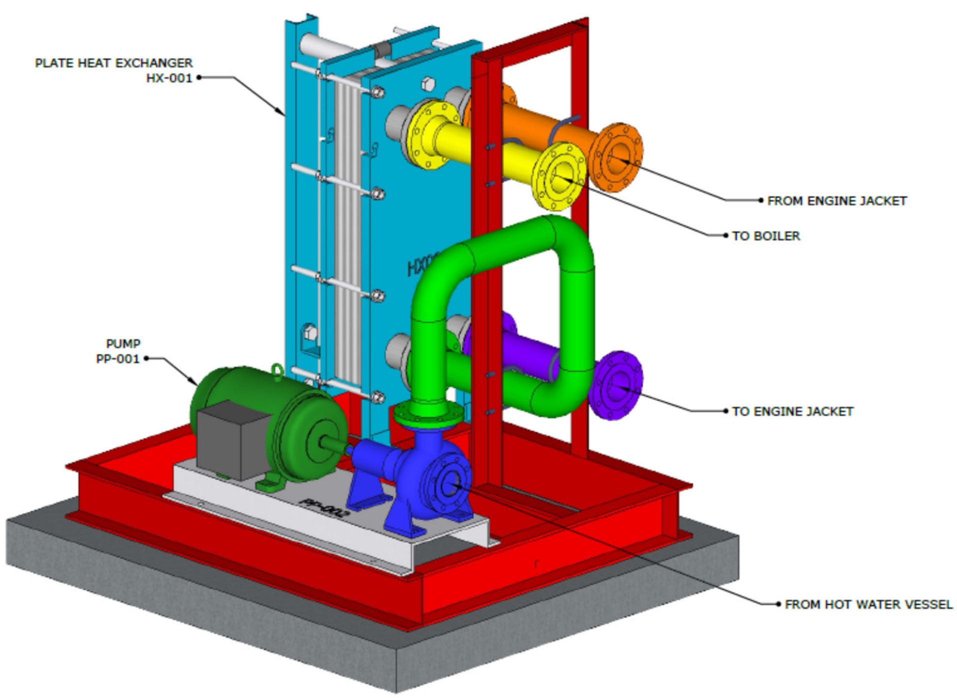

Figure 8: Heat recovery plate frame heat exchanger.

5.6 Additional feedstock

Additional clean liquid feedstocks can be decanted into the in-ground tank situated to the east in the tipping hall and built into the floor.

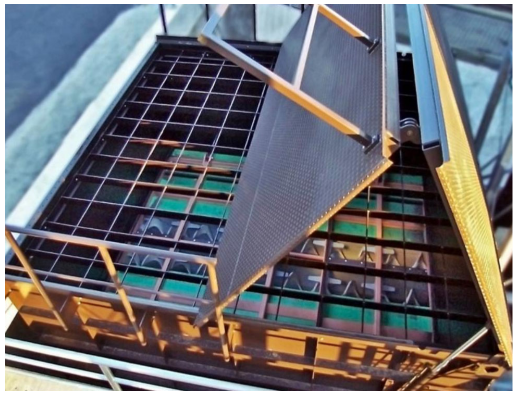

Figure 9: Sludge and liquids receiving pit.

5.7 Utilities

5.7.1 Gas

Natural gas is available on site from Egoli gas as this was used by the incinerator. This will need to be reinstated. This will only be used on an adhoc basis for backup heating and power generation.

5.7.2 Electricity

The plant will obtain electricity from the substation on site. Currently the facility needs repairs to the low voltage panels as well as the facility ceiling. The transformer needs to be upgraded to a newer unit as the current one is damaged and old. It is a 500 kVA unit and since more loads may come on in the near future it is suggested to upgrade this unit to a 1000 kVA unit and the electrical panels fixed to allow for the connection of the cable to the biomethane plant. The power is supplied by City Power. A 70 m cable connection to Energy Systems waste heat recovery to electricity system is envisaged as this will be able to supply baseload power to the project at a lower cost than City Power. The property, Robinson Deep Landfill operated by Pikitup, may then in some instances export power to the City Power network. It is therefore essential that the electrical mini substation comply with the local grid-code and the Small Scale Embedded Generator rules to synchronize and export to the grid.

20 kWe of solar energy can be installed on the MRF building used for the biogas plant preprocessing. During noon periods the solar power will contribute about 20% of the full electrical load of the facility.

The current infrastructure is:

1. Utility supply - Incomer 11 KV
2. Utility supplier - MV switch
3. Utility supplier - Transformer 11KV/400 Volts (500 KVA)
4. Connection between Tx / MPDB - Busbars
5. Main Power Distribution Board (MPDB)
   Incomer breaker - M+G M16 H1 - 1600 Amp
6. Existing feeder breaker to new project is 125 A
7. Existing - Transformer

Make - BBBT distribution Transformers
Size - 500 KVA
11,000 V / 400 V
Year of manufacturing - 1990

The following improvements will be required:

1. Sub Station ceiling need replacement
2. Sub Station signs need to be install
3. MPDB - feeder to new project to be replace with new 630 A breaker adjustable to 550 Amp
4. MPDB - Feeder CT's to metering to be reinstated
5. MPDB feeder - Power Meter should be installed (Schneider PM 710)
6. Feeder cable to be replaced with 2 x 150 mm 2 4 core SWA cable + separate earth
7. New MCC / power DB to be installed in MCC Room
   Incomer breaker 630 A adjustable
   Other feeder to be clarified by contractor

5.7.3 Hot water

This is purchased from Energy Systems, an adjacent landfill gas to energy company that has available waste heat in the form of hot water. An insulated and clad steel pipe on a gantry running side by side with the power supply to the facility will be the means of reticulation of hot water. A return pipe brings cooled water back in a closed circuit. An expansion vessel of 300L capacity will be installed in line with adequate expansion allowances in the line.

5.7.4 Compressed air

This will be supplied at 6-8 bar from a compressor that is to be installed as part of this project. This air will mainly be used for instrument and cleaning purposes. It will be dried to prevent condensation in air lines to equipment.

5.7.5 Sewer

Domestic effluent will be reticulated to the existing sewer connection on site. Depending on the final discharge of the centrate and whether it goes through a waste water treatment plant, the treated effluent may also be discharged to sewer. The sewers have been identified and the capacity should be suitable for discharge, this however needs to be confirmed after the cleaning of the sewers as it has been filled up with rubble and waste on site by the informal activities currently prevailing there.

5.7.6 Water

Fresh potable water (SANS 241) is available on site and will be used for toping up the water scrubbing system, the de-sulphurisation, washing, dilution, polymer makeup and domestic uses. This will be metered. The capacity is expected to be adequate as there are signs of water in pipes on site but the mains have not yet been located.

5.8 Site Development and Infrastructure

The following works are part of the project and ensure the safe and proper functioning of the plant.

- Lightning conductors will be erected as this is a high lightning incidence zone. The layout and location of the conductors are indicated and to be ratified by the main contractor;
- Fire water allowance has been made for onsite water storage and a fire hydrant;
- The existing incinerator building ventilation can be reinstated. New buildings will require adequate ventilation, for odor, temperature and in the case of the pump room, safety;
- Solar PV will be mounted on the north facing roof of the incinerator building;
- Fencing will be ClearVu type panels. The existing walls to the north will remain in place. The main gate to the site will be an electric sliding including a boom gate type and will be controlled from the security office in the weighbridge and management building.
- CCTV will be put in place for monitoring the bus filling station, the upgrading plant, the pump room, the access gate and other critical areas. This will be remotely accessible, and can will be displayed onsite in the security office at the weighbridge and/or alternatively in the main control room.
- A 22 m weighbridge is allowed for the waste delivery and removal trucks;
- Backup natural gas generator is included and is specified at 100 kWe. This will run critical control systems and a UPS keeps the control and critical safety systems online until the backup generator kicks in;
- Roads will be upgraded and established as per the layout. This will can be interlocking paving bricks as is currently used or similar strength material and must be suitable for the weights, and vehicle flows on site. No articulated buses are allowed. Buses will have right of way and signage should clearly indicate from the roadside, how buses and waste vehicles should route.

Three new buildings will be built for this plant.

- Weighbridge building
    - Ablutions (accessible from inside and out)
    - Weighbridge office
    - Induction room
- Management office building;
    - Kitchenette;
    - Server room/cupboard;
    - Reception;
    - Meeting room;
    - Managers office;
    - Infermary
    - Ablutions
- Control and laboratory building;
    - Control room;

    - Server room/closet;
    - Laboratory;
    - Kitchen;
    - Mess room with lockers;
    - Ablution facilities (including showers);
    - Spares and consumables storage.
- Digester pump room

Renovations on the existing site includes the following:

- Removal of wash-bay;
- Demolition and removal of incinerator and flue gas treatment;
- Removal of lean-to on the north;
- Removal of weighbridge on the north;
- Moving of boundary walls;
- Removal of the in-ground diesel tank to the west;
- Removal and rehabilitation of trees;
- Increasing the incinerator roof height;
- Re-sheeting of incinerator building and removal of the north facing substandard wall;
- Re-screeding the main floor in the incinerator tipping hall to allow for central runoff collection and the expansion of the current incinerator ash pit to allow for liquids delivery;
- Removal of most internal walls in the incinerator building.

The laboratory will be fitted out with the following equipment.

- Mobile gas analyser;
- pH analyser;
- FOSTAC measurement unit;
- Titration setup;
- Ammonia analyser;
- Alkalinity analyser;
- Conductivity analyser;
- Desiccator;
- Laboratory scale;
- Muffle furnace;
- Drying oven;
- Double wash basin;
- Fridge and freezer;
- Space for BMP units;
- Microscope;
- Storage for consumables and spares.

6 PROCESS CONTROL & INSTRUMENTATION

The process is controlled by PLC with a SCADA for interfacing with the operator. Analogue and digital control is used. The main control loops are as follows:

1. Gas buffer storage – the gas buffer volume is measured by a level transmitter probe in the top of the outer membrane. When gas level is detected to be at a high level the PLC is triggered to open the appropriate valves flaring. If the gas level is to low, the PLC will close any biogas utilisation lines and prevent those lines from being opened;
2. Gas pressure to utilisation – the pressure at the inlets of the gas boiler and gas engine will need to be controlled very well to ensure good operation. A pressure sensor just after the gas fan measures the pressure and relays it back to the PLC via a 4-20 mA signal. The PLC then regulates the VSD on the gas fan to attain the correct pressure of 10 kPa;
3. Tank levels and pump interlocks for preventing overfilling and unintended emptying of tanks. Some liquid levels need to be maintained in the tanks to ensure certain airlocks to prevent biogas from escaping to the atmosphere;
4. Feed quantity to digester – the feed rate can be calculated from the difference in weight if the feed tank over time as the secondary feed pump pumps waste into the digester. The level control on the tank acts as a backup to the load cell and prevents the tank from overfilling. The primary feed pump is only put on when the macerator runs to pump in the new waste into the feed tank;
5. Organic waste processing – the daily scheduled amount of waste is determined by the operator and management the day before and a weekly projection is made for the waste requirement based on digester performance, waste composition and digester loading rate.
6. The feed tank high level triggers the recycle rate – the recycle rate will be determined manually and the pump on / off sequence adjusted accordingly. This will only be required when loading the digester;
7. Digestate discharge and digester level – the discharge pump from the digester will switch on and off as the level in the digester fluctuates between a high level and low-level setting.
8. Digester temperature – The digester temperature is measured with a RTD. This temperature is used to determine if the heating on the digester is adequate and if the gas mixing of the digestate is adequate. If more heating is required, the hot water boiler will be turned on and off more frequently.
9. Digester mixing – this is done manually in override or on a preprogramed timer basis.

Safety interlocks can be viewed in the “Safety Systems” section.

The SCADA system communicates with PLCs, which in turn communicate, via Profibus connections, to the actual field instruments and equipment. A screen replicates in a schematic format, all the elements of the plant and provides status information and historical data of all components, process levels, positions of valves, temperatures and all essential information to visitors to the control room. A vast number of different screen display menus can be selected to provide status information and historical data for all mechanical and process aspects of the plant, including operating and rest intervals for each item of plant, aggregate operating time, process levels, process pressures, process flows and gas production. Each individual function of the process can be isolated, operated manually, or switched to fully automatic mode.

The PLC panel is equipped with a battery-backed power supply to safely shut down the controller in the event of power failure.

- Input power: 400V, 50Hz, zero, earth
- Control voltage: 230V, 50Hz, +24V DC

The control system with critical lighting and equipment will be run off a UPS that can sustain stable power for long enough for the backup generator to start up. A data logging and historian for all plant data including manual parameters that are input by the operators and weighbridge data will be put in place. The minimum retention period for the data on an onsite hard drive is 2 years. Offsite backups will be made on a revolving 2-year basis and constant loud backup storage will be done to ensure that the system changes can be recovered. It is therefore of primal importance that the plant has a good and stable internet connection. Uncapped and unshaped for >100 Mbps.

7 SAMPLING AND ANALYSIS

Sampling is crucial for determining the success of the plant on several levels:

1) The digestate is sampled and analysed for the following reasons:
    a. Day to day monitoring of the digester health to determine federate. For this the following analyses are done:
        i. FOSTAC VFA balance to ensure optimal gas production;
        ii. TS and VS to understanding solids destruction and process control;
        iii. Alkalinity to determine digester health and prevent foaming;
        iv. pH to determine digester health;
        v. Ammonium concentration to prevent toxicity;
        vi. Conductivity to prevent toxicity to anaerobic organisms.
    b. Analysis of final digestate cake according to standards for the ability to use it as compost. For this the following analyses are done:
        i. VFA content;
        ii. Nutrient content analysis;
        iii. TS and VS;
        iv. Alkalinity;
        v. pH;
        vi. Heavy metals;
        vii. Pathogen tests.
    c. Analysis of final digestate liquor according to standards for the ability to use it as liquid fertiliser. For this the following analyses are done:
        i. VFA content;
        ii. Nutrient content analysis;
        iii. Total dissolved solids;
        iv. Total settleable solids
        v. TS and VS;
        vi. Alkalinity;

vii. pH;
viii. Heavy metals;
ix. Pathogen tests;
x. Conductivity.

2) The biogas composition is analysed in with online or mobile gas analyser to determine the H_2S, CH_4, O_2 and CO_2 contents.
3) The biomethane is analysed with an online gas analyser to ensure the quality of the biomethane as per the CoJ Biomethane specification

Sampling points will be made available on the digesters and in the gas line.

Measured performance parameters of the plant will be as follows. This data will be logged for future analysis and used as up scaling input:

1. Electrical power consumption by the plant (kWh);
2. Biogas produced by plant (Nm^3/hr);
3. Biomethane produced by plant (Nm^3/hr);
4. Amount of biogas or biomethane flared (Nm^3/month);
5. Temperature variation in digesters (°C);
6. Water consumption of plant (L/day);
7. Feed rate into the digester from the feed tank (m^3/hr);
8. Daily digestate recycled (m^3/day);
9. Daily digestate cake removed (t/day);
10. Daily waste received (t/day);
11. Daily residual waste removed (t/day);
12. Daily digestate liquor removed (kL/day);
13. Daily amount of digestate liquor treated and disposed to sewer (kL/day);
14. Daily amount of digestate liquor treated and recycled to uses on plant (kL/day);
15. Pressure in digester and high-pressure gas storage tanks;
16. All data from vendor packages such as the upgrading plant and the gas cleaning;
17. Egoli gas consumption to boiler (Nm^3/day);
18. Egoli gas consumption to backup generator (Nm^3/day);
19. Amount of power produced from the solar roof (kWh/day);
20. The flowrate of hot water from Energy Systems (m^3/hr);
21. The temperature of the hot water from Energy Systems (°C);
22. The temperature of the return hot water from Energy Systems (°C);
23. Items 20,21, and 22 are combined and measured in such a way for use in billing for monthly heat energy use (GJ/month);
24. Amount of biomethane filled into which specific bus or vehicle by use of card system (Nm^3);
25. Levels on all major tanks (%);
26. Gas storage level (Nm^3);
27. Operating hours of machines (hrs).

8 SAFETY SYSTEMS

Safety is of utmost importance on a biogas plant. Intrinsic safe design ensures that risks are minimised. This is done by:

1) Adequate material selection – corrosion resistance, mechanical strength and durability;
2) Layout so as to ensure easily accessible equipment;
3) Easy escape routes from site;
4) Open installation – no enclosed areas where gas can build up in dangerous concentrations;
5) Standard biogas industry designs used for process units;
6) Spark proof installation in digester gas zone.
7) Ensuring signalling systems and assistance are in place for traffic at the entrance (where the road splits, at the weighbridge and where reversing into the building

The plant will be monitored 24/7 by a PLC system that has certain alarms and corrective measures that are activated during hazardous situations that can be measured either by.

1) High pressure – to prevent rupturing of membrane components. Secondary fail safe is a pressure relief valve;
2) High temperature – prevents non-optimal operation of digester. Temperature of both the hot water and the digestate is measured;
3) High level – to prevent overfilling and spillage. Level sensors measure this;
4) Low level;
5) Low pressure;
6) Low temperature;
7) Methane detection.

Firefighting equipment will be available on site and proper signage and training will be supplied with personal protective equipment (PPE) for the operator. Location of firefighting equipment and the specific types are to be finalised based on input from the Fire Department and the MHI specialist. The detailed Hazardous Area Review will need to be done as well as a HAZOP based on the final design by the EPC contractor.

9 MASS AND ENERGY BALANCE

The mass and energy balances are included in the Process Flow Diagram document package. The summary Mass Balance diagram is shown in figure 10 below. This is based on the options set forth in the PFD, the financial model and budget.

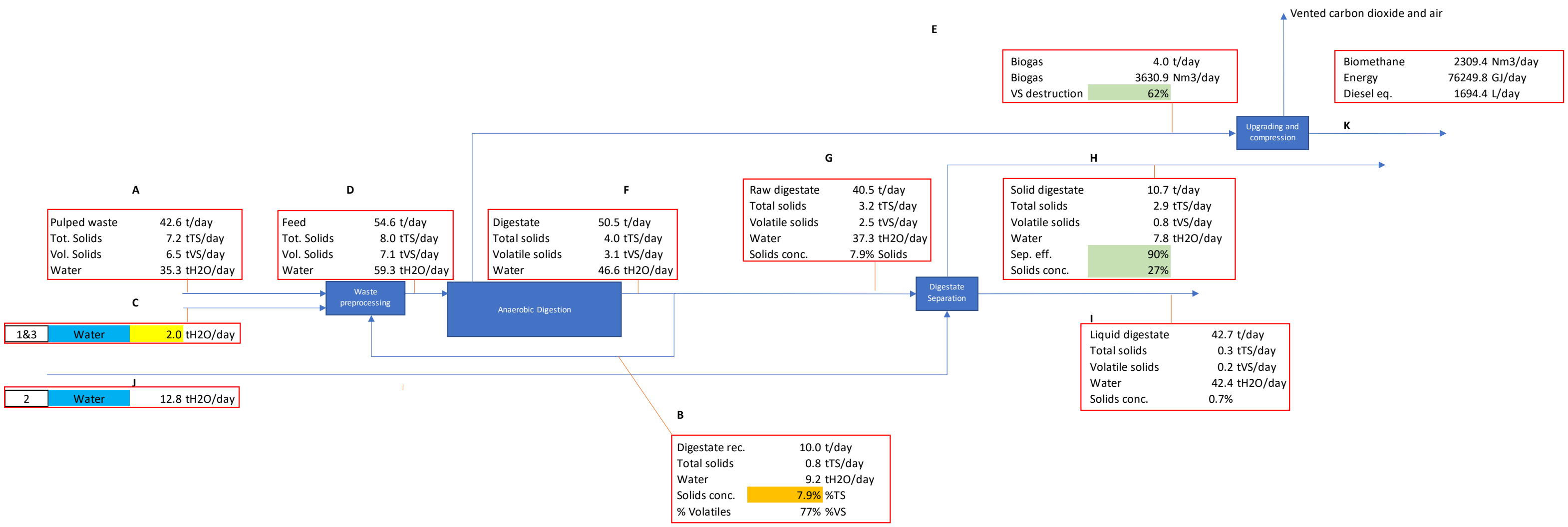

Figure 10: Summary Mass Balance diagram

The energy required to power the facility will be divided into heat and electrical energy.

The heat energy required will be used for heating the digesters (in the case of no drying). This will be done with hot water from the nearby source and will be supplied at 65-80 Deg C. The majority of heat required is for heating the feedstock to the required operating temperature of 38 deg C. Some energy is also supplied to balance the heat loss from the system. Figure 11 Shows the heat loss balance per tank, of which there are two. The heating for the feedstock will determine on quantity and ambient temperature (feedstock temperature), but this is expected to vary between 70 and 105 kW th.

TANK HEATLOSS		MAX		AVG	
			kWth		kWth
	TOTAL	**Qlost**	**17.8**	**Qlost**	**11.3**
		Qroof	5.9	Qroof	3.2
		Qwall	8.3	Qwall	4.5
		Qfloor	3.6	Qfloor	3.6

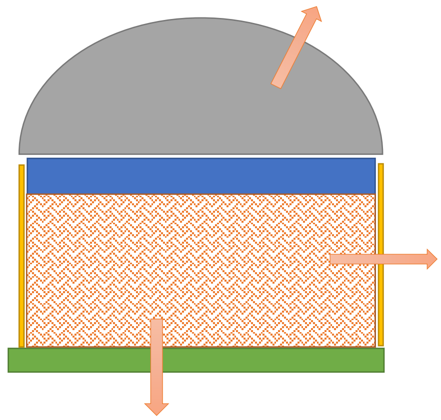

Figure 11: Heat loss depiction from the tanks.

The total heat requirement will therefore be in the region of 80 to 122 kW thermal.

Electrical energy will be used for driving pumps, fans, conveyors, mills, lights ventilation, compressors etc. The operation of the waste pre-processing will be a day-time operation. Hence many of the loads will run during the time that there will be solar energy available. This is part of the smart design to ensure lower electricity costs for the facility. It specifically assists to reduce maximum demand charges. The maximum predicted load is 341 kW electrical with all the equipment running. To prevent high costs sequential starting of equipment is advised and soft starters or VSD's on large motors need to be installed. The average estimated electrical power consumption is 140 kW electrical. This results in an estimated total yearly electricity consumption of 1207846 kWh/year.

10 OPERATIONS & MAINTENANCE

It is envisaged that during operations the plant will employ, through the operating contractor approximately 30 people. The operators will undertake preventative equipment inspection and maintenance in addition to normal operator activities. These checks allow for early action on

problems caused by failure, normal wear and tear on certain parts of the digester and the rest of the plant. Maintenance interventions can be divided into the following sections:
Low risk – these are changes that can be done while the plant is online or while a section of the plant is still running. Pumps can be replaced by isolating the line where the problem is and removing the unit without much disturbance to the system.
High risk – these interventions would require the entire shutdown of the plant to ensure safe access by maintenance personnel. Any intervention of the gas line will require such a shutdown and safe declaration. This will include securely sealing off potential hazardous streams, putting off all electrical equipment except critical units and oversight by another suitably qualified person.

11 PERMITS AND PLANNING

Permits required by the plant are as follows:

- Waste license for the biogas plant (<100 tons per day) - Completed;
- Waste management license for the decommissioning of the old Health Care Risk Waste Incinerator - Completed;
- Township Establishment for Green Infrastructure land use – In process;
- A site development plan based on the final design to be built signed off by Architect – by EPC contractor;
- Building plan approval– by EPC contractor;
- Fire Chief approval – by EPC contractor l.

12 CONSTRUCTION

The construction period is expected to take 14-18 months. Epoxy coated steel tanks are preferred as the civils works are recycled and time and risk of implementation is less.

13 COMMISSIONING

Commissioning will take 4 - 6 months. This will entail Cold and Hot commissioning. Cold commissioning involves the checking of all motors and systems from a checklist to ensure installation is correct.

Hot commissioning requires seeding of the digesters and this would need to be sourced from a functioning biogas plant. A quantity of ~1000 m^3 should be allowed for. During hot commissioning the biogas plant starts to produce biogas and this is the most dangerous and critical part of startup as air may be present in certain sections and special care should be taken to flare and vent gas safely while purging vessels and lines.

Tanker filling points on all the tanks allow for fast filling with seeding sludge or for the removal of digestate during maintenance.

14 LAYOUT

The layout has been designed to split the operations of the MRF and biogas production from the bus filling station for safety reasons. The layout also indicates the locations for the optional water treatment plant and the digestate dryers as well as the space for future digester capacity expansion. Reticulation of service vehicles around the site is allowed for but the main heavy vehicle moving area is situated to the south where the intake of waste and the removal of digestate and residues is managed from.
The layout shows and integrates the heat distribution connection from Energy Systems' landfill gas operation and from the electrical substation outside the boundary.

Please see attached the CoJ Biomethane Plant Layout in Annexure 3.

A 3D model has also been compiled showing the indicative final structures and dimensions of the plant.

15 ANNEXURES

Annexure 1: CoJ Biomethane Specification ED002
Annexure 2: CoJ Biomethane Process Flow Diagram
Annexure 3: CoJ Biomethane Plant Layout

16 DOCUMENT CONTROL REGISTER

Rev. No	Nature of Revision	Date Approved	Prepared By:
R11	Finalised Report	2020-01-10	D. Boshoff

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