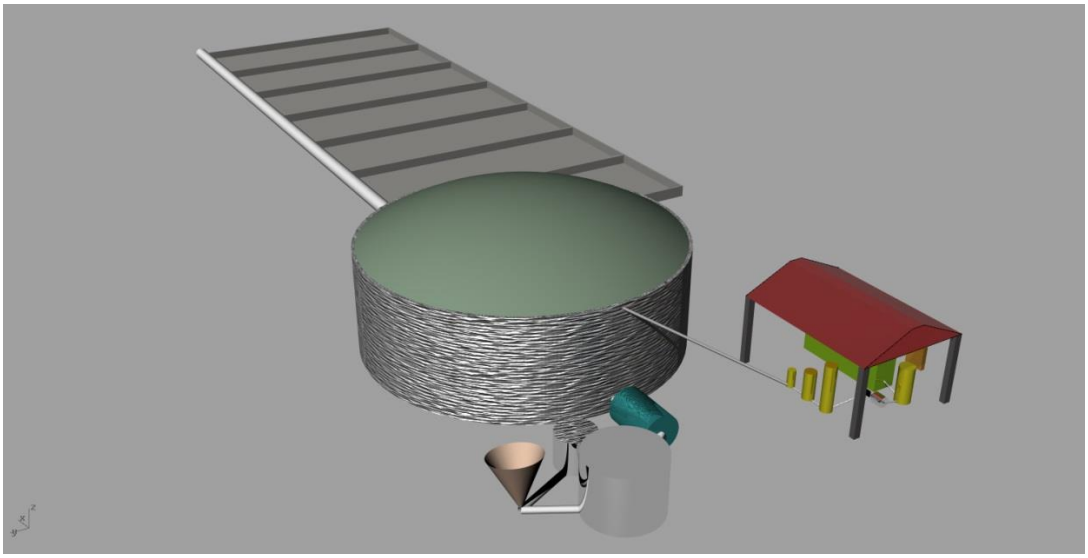
Project Proposal Chicken Chain Farm

Cattle Excreta, Pig Excreta, Sewage Sludge, Abattoir Waste and Food Waste Biogas Plant

Yonis Le Grand, Steven Roerink, Job Seuren and Eva ten Velden

12/14/2015



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Project Organization

Our project team

Y.S. le Grand	Mechanical Engineering
S.J. Roerink	Technical Policy and Management
J.J. Seuren	Maritime Technology
E. ten Velden	Architecture

Our project team consists of four students form the Delft University of Technology who are in the final year of their bachelor.

Job Seuren and Yonis le Grand will be mainly concerned with the technical aspects of the project. Research and design will be their prime responsibility. The designing will be supervised and valorised by Bart Frederiks.

Steven Roerink and Eva ten Velden will focus their attention towards the management- and marketing aspects of the project.

Most of our design is based on a feasibility study done by three other students beforehand, the advice of professors in the Netherlands and the advice of Peet Steyn, local Biogas engineer and owner of Botala Energy Solutions.

Supervisors

Prof. T.A. Mofokeng
Prof. Takatso Mofokeng is the owner of the Chicken Chain Farm enterprise and the client of this project. Originally obtaining a doctorate in Theology at Kampen University he decided to become a cattle farmer. He chose this career path because of the lack of black farmers in South Africa. He runs a mentorship program for the emerging black farmers in South Africa.

Dr. Otto Kroesen
Otto Kroesen has a background in theology and received his doctorate from the Theological University of Kampen. At present, he is an Assistant Professor in ethics, intercultural communication and development theory at the Technical. He also teaches technology, innovation and development at the Technical University of Eindhoven. He has an affinity for the development of technology in developing countries. In the context of the project he advises the team of students on the business development side with a particular focus on the socio-cultural context.

Technical Advisors

Bart Frederiks MSc.
Bart Frederiks received his Master's degree in Development Studies from the Technical University of Eindhoven. Currently, he works as a freelance consultant with some 15 years of experience in the field of biomass and bioenergy. Bart Frederik's has supervised the previous project team on their feasibility study. He has given our team recommendations on the design but will not be further involved in the project due to time constraints.

Dr. Henri Spanjers
Henri Spanjers graduated in 1985 from Wageningen University as an Environmental Engineer. He received his doctoral degree in 1993 in Activated Sludge Process Respirometry. He has

worked at several universities and research institutions across Europe. He was project director with Lettinga Associates Foundation in Wageningen. He is secretary of the International Water Association Specialist Group on Anaerobic Digestion. He will be increasingly involved as an advisor of the project towards the future.

Scope of work

The mission of this project is the realization of a functional and financially Biogas Digester with Electricity Generator. The gas will be used to power the generation and provide electricity to a client.

The scope of work for this team:

- To provide a preliminary design of the 100 kW installation.
- The team will also seek cooperation with local industry and institutions for the continuation of the project.
- A follow up team of South African students will be recruited to finalize the design. This will ensure the completion of the project. It will also provide a useful opportunity for lasting knowledge transfer and an Afrocentric aspect to the project.
- Write a business plan to be used after the completion of the plant.

Executive Summary

Project Description	**Mixed-feedstock Biogas Facility with Electric Generator**
Plant Model	**Continuous Stirred Tank Reactor**
Packages	Feed preparation: Pasteurizer, Shredder, Water pump Digestion: Stirred tank anaerobic digester (incl. Mixing and Heating systems) Discharge Handling: Digestate de-watering drying beds & Post store Biogas Handling: Gas treatment , pressure boosting system and 4 hours of storage Generation: Electrical generator set 120 kW + CHP boiler Plant Controls: Electricity distribution, connection an Manual Control Panel

General information		
Feedstock – Average daily availability		
Cattle excreta	6500	kg
Pig excreta	1000	kg
Sewage sludge	2000	kg
Slaughterhouse waste	2100	kg
Cattle stomach content	4200	kg
Food waste	700	kg
Total	16.5	ton

Plant Output Capacity			
Peak Electrical Power Generation Potential		1,800	kWh/day
Peak Monthly Electrical Power Generation Potential		54,000	kWh/month
Nominal Annual Electrical Power Generation@ 90% availability		583,200	kWh/annum
Peak Monthly Electrical Account at annualized average electrical price of R0.9118/kWh		49,000	R/month
Generation: 1 X Electric generator sets 112.5 kW 3-Phase + CHP Boiler		112.5	kW
Genset Heat Recovery CHP Hot Water @ 80°C		7.5 ~ 178 ~ 150,000	m^3/h kW (Heat) Liters/day
Generator Daily Operating Hours		20	hours/day
Plant Footprint Size			m
Organic Fertilizer Discharge	Compost Fibers: 3.7 ton/day @ R20/ton	22,200	R/annum
	Liquid (dissolve Nutrients)	4,800	Liters/day
	N : 33095kg @ R6.4 /kg	212,000	R/annum
	P : 19858kg @ R19.2 /kg	381,000	R/annum
	K : 21182kg @ R6.4 /kg	136,000	R/annum
	Total Organic Fertilizer Value	751,200	R/annum
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Initial cost estimate*		
Feed preparation: Pasteurizer, Shredder, Water pump	R	34,845
Digestion: Stirred tank anaerobic digester (incl. Mixing and Heating systems)	R	338,000
Discharge Handling: Digestate de-watering drying beds & Post store		
Biogas Handling: Gas treatment , pressure boosting system and 4 hours of storage	R	15,820
Generation: Electrical generator set 120 kW + CHP boiler	R	431,000
Plant Controls: Electricity distribution, connection an Manual Control Panel	R	66,250
Total:	R	885,915

*This cost estimate is still a draft and may vary in the future.

Biomass inputs

The biogas production on site will be based on different types of biomasses. The following biomasses are expected to be included:

- Cattle excreta
- Pig excreta
- Sewage sludge
- Slaughterhouse waste
- Cattle stomach content
- Food waste

These biomasses will be collected from different biomass suppliers throughout the region. As can be seen from the table, the following inputs are preliminary used for calculations.

Feedstock – Average daily availability		
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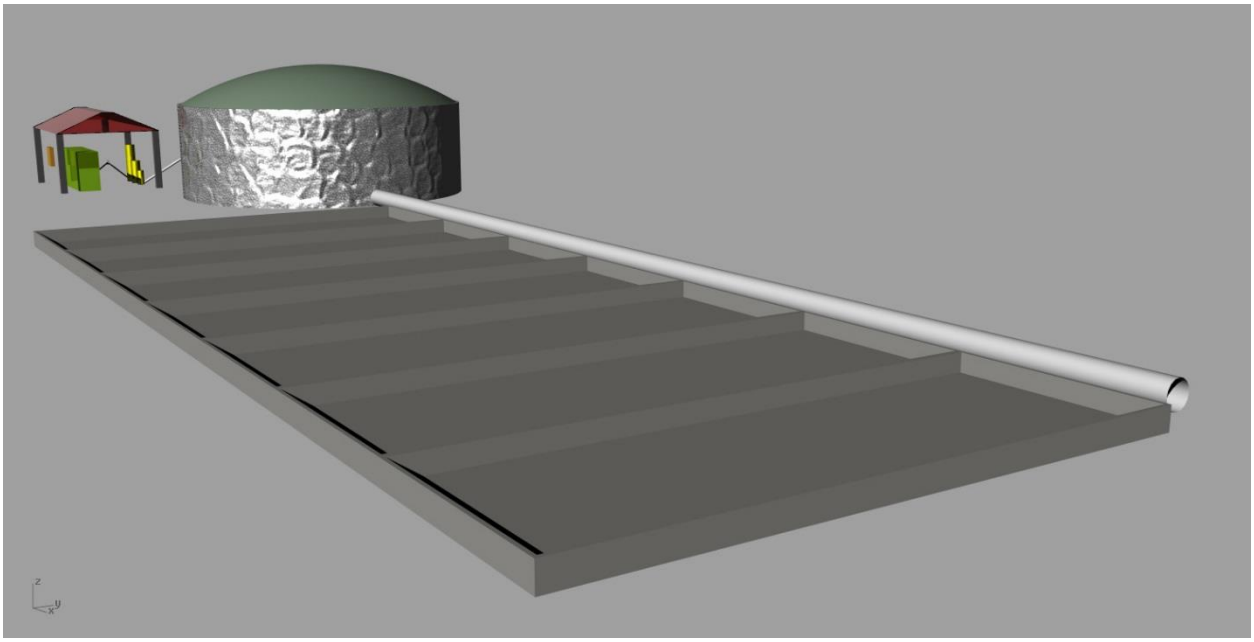
Cattle stomach content	4200	kg
Food waste	700	kg
Total	**16.5**	**ton**



Energy, heat / hot water and fertilizer outputs

The feedstock above is used to calculate the outputs in the given table below. The table summarizes the plant capabilities.

Plant Output Capacity			
Peak Electrical Power Generation Potential		1,800	kWh/day
Peak Monthly Electrical Power Generation Potential		54,000	kWh/month
Nominal Annual Electrical Power Generation@ 90% availability		583,200	kWh/annum
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Electricity

The peak electrical power generation per day is equal to 1,800 kWh. This will be 583,200 kWh per year at 90 percent availability. The monthly electrical account at an annualized average electrical price of R0.9118 per kWh will be R49,000 per month.

Heat / hot water input and output

Hot water of a temperature of 80°C is generated by the CHP boiler. This hot water can be circulated at a flow rate of 7.5 m^3/hour and will re-enter the CHP boiler at 60°C. Thus the generator CHP boilers create a heating power of 178 kW, which can be used to heat the pasteurizer and digester to respectively 70°C and 35°C.

Fertilizer

The fertilizer is extracted on a daily basis. The digestate can be distributed in a mud-like fluid or it can be dried and sold in as dry fertilizer in order to improve its saleable qualities. The estimated liquid fertilizer is 17 m^3 per day, if dewatered the dry fertilizer will be 850 kg per day. The liquid fertilizer will be stored dewatered in drying beds. Each day a different drying bed will be used, in that way fertilizer will be dried for 7 days and eventually stored on a pile.

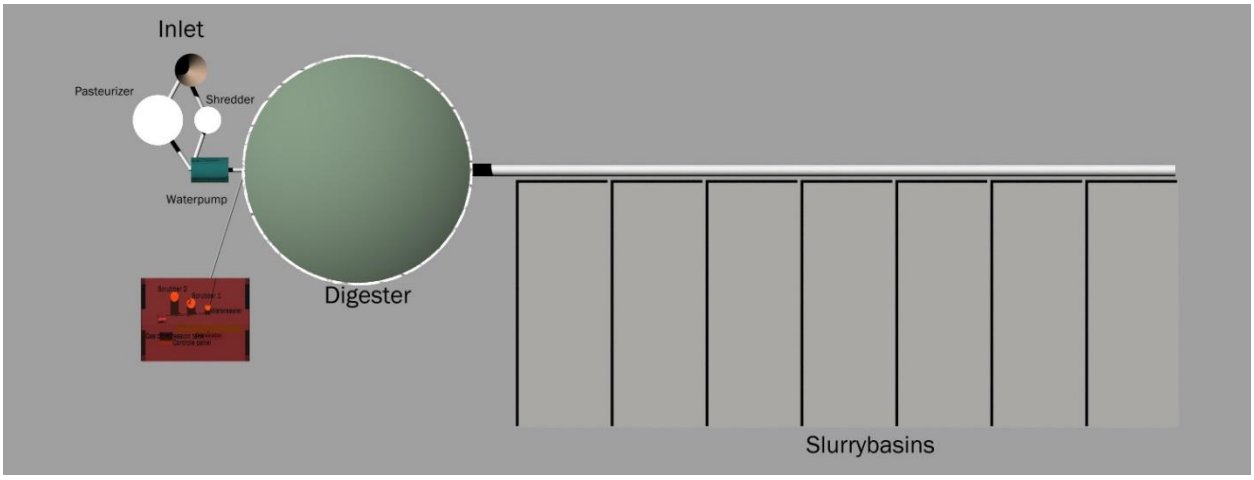
Technical components specifications

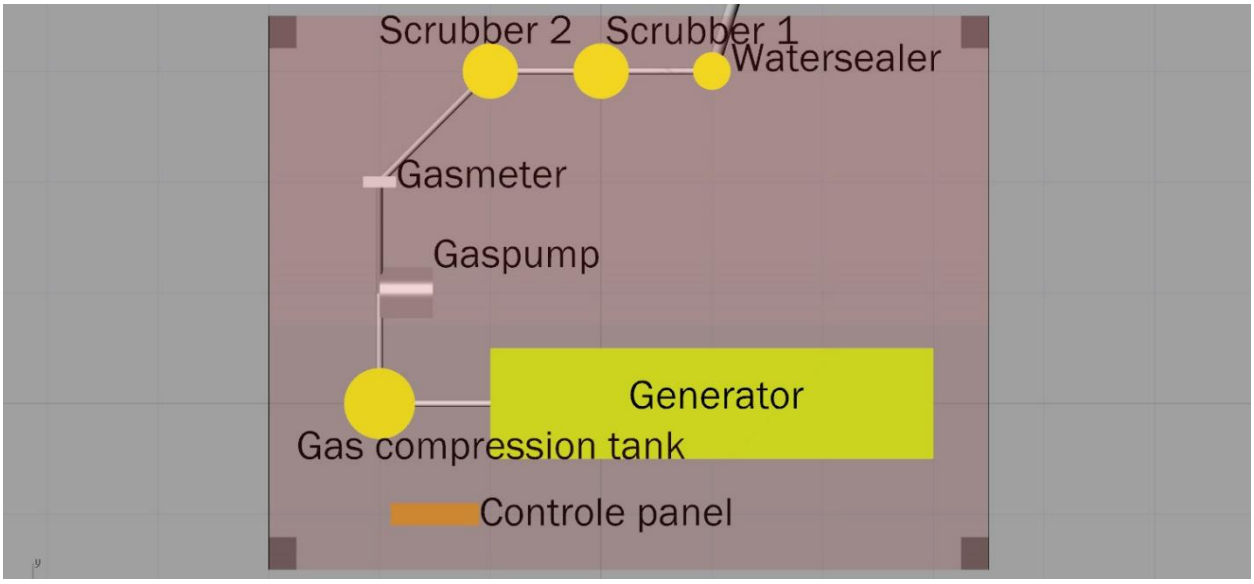
The biogas plant will consist of a 650 m^3 digester of 13.5 m diameter x 4.5 m tall, which is made of a zinc aluminum alloy. The plant will be equipped with a 120 kW generator with a CHP boiler to mainly heat the digester and the pasteurizer.

The abattoir waste will be pre-treated by a pasteurizer and the food waste will be pre-treated by a shredder.

The following biogas plant system is proposed:

Plant Model	Continuous Stirred Tank Reactor
Packages	Feed preparation: Pasteurizer, Shredder, Water pump Digestion: Stirred tank anaerobic digester (incl. Mixing and Heating systems) Discharge Handling: Digestate de-watering drying beds & Post store Biogas Handling: Gas treatment , pressure boosting system and 4 hours of storage Generation: Electrical generator set 120 kW + CHP boiler Plant Controls: Electricity distribution, connection an Manual Control Panel





Digester Tank

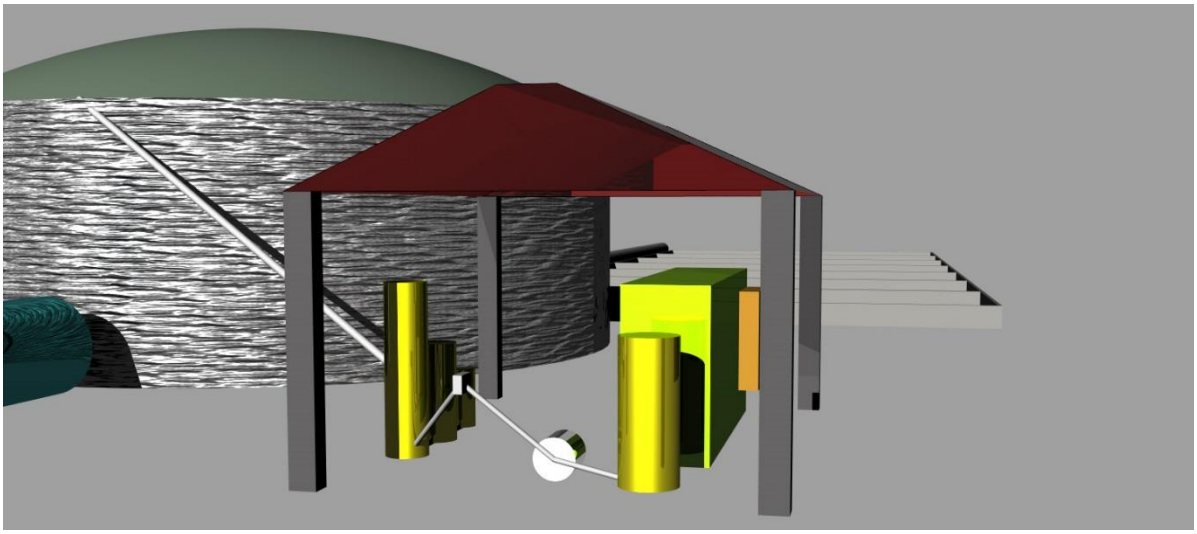
A zinc aluminum water tank has been chosen for the digester. The tank itself costs R250,000. A Concrete ring will need to be added around the lower layer to prevent corrosion. This will cost an additional R 80,000.

Digester Tank Properties	
Digester tank	Zinc Aluminum Water tank
Dimensions	
Diameter [m]	13.5
Height [m]	4.53
Volume [m^3]	648
Daily substrate input quantity	18.13
Daily wet biomass input [m^3/day]	16.56
Daily additional water input [m^3/day]	1.58
Price	R 330,000

Generator

Generator Properties	
Type	CHP open type
Price	R 431,000
Prime/continuous power	120kW/100kW
Fuel consumption	56.92 m3/h
Cogeneration(heat) efficiency	85%
Electric efficiency	~30%
Service life	30 years
Producer	Camda New Energy Equipment Co., Ltd.
Source	Alibaba

This combined heat and power engine will generate electricity and the needed heat to keep the pasteurizer and digester running. The maximum estimated power generation is 91 kW and will run 20 hours per day. A safety factor of 125% has led us to choose for a generator of 120 kW prime power. An open generator ($28,600) was chosen because the cost of the silent type was $32,600 dollars, a $4000 dollar difference. The generator will have to be placed inside a concrete structure to counteract the noise. The heat cogeneration option costs an extra $8733 resulting in the total cost of $37,333 (Generator, Alibaba, 2015).

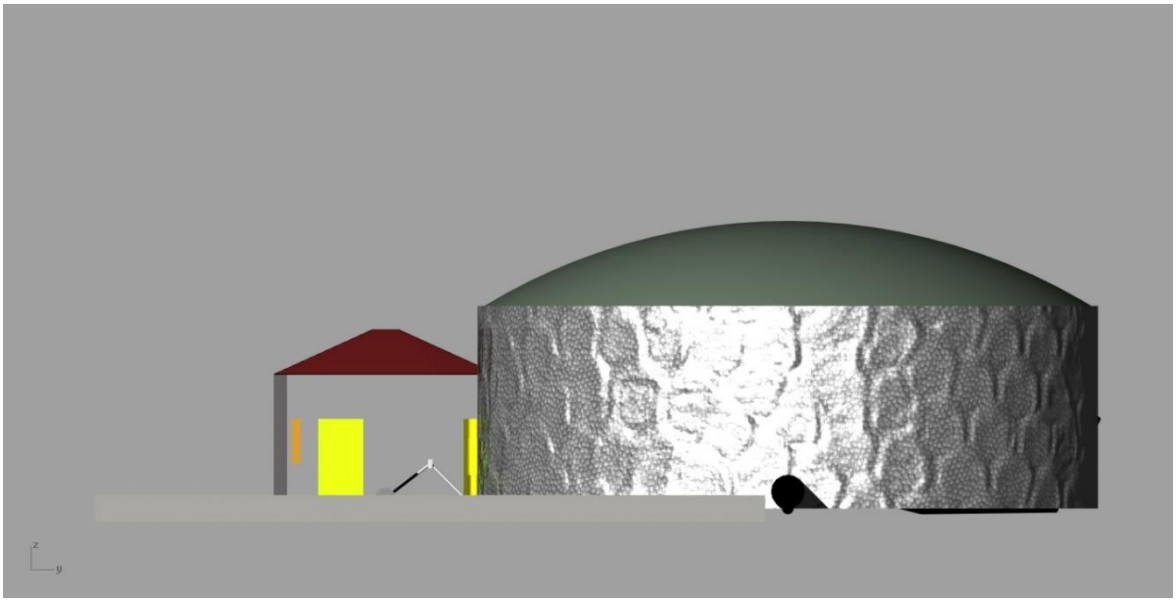


Digester

Insulation

The current design has a diameter of approx. 13.5m and a height of 4.5 m. The surface to be insulated will be 191m^2. With a thickness of 20 mm, polystyrene sheeting will cost approximately R3500.

Digester Tank



Heat exchanger

Within the Digester tank a heat exchanger will be placed to maintain the working temperature of 35^{o}C. The heated water from the CHP will pass through this exchanger at a rate of 7.5 m^3/h. A titanium corrosion resistant tubular heat exchanger will cost R 3000 (Heat exchanger, Alibaba, 2015)

Mixer

According to Energies journal research (Lemmers et al, 2013) highest agitator efficiency can be achieved with inclined axial agitators. This has been done in a tank with similar dimensions to our design. Our current estimated price is R15,000.

Shredder

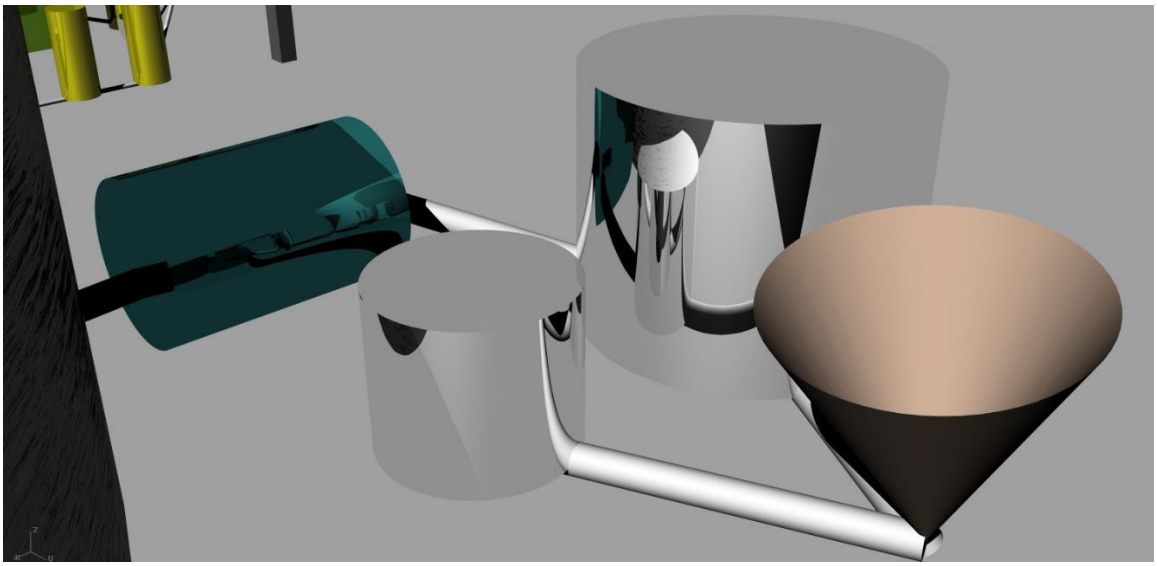
Description	Quantity
Type	Food Waste Disposer
Price	R 7294
Volume	226 l
Capacity	1 ton/hour
Power	2.2 kW
Height	1.35 m
Diameter (valve)	80 mm
Source	Alibaba

The food waste shredder is an optional object. A shredder is needed to shred food waste into small pieces, because not shredded food will affect the digester negatively.
If a more budget option is required, it's possible to buy a smaller shredder, shred the food and then put it into the digester (Shredder, Alibaba, 2015).

Pasteurizer

Due of money, a big tank will be used as a pasteurizer with the usage of heat of the engine, to heat the tank for 1 hour at 70 Degrees Celsius. The pasteurizer is needed to ensure a sufficient percentage of pathogens in the feedstock are removed. It also prevents any bacterial competition in the digestion stage. The pasteurizer will be heated by the hot water generated by the CHP boiler, as described in the heat / hot water input and output (Pasteurizer, Alibaba, 2015).

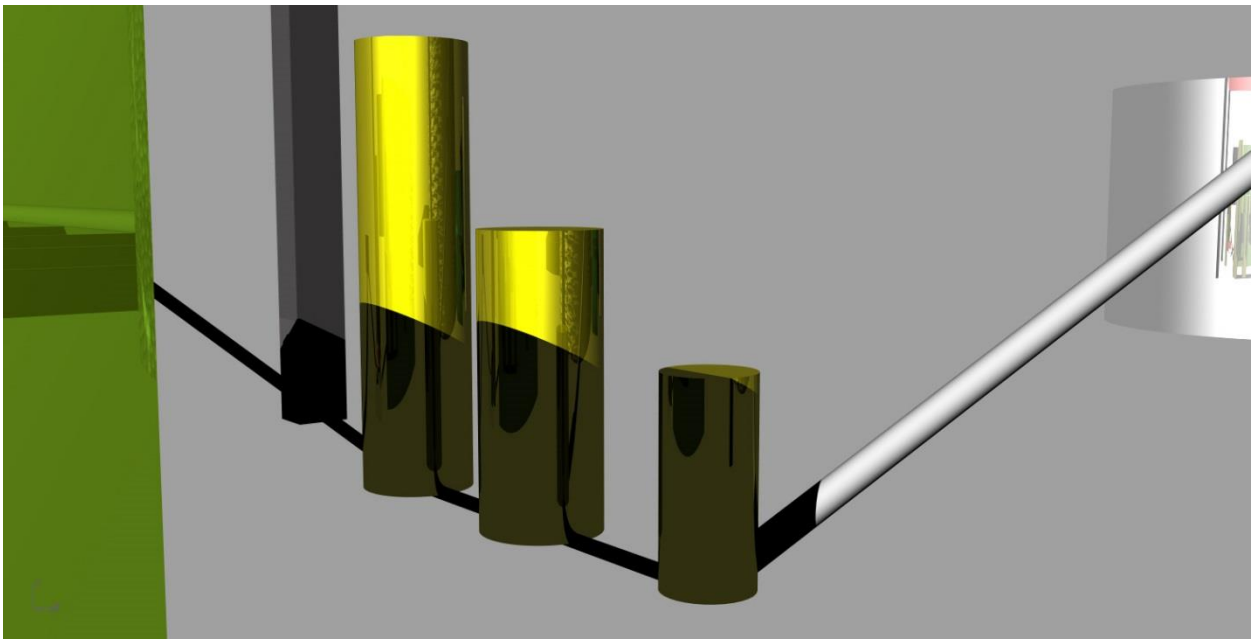
Description	Quantity
Daily slaughterhouse waste	6300 kg
Daily slaughterhouse waste	12194 L
Work Volume pasteurizer	15000
Tank Dimensions	2,530 x 3,0 (m x m)
Total height	5200 mm
Insulated layer	60 mm
Diameter of inlet & outlet	51 mm
Price	R 15,678
Source	Alibaba



Scrubbing

H_2S Removal Properties			
Description	**Quantity**	**Price**	**Comment**
Iron oxide pallets	5 m^3	R 15,820	
Scrubber tank with use of oxygen		0	Since Mr. Mofokeng already possesses suitable scrubber tanks, the price is set to 0.
Source	Alibaba		

Hydrogen sulphide should be removed from the digester before it can turns into normal, not toxic, gas. Hydrogen sulphide reacts easily with iron oxide or hydroxide which is usually bound on wood chips or red mud pellets to increase the reaction surface. In a two-column plant one column binds H2S whereas the other is regenerated. To use iron pallets is a solid and cheap method to remove the hydrogen sulphide (Scrubber, Alibaba, 2015).



Control Panel

Description	**Price**
• **Electricity distribution: 3-phase cabling on plant & plugs** **• Connection: Generator to site connection switches and generator paralleling unit.** **• 50-100m cabling allowed for connection** **• Manual control panel: Plant control circuit breakers and switches** **• **Optional 1 x 15 kVA UPS standby power supply for black generator start up. (12674 US Dollar)**	R 66,250

After research on different control systems, SCADA seems to be the best one. SCADA is a full automatic system. “The SCADA system has a user-friendly interface that is easy to operate. The remote control and monitoring facilities allow users to log in to the system anywhere with an internet section, thus making it possible to control the plant at a distance. Operators can monitor the plant from a PC and therefore do not always have to be physically present in order to make operational adjustments (XERGI, 2015)”.

However, according to Peet Steyn, director of Botala Energy Solutions, the use of the SCADA system is not required for this project. Only the temperature should be regulated automatically, while the other regulations can be manually controlled by an operator. Therefore the best system is one with push buttons.

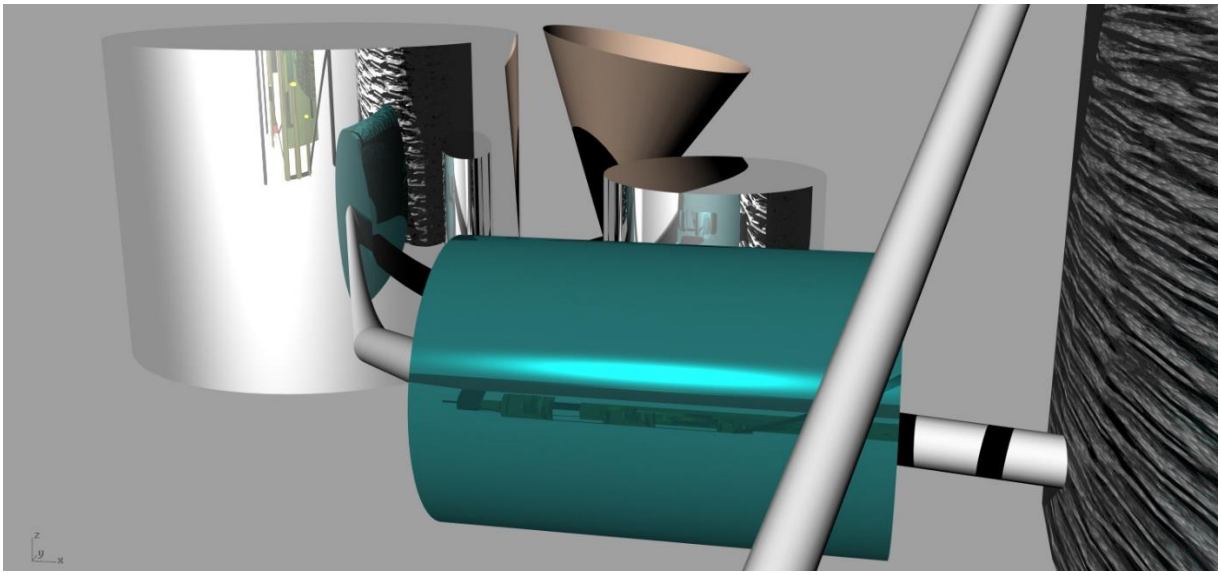
Pumps

Description	Value
Type	Gas (vacuum) pump
Power	4kW, Electric
Pressure	380 Mbar
Output	350 m^3 /hour
Price	R 7294
Source	Alibaba

A gas pump is needed to attract the gas to the generator (Gas pump, Alibaba, 2015)

Description	Value
Water pump	R 3079
Power	11kW
Size	100 – 650 mm
Material	Cast Iron
Fuel type	Diesel
Minimum Flow rate	70 m^3 /hour
Maximum Flow Rate	20000 m^3/hour
Company	Jiangsu XuRi Pump Manufacturing Co., Ltd.
Source	Alibaba (Water pump, Alibaba, 2015)

“Pumps are required to bridge differences in height between the levels of slurry-flow through the biogas unit. They can also be required to mix the substrate or to speed up slow flowing substrates. If substrates have a high solid content and do not flow at all, but cannot be diluted, pumps or transport belts are essential” (Energypedia, 2015).



Piping

Description	Value
Piping	PVC Pipes
Price	R 1500
Company	DPI Plastics
Source	

The pipes, which will be used for connections of the digester, will be bought in South Africa. For the digester plastic pipes will be used (Piping, 2015).

Route planning

On a daily base a route of 82 km will be driven with a truck for collecting biomass at the biomass suppliers. This route is chosen with a use of Dijkstra's Algorithm.
The sequence of picking up will be the following:

Route Planning		
#	**Location**	**Coordinates**
1	Chicken Chain Farm	(-26.413267, 28.756858)
2	Mr. Twala	(-26.413290, 28.760201)
3	Abdul	(-26.419397, 28.758061)
4	Kobus Louw Farm	(-26.416895, 28.790659)
5	Prison Devon	(-26.368672, 28.799086)
6	Sewage Treatment Installation Devon	(-26.348888, 28.743622)
7	Devon Abattoir	(-26.381180, 28.733466)
8	Mrs. Mampe's Farm	(-26.392010, 28.665854)
9	Leandra Abattoir	(-26.379949, 28.896036)
10	Chicken Chain Farm	(-26.413267, 28.756858)

In the table below

Fuel costs		
Description	**Value**	**Unit**
Route	82	km
Specific truck fuel consumption	25.8	liter/100km
Fuel consumption per trip	21.16	liter/day
Diesel price	10.81	R/liter
Fuel costs per day	229	R/day

Literature

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