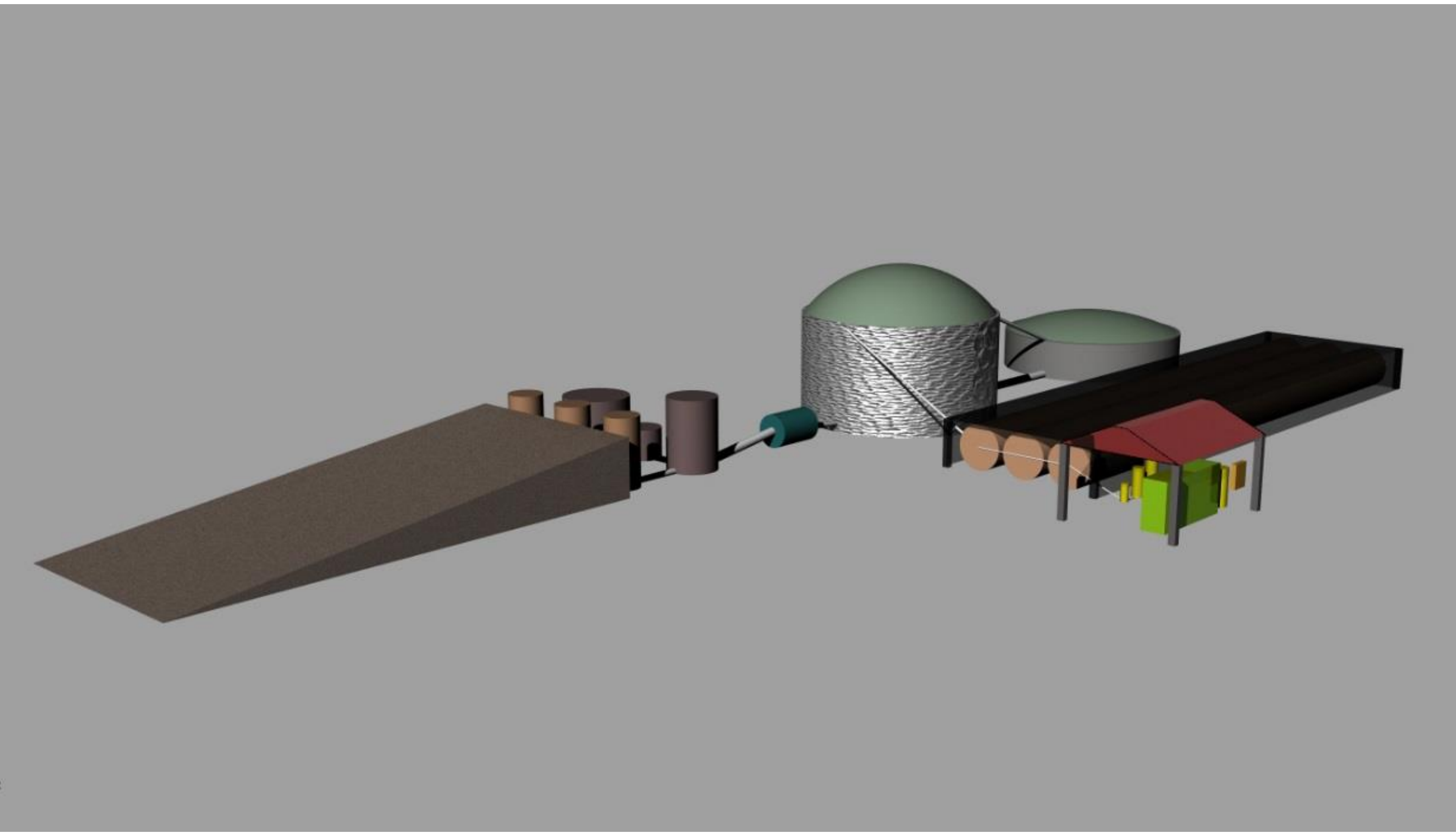
Intership duration 05/11/2015 – 27/01/2016

INTERNSHIP REPORT

OPERATING BIOGAS PLANT
CHICKEN CHAIN FARM
DEVON, SOUTH AFRICA



By

Yonis Le Grand – 4081633
Steven Roerink – 4314751
Job Seuren – 4289021
Eva ten Velden – 4275624

Supervisor: Dr. Otto Kroesen
Project Owner: Prof. T.A. Mofokeng

TU Delft

TABLE OF CONTENTS

Project introduction

Project organisation

In the following paragraphs the structure of the organisation during the project will be further explained.

Our project team

Y.S. le Grand	Mechanical engineering
S.J. Roerink	Technology, Policy & Management
J.J. Seuren	Maritime technology
E. ten Velden	Architecture and the Built Environment

Yonis Le Grand
Yonis Le Grand is a student who is enrolled in his Bachelor studies in mechanical engineering at Delft University of Technology. His focus will be on the designing of the biogas digester

Job Seuren
Job Seuren is a student who is enrolled in his Bachelor studies in maritime technology at Delft University of Technology. His focus will be on the designing of the biogas digester

Eva ten Velden
Eva ten Velden is a student who is enrolled in his Bachelor studies in architecture at Delft University of Technology. Her focus will be on the drawing of the design of the biogas digester and also of the management of the Technology.

Steven Roerink
Steven Roerink is a student who is enrolled in his Bachelor studies in Technology, Policy and Management at Delft University of Technology. His focus will be mainly on the management of the Technology and besides on the designing of the biogas digester

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 managing director of Botala Energy Solutions.

During the course of the project a natural overlap of the assigned tasks will take place. The major steps will be decided as a group. Also every member of the group will be a contact person towards the outside world.

The following stakeholders, with exception of Henri Spanjers, are the clients and supervisors as described in the Mid-Term Report by Goemans et al. 2015 and the Final Project Report by Goemans et al. 2016.

Project owner

Prof. T.A. Mofokeng
Prof. 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.

Supervisors

Dr. Henri Spanjers

Henri Spanjers graduated as an Environmental Engineer from Wageningen University. He later received his doctoral degree in Activated Sludge Process Respirometry. He worked at several technological institutions like the department of Agricultural, Environmental and Systems Technology of Wageningen University, at the Lund Institute of Technology in Sweden, at the University of Ottawa in Canada, at the Joint Research Centre of the European Commission in Ispra, Italy, at Ghent University in Belgium, and he was project director with Lettinga Associates Foundation in Wageningen. Furthermore is he a secretary of the International Water Association Specialist Group on Anaerobic Digestion and editor-in-chief of the journal Water Resources and Industry. Henri Spanjers will be our technical supervisor during the project.

Bart Frederiks MSc.

Bart Frederiks received his Master's degree in Development Studies from Eindhoven University of Technology. Currently, he works as a freelance consultant with some 15 years of experience in the field of biomass and bioenergy. Hence, he is an experienced and capable supervisor who supervised the previous team of students during the project mainly in the technical field.

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 Delft University of Technology. He also teaches technology, innovation and development at the Eindhoven University of Technology. He has an affinity for the development of technology in developing countries. In the context of the project, he is supervisor of our team during our preparing time in the Netherlands and our stay in South Africa and will advise the team on the business development side with a particular focus on the socio-cultural context.

Previous team

Evan Roberts

Evan Roberts is a student who is enrolled in his Bachelor studies in mechanical engineering at RWTH Aachen University. He specializes in energy engineering and strives to complete his degree by the end of next year. Due to his technical background, he will mainly focus on the technical realization of this project. He will also be involved in several of the business related areas.

Len Rijvers BSc.

Len Rijvers is a student who received his Bachelor's degree Mechanical Engineering from Eindhoven University of Technology. Currently, he is enrolled in the Master program Sustainable Energy Technology at the aforementioned university. In the context of an internship he participates in this project. Due to his technical background he will deal mainly with the technical issues. Moreover, he will also be involved in several of the business related areas.

Roxanne Goemans BSc.
Roxanne Goemans is a student who received her Bachelor's degree Molecular Science and Technology from Delft University of Technology. Currently, she is enrolled in the Master program Management of Technology at the aforementioned university. In the context of her Master thesis project she participates in this project. Her focus will be on management of the technology in a socio-cultural context.

Mission of the project

"The mission of the project is to introduce ***sustainable energy,*** *with the use of available resources. To build a biogas plant with generator and create* ***awareness****, of this renewable technology, in the local population."*

Summary of the problem

Our mission and project is to provide a small scale improvement to three major global and local problems in South Africa stipulated by Mr. Mofokeng's business plan:

- The global state of environmental degradation and climate change;
- Rising energy demand in South Africa;
- Economic (racial) inequality in South Africa.

The first major issue is the commonly known negative effect of industrialization throughout the world. South Africa has been heavily reliant on fossil fuels which have a negative impact on its ecosystem. This is why the South African government and various institutions in the private sector are making a push for alternative renewable resources.
This issue is closely coupled to the increasing energy demand. The national energy supplier, ESKOM, is having difficulties expanding at a rate that could satisfy the increasing demand. Rolling blackouts and electricity price escalations are the general experience of the locals. These inevitably lead to commodity price increases and the strangling of emerging agricultural producers.
This is the third problem that we wish to tackle. Even after the end of apartheid most farms are in the hand of the white minority. Black Africans have lost the contact with the land after years of oppression and lack of opportunity under apartheid. Skilled black farmers are still a (growing) minority. This problem is evident across other economic sectors of South Africa. The lack of educated individuals is making one of the most powerful economies of the African continent increasingly difficult to maintain.

Scope (summary of the solution)

Before the actual construction of the biogas plant certain actions need to be taken care of. First of all, the team will be writing a business plan for the situation on the farm of Mr. Mofokeng about the use of the biogas plant. This business plan will show the possibilities about the electrification of biogas and the sale of the electricity to the network of ESKOM.
During the stay at the Chicken Chain Farm, the team will visit an experienced biogas company in the region. After contacting this company the designing of a biogas plant will take place. Because the team is not able to design a biogas plant from scratch, an existing approved design will be adapted to the specific situation of the Chicken Chain Farm. The design will also take into account the possibility of upscaling in the future.
After the design has been finalised contact will be made with a contractor. This company will start constructing the biogas plant. The agreements with the contractor will be made before the team returns to the Netherlands.
Furthermore, the earlier mentioned business plan will be further adapted during the stay at the Chicken Chain Farm. Besides this case specific business plan, a general business plan will also be written. This general business plan could be used by other farmers in Gauteng when they ask Mr. Mofokeng for help.

Adapted scope (adapted solution during the internship)

After getting settled in South Africa the team came to certain realisation pertaining to the project, and the culture. The team has realised its weaknesses and strengths and found ways to combine them. There were two important issues which came up during the project. This is the reason why the team had to adapt the scope during the internship.

First of all, the universities are not that much involved in the biogas industry. Secondly, the three months of the internship will, by far, not be enough to finish a complete design and especially the construction of the biogas digester. For example; legislation and funding generally take around two years.

After the conclusion of these issues the team made the following observations. For a start, the team has learned very much about biogas technology, the business, legislation and the stakeholders during the project. The implementation of the project is essentially a learning process in itself. Another observation is the regard in South Africa for the TU Delft. This in itself is a good selling point for the project and this is why the TU should stay involved in the project. The last observation is about the potentially strong network of the team in The Netherlands and South Africa, like stakeholders in the previous biogas reports, Mr. Mofokeng's contacts at Tshwane University, Yonis' contact at Vaal University and of course the contacts at the TU Delft.

With the before mentioned issues and the observations the following conclusions were made and tasks were given;

- The team will provide Mr. Mofokeng with a preliminary design for the construction of the biogas digester on the Chicken Chain Farm. Therefore the team will visit an experienced biogas company in the region, named BOTALA energy solutions. After contacting this company the designing of a biogas plant will take place. The design will also take into account the possibility of upscaling in the future.
- The fact that the project cannot be finished in three months is not necessarily a weakness in itself; it is a possibility for the country too. The idea of letting students from the Netherlands do this project instead of the local students is in the opinion of the team a missed opportunity. The main advantage of the team doing this project is our network and the weight of the TU Delft name, but when the team will leave the country all learned knowledge will leave the country as well. The starting of an internship project for local students may take a larger role in the scope than previously thought before our arrival because it is, in the eyes of the team, necessary in the continuation of the project. It will also be a great contribution to our original mission to spread more knowledge about biogas. Therefore the team will write a short and long term internship plan for local students to work at the project of Mr. Mofokeng as a follow up group. This will include a list of necessary disciplines.
- During the internship the team was assuming, based on what Mr. Mofokeng has told the team, that there are little to no courses in biogas at the local Universities of Technology. The team has to visit local universities to investigate this assumption. This will take place after the holidays when universities will be open again and not busy with examination.
- When there will be any time left during the internship a long term plan should be written about the possible expansion of this project. The pilot project of Mr. Mofokeng can become an annual program. Students can be assigned to different biogas projects around the country as part of their studies.
- The business plan made in the Netherlands and the business plan made by Roxanne Goemans of the previous group will be combined and adjust to the updated situation at the farm of Mr. Mofokeng. When there will be any time left during the internship this specified business plan will also be turned into a general business plan. This plan could be used by other farmers in Gauteng when they ask Mr. Mofokeng for help.

- At last the agreements with the constructor of the biogas plant will be made if there is enough time left during the internship. If not, the follow up group will be informed of this.

Internship

Design

The plant design is executed to a level of detail in which the main specifications of the individual components of the biogas installation are determined. The process of designing the plant is implemented in the Excel tool in which the energy potential is generated, based on the given biomass quality and quantity. As aforementioned two scenarios are considered.

Components

This chapter highlights the team's proposed main specifications of the individual components this power plant will feature: mixing tank, pasteurizer, shredder, anaerobic digester, post storage, gas treatment, gas storage, generator, heating system, electricity distribution.

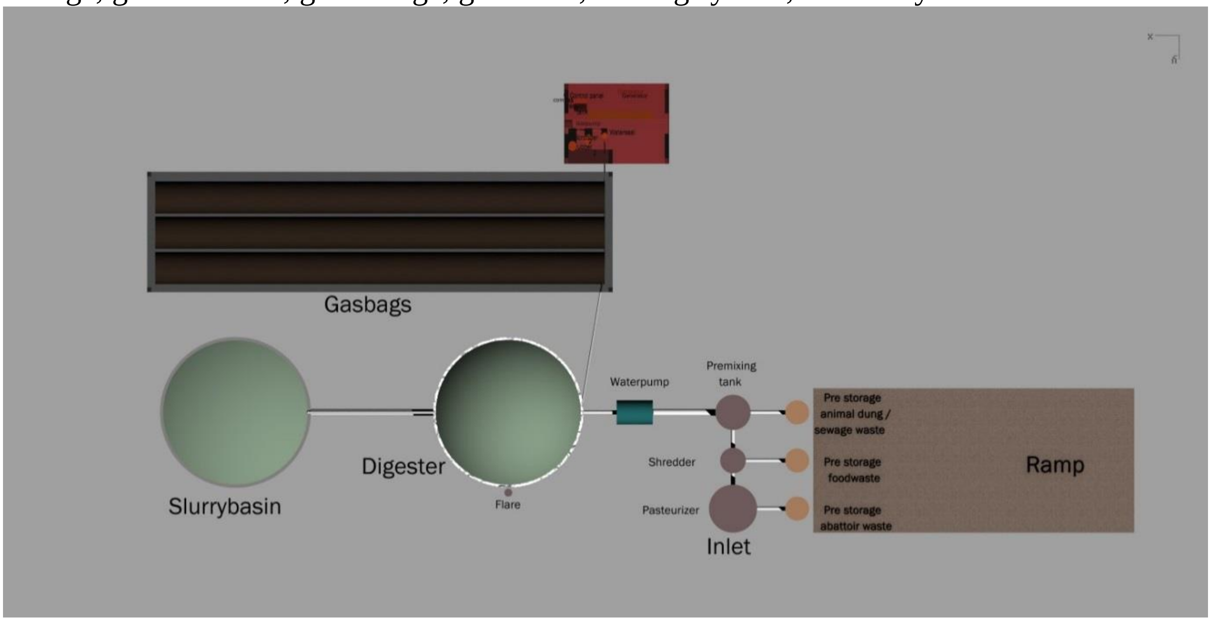


Figure 1 Top view Biogas Plant

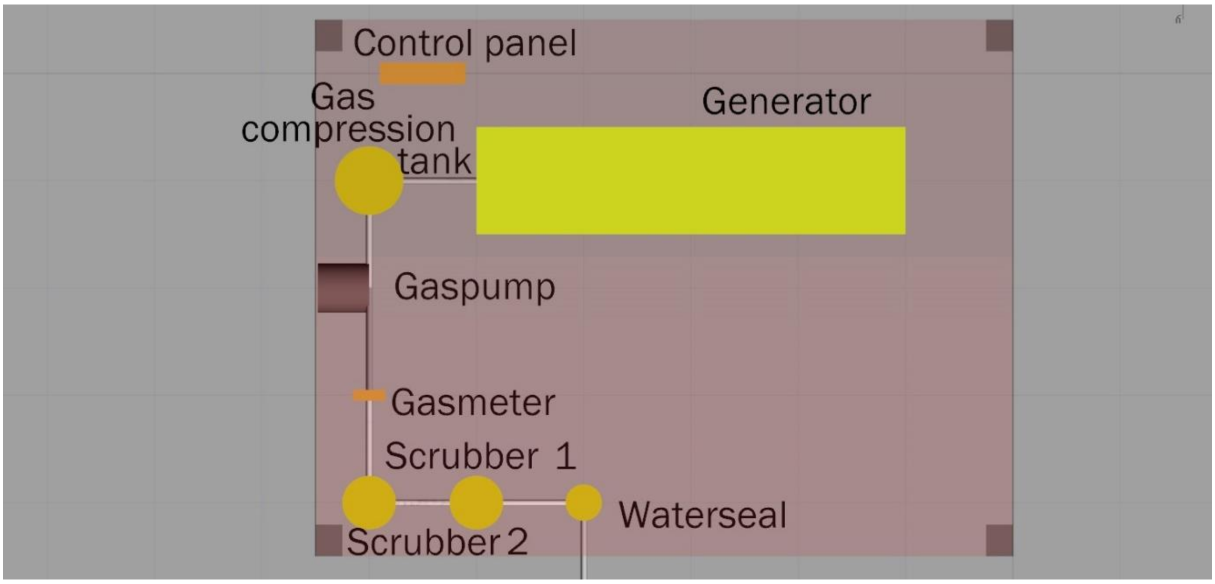


Figure 2 Top view Gas Treatment & Generator Housing

Pre Storage

For a temporary storage of the different feedstocks (food waste, manure and slaughterhouse waste) the three silos that are already on the farm will be used. This means that the silos that were used for the chicken house can be useful for pre-storage. This means that no extra costs will be made. The silos each have a capacity of 6 m^3.

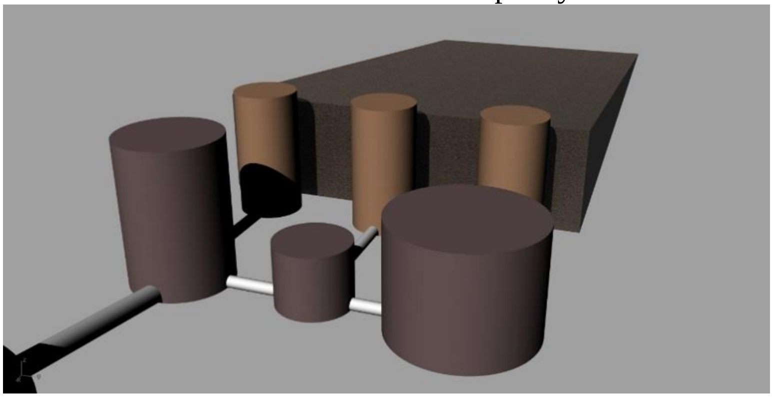


Figure 3 Feed-in

Post storage

The already existing silo next to the house will be used for the post storage. There will still be gas production in the post storage. A PVC membrane will be needed (PVC, Alibaba, 2015) to capture this. The gas will be pumped back into the flair or into the gas storage depending on the quality.

Table 1 Post Storage Properties

Post Storage Properties	
Type	Post Storage
Diameter	9 m
Surface	89 m^2
Membrane material	PVC
Price	30 ZAR/m^2
Price in total	1350 ZAR

Feed Preparation

Biomasses of different types are being used for digestion. Some types have to be prepared before fed in the digester. Also the biomasses have to be mixed before fed in the digester.

Pasteurizer

A 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 C. 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, since abattoir waste can be hazardous if not done. The pasteurizer will be heated by the hot water generated by the CHP boiler of the generator.

Table 2 Pasteurizer Properties

Pasteurizer Properties	
Daily slaughterhouse waste	3500 kg
Daily slaughterhouse waste	3500 L
Work Volume pasteurizer	5000
Tank Dimensions	1,910 x 2,0 (m x m)
Total height	3850 mm
Insulated layer	60 mm
Diameter of inlet & outlet	51 mm
Total Cost	**ZAR 15,678**

Figure 4 Pasteurizer

Shredder

The food waste shredder is an optional object. A shredder is needed to shred food waste into small pieces to avoid blockage in the tubing or pumps. If a more budgeted option is required, it is possible to buy a smaller shredder, shred the food and then put it into the digester (Food Waste Shredder, Alibaba, 2015).

Table 3 Shredder Properties

Shredder Properties	
Type	Food Waste Disposer
Volume	0.226 m^3
Capacity	1 ton/hour
Power	2.2 kW
Height	1.35 m
Diameter (valve)	80 mm
Total Cost	**8,900 ZAR**

Figure 5 Shredder

Mixing Tank

A mixing tank is needed to ensure a homogeneous sludge is fed in the digester with the right biomass proportions. A capacity of 12 m^3 is needed, since the daily substrate input is 9.46 m^3 and a safety factor of 1.2 is used. A horizontal submersible mixer has to be used for mixing the substrate.

Table 4 Mixing Tank Properties

Mixing Tank Properties	
Mixing Tank Type	Water tank
Dimensions	
Slurry level	1.5 m
Radius	1.6 m
Volume	12 m^3
Mixer type	Horizontal submersible mixer
Cost Tank	ZAR 12,000
Cost Mixer	ZAR 17,000
Total Cost	**ZAR 29,000**

Figure 6 Mixing Tank

Pumps

Between the mixing tank and de digester a sludge pump will be used to feed the biomass into the digester. The properties of this pump still have to be researched.

Figure 7 Water pump

Piping

The pipes, which will be used for connections of the digester, will be bought in South Africa. For the digester PVC pipes will be used and a length of 50 meters is estimated (Piping, 2015).

Table 5 Piping Properties

Piping Properties	
Type	PVC Piping
Estimated length	50 m
Total Cost	**ZAR 1500**

Figure 8 PVC Piping

Digestion

The team recommends the construction of a concrete and heated continuously stirred tank reactor (CSTR) under mesophilic conditions, as a proven technology for commercial biogas applications worldwide. Moreover, this is the only technology available in South Africa that has been proven on a commercial scale so-far. Table and Table below demonstrate the conditions the digester will be operating at, the proposed geometry, and the input and output (mass balance).

Digester Tank

Geometry

The chosen digester type will be cylindrical in shape. By defining a height to radius ratio, the calculated slurry volume can be broken down into the two variable dimensions of the chosen geometric figure. In this work a slurry level to radius ratio of $\frac{h_{slurry}}{R} = 1$ was chosen. To prevent overflow a safety factor of $S_{tank} = 1{,}2$ as a factor for additional height of the digester was chosen. Thus determining the ultimate height and volume of the digester.
A zinc aluminium water tank with a volume has been chosen for the digester. The tank itself costs ZAR 140,000. A concrete ring will need to be added around the lower layer to prevent corrosion. This will cost an additional ZAR 55,000.

Table 6: Key geometrical data of the proposed digester design.

Description	Value	Unit
Digester Volume	324	m^3
Slurry Volume	290	m^3
Buffer Volume	34	m^3
Radius	4.52	M
Thickness	0.15	M
Digester Height	5.06	M
Slurry Level	4.52	m

Input and Output

The input and output of the biogas digester is based on a mass balance as visualized in Figure 9.

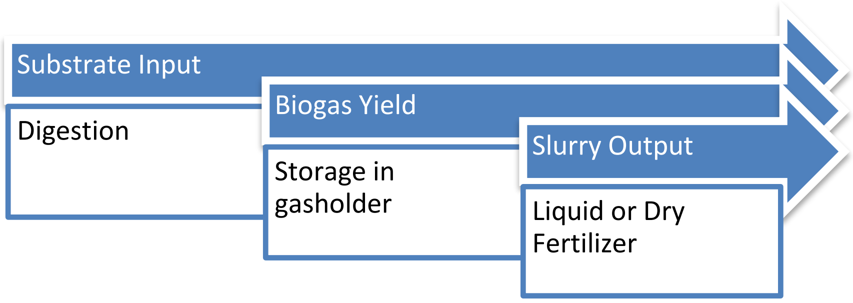


Figure 9: Flow-chart demonstrating the substrate conversion into 2 products.

Figure 9 shows the most important input and output values. The calculations of these values can be found in Table 7

Table 7: Inflow and outflow values of the digester.

Description	Value	Unit
Substrate input	9.6	m^3/day
Liquid fertilizer output	8.9	m^3/day
Dry fertilizer output	1318	kg/day
Biogas yield	649	m^3/day

Insulation

The current design has a diameter of approximately 9.04 m and a height of 5.06 m. The surface to be insulated will be 144 m^2. With a thickness of 20 mm, polystyrene sheeting will cost approximately ZAR 2630.

Flexible dome

Before the gas goes from the digester into the gas treatment it is stored in the digester itself. Therefore a flexible dome is needed to keep the gas in the digester. (PVC, Alibaba, 2015)

Table 8 Digester Tank Properties

Digester Tank Properties	
Digester tank type	Zinc Aluminium Water tank
Tank Dimensions	
Radius	4.52 m
Height	5.06 m
Volume	325 m^3
Dome material	PVC
Dome Surface	23.3 m^2
Dome Thickness	15 mm
Cost Tank	ZAR 140,000
Cost Concrete Ring	ZAR 55,000
Cost Insulation	ZAR 2,630
Cost Flexible Dome	ZAR 360
Total Cost	**ZAR 197,990**

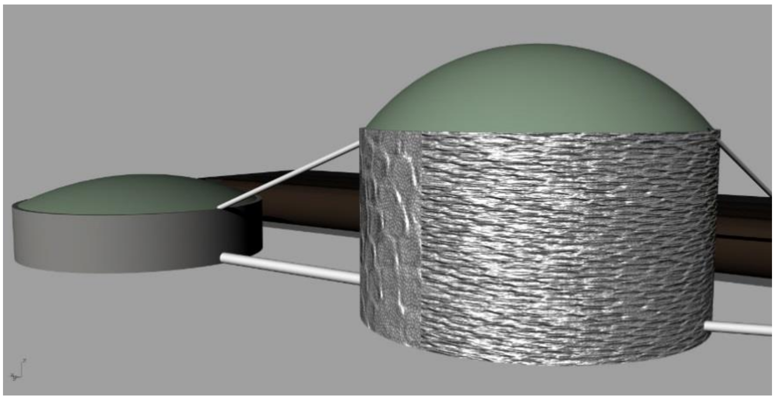


Figure 10 Digester Tank and Post Storage Tank

External Gas Storage

Functional Requirements

The back-up storage will be three gasbags designed to hold approximately a total of 8 hours, $t_{storage}$, of gas produced per day to compensate for the load duration of 16 hours per day. Due to the material strain the pressure inside cannot exceed a certain threshold. In this case the maximum pressure difference cannot exceed 5 mbar (Steinhauser, 2008). If the pressure exceeds this threshold the gas must be flared off, which will be the case during maintenance. The relevant design parameters of the gasholder can be found in Table . The costs still have to be researched.

Table 9: External Gas Storage Properties

External Gas Storage Properties	
Type	Flexible Biogas Holding Bag
Biogas Storage Capacity	12 h
Maximum pressure difference	5 Mbar
Volume	260 m^3
Dimensions	3x Ø 2 x 28 m
Material Surface	547 m^2
Cost	ZAR 58.5/m^2
Total Cost	**ZAR 32,000**

Figure 11 Flexible Bag

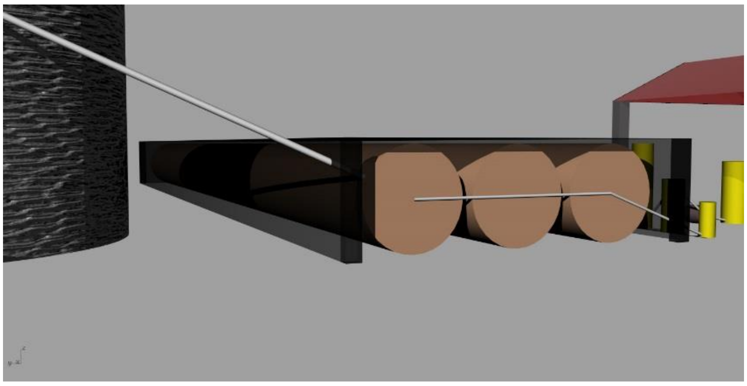


Figure 12 Gas Bag Housing

Mixing system

According to Energies journal research (Lemmers et al, 2013) highest agitator efficiency can be achieved with inclined axial agitators. According to experts (Chemicalprocessing, 2015) the size of the impellers should be 25% of the tank diameter. While the tank diameter is 4,72m an agitator with a diameter of 1,00 m would be fitting for this digester. Therefore two agitators of both a diameter of 0,5m will be used for this project (Agitator, Alibaba, 2015)

Table 10 Mixer Properties

Mixer Properties	
Type	Airfoil Axial Agitator
Speed	10-420 RPM
Power	0,75 kW
Material	Stainless steel
Propeller Diameter	500 mm
1 x Agitator Cost	17,000 ZAR
Total Cost	**34,000 ZAR**

Figure 13 Airfoil Axial Agitators

Heat Exchanger

Within the Digester tank a heat exchanger will be placed to maintain the working temperature of 35°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 be used (Heat exchanger, Alibaba, 2015).

Table 11 Heat Exchanger Properties

Heat Exchanger Properties	
Type	Heat exchanger MHTA-5
Liquid Flow Rate	7.5 m^3/h
Heating capacity	17 kW
Heat Transfer Coils Material	Titanium
Transfer Coils Dimensions	Ø12.7 x 20,000 mm
Total Cost	**6,000 ZAR**

Figure 14 Heat Exchanger MHTA-5

Electricity Generation

The team recommends installing a generator of the power of 91 kW. This combined heat and power engine will generate electricity and the needed heat to keep the pasteurizer and digester at respectively 70 °C and 37 °C. The maximum estimated power generation is 91 kW and will run 20 hours per day. A safety factor of 1.2 has led us to choose for a generator of 120 kW prime power. An open generator is chosen above a silent generator due of the cost. The generator will be placed in housing together with the gas treatment installation. The heat cogeneration option costs an extra USD 8733 resulting in the total cost of USD 37,333 (Generator, Alibaba, 2015). The global generator design parameters can be found in Table.

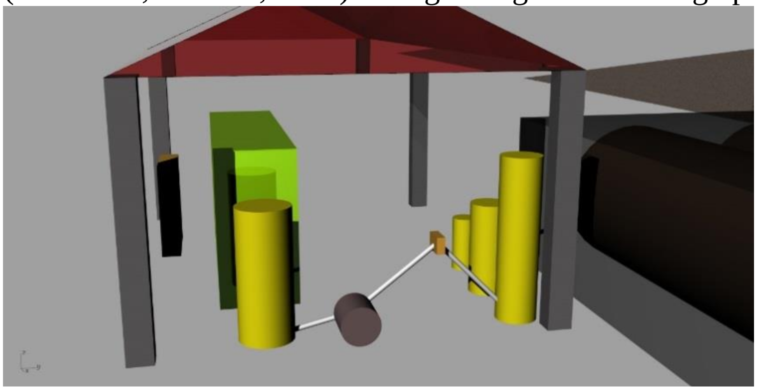


Figure 15 Generator and Gas Treatment Housing

Table 12: Generator Properties

Generator Properties	
Type	CHP Open Type
Prime/continuous power	120kW/100kW
Fuel consumption	56.92 m3/h
Cogeneration(heat) efficiency	85%
Electric efficiency	~30%
Service life	30 years

Dimension	2950 x 1100 x 1800 mm
Cost Gas Generator	ZAR 480,000 (USD 28,600)
Cost Heat cogeneration	ZAR 147,000 (USD 8,733)
Total Cost	**ZAR 627,000 (USD 37,333)**

Figure 16 CHP Open Type

Gas Treatment

When biogas is formed in the digester it will be led to the gas treatment installation which contains a water seal, flare, biogas purification with pressure boosting and external gas storage. The gas treatment will be housed together with the generator.

Water seal and flare

To prevent biogas from flowing back into the digester a water seal is placed at the biogas outlet. Furthermore a flare is placed at the biogas outlet for security reasons. It is essential for every biogas installation to have a flare as a fail-safe. In the case of the gas levels exceeding the capacity of the storage and generator, the flare will dispose of the gas in an environmentally friendly fashion. Burning the excess gas will prevent methane from entering the atmospheres. This will only be used when there is no other option.
Our gas holder has a capacity of 150 m3. The gas production is 32m3 per hour. Multiplying this by a safety factor of 125%, a flare is chosen with a capacity of 40m3 per hour.

Figure 17 Biogas Flare

Biogas Purification System

To prevent corrosion downstream in the installation, the content of H_2S (hydrogen sulphide) in the gas should be reduced. H_2S 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 skid-mounted biogas pre-treatment system one column binds H2S whereas the other is regenerated. The use of iron pallets is a solid and cheap method to remove hydrogen sulphide (Scrubber, Alibaba, 2015). The iron pallets will be placed in a scrubber tank where the biogas will be led through. Furthermore, the biogas will be dehydrated. The biogas will be led through the system by a gas blower which is included in the system.

Since there are three empty tanks available on the farm that can be used for the biogas purification system, the cost of the biogas purification system will be decreased. In Table 1 the properties of a biogas purification system are listed. In the total cost of the system the cost of the tanks are not included.

Table 1 Biogas Purification System Properties

Biogas Purification System Properties	
Type	Biogas Purification System/Biogas Scrubber
Gen – Set power	24 kW
Gas Blower Power	1.1 kW
Gas Flow	30 – 50 m^3/h
Pressure	10 kPa
Dimension	2000 x 1600 x 2160 mm
Gen-set Cost	ZAR 100,200 (USD 6000)
3x Tank Cost	ZAR 7,515(USD 450)
Total Cost	**ZAR 92,685 (USD 5550)**

Figure 18 Iron Pallets

Figure 19 Biogas Purification System

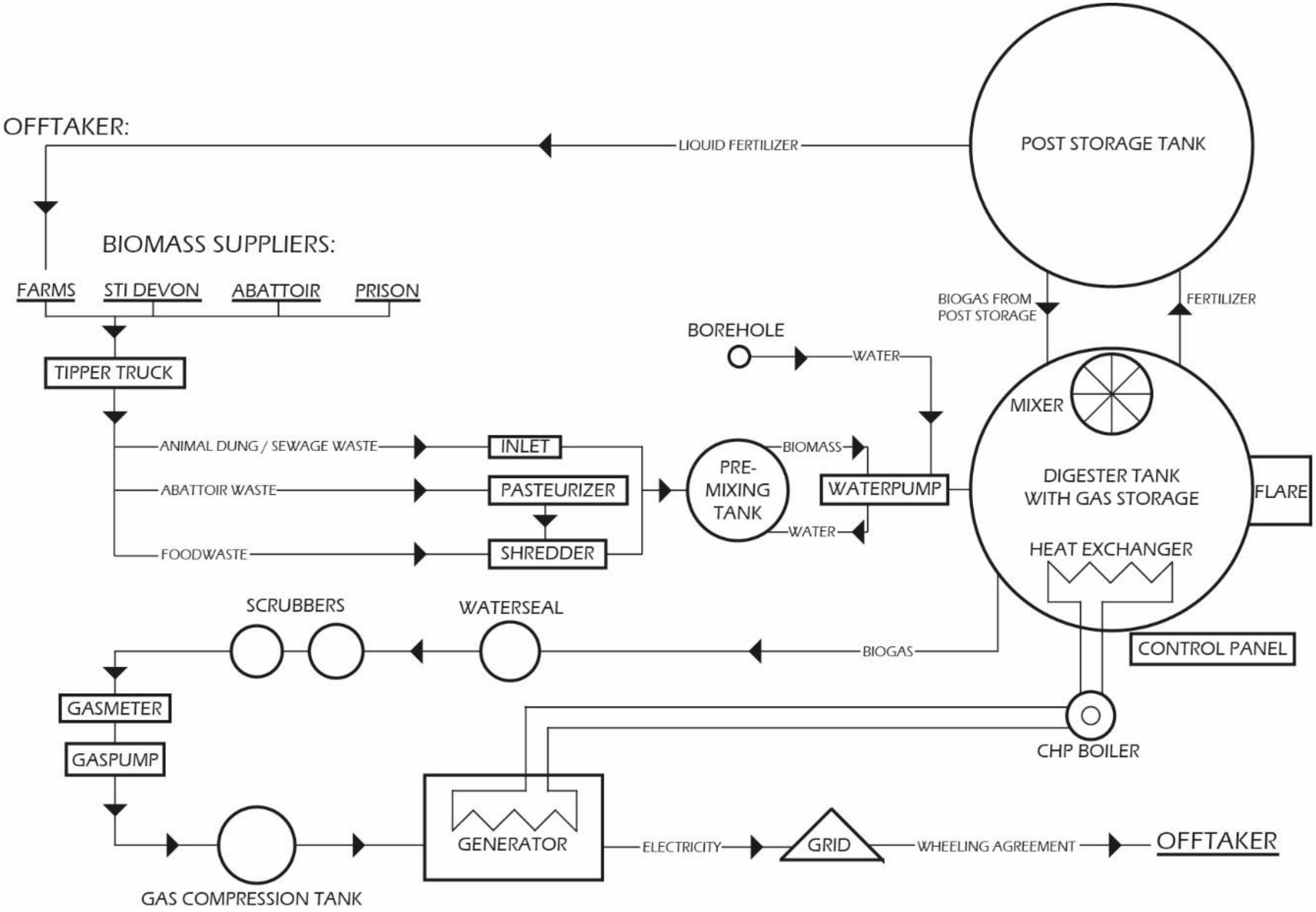


Figure 20 Flow Chart Biogas plant

Business model

The company strives towards a business model, known as a wheeling agreement. A wheeling agreement is a bilateral trade agreement for the wheeling of energy—typically electricity. It involves generators and buyers entering into bilateral contracts for the sale of electricity. The wheeled power is injected by the seller (a generator) into the network of the party owning the network and extracted by the buyer (an electricity consumer) at the point of delivery on the network. A wheeling agreement does not directly reduce the capacity required on the network and therefore charges are payable for the cost of the delivery of the energy to the buyer. As, typically, there is not dedicated physical network connection between the seller and buyer, the electricity is not transmitted directly between the two parties. It should be noted that a wheeling agreement does not prevent the off-taker from being affected by load-shedding at peak demand as this is caused by a system interruption related to the local network and energy constraints, for which wheeling does not provide an exception (Eskom, 2012). More information on the wheeling mechanism can be found in Annex F of the feasibility study rapport.

In this chapter, this business model will be elaborated on in more detail. Alternative business models and possible additions to the business model can be found in Annex F, yet it should be noted that these were not further pursued or investigated as the company requested a feasibility study based on a wheeling agreement.

Operating Biogas Plant Chicken Chain Farm

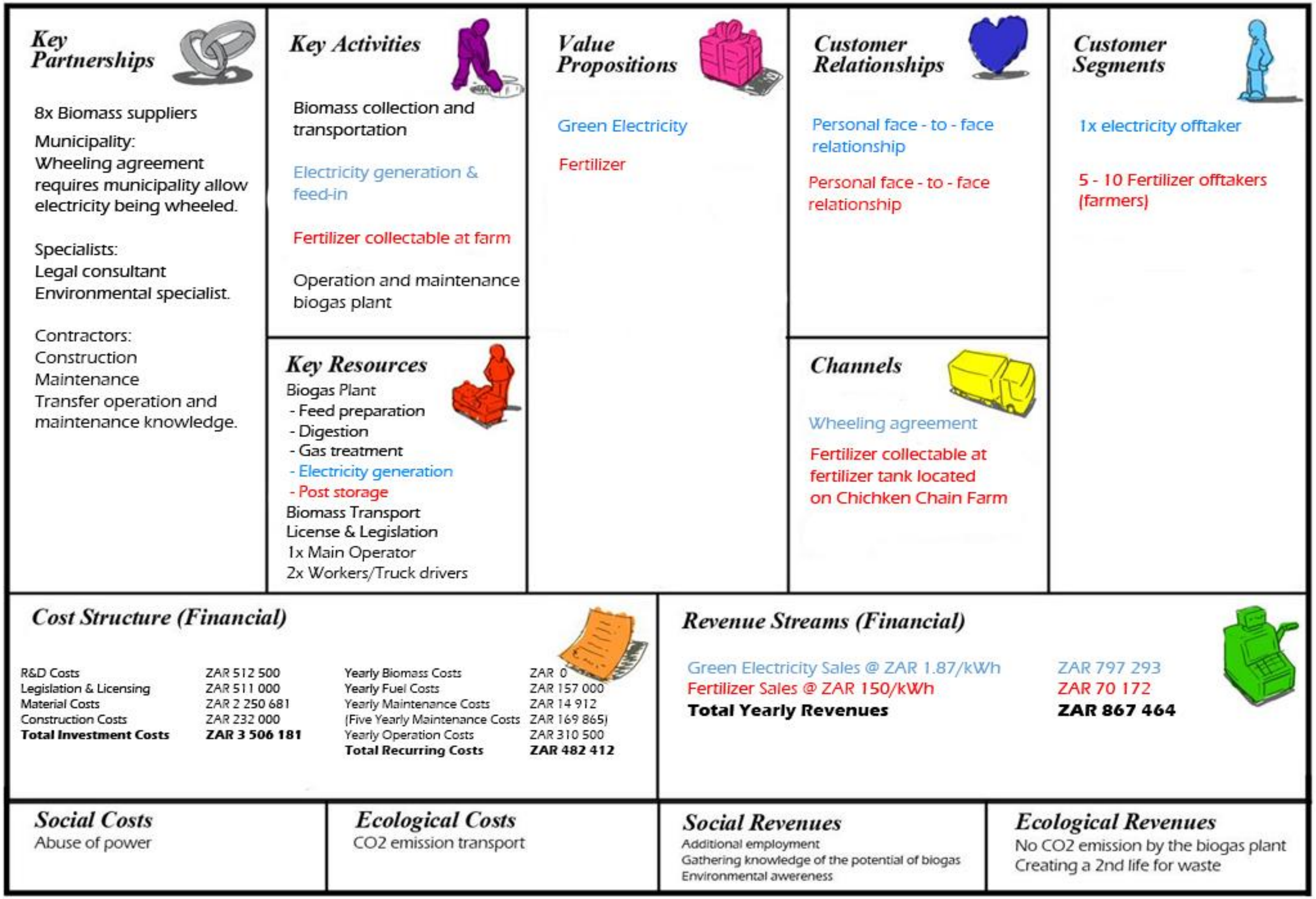


Figure 21 Business Model Canvas

1. Value Proposition

The biogas business that the company intends to set up is an innovative project in the small settlement of Devon, Gauteng. This project will contribute to Devon and the country as a whole in several ways. On a national level, the company will support the shift towards a green economy. On a local level, the biogas business will not only stimulate job creation and skill development, it could also play a significant role in defining the direction of the economic development of Devon, as the area is currently being investigated for coal mining as well.

By purchasing the green electricity generated by the biogas plant, the off-taker supports the transition to a green economy in South Africa and the development of a rural community with low living standards. Furthermore, they portray themselves as being innovative and willing to take risks as biogas technology is still in its infancy phase in South Africa. As such, the off-taker shows social involvement, environmental awareness and innovativeness by associating themselves with the presented project and a great value thus lies in the improved image that the off-taker will enjoy. This value of an improved image can only be established thru other more tangible values, which will be further explained below.

After the company sets up a biogas plant; it will have two main value propositions. One of these values is the before mentioned green electricity and the other one is an environmental friendly fertilizer.

Green electricity

The fresh biomass the company collects will be around 9642 kg on a daily basis. With this biomass the digester produces 650 m^3 of biogas per day. This amount of biogas is enough for the plant to produce 3897 kWh of electricity per day. The electricity is green and, if the delivery of the biomass is steady, the electricity can be produced at any time the company wants. This is not the case with other green electricity such as wind and solar, when the company has to depend on the forces of nature. As earlier mentioned has the company requested for a wheeling agreement if it comes to selling the electricity.

Fertilizer

Besides producing electricity the plant will also produce digestate. This digestate could be used as a fertilizer on farmland. The fertilizer is off high quality and environmental friendly. It is an alternative for chemical fertilizer because the quality of this fertilizer will be much higher after the digesting process. Pathogens such as E-coli and Salmonella will be killed by the process and this makes the fertilizer suitable for application on land for less money than the chemical fertilizer (Steyn, 2015). The digestate will be extracted from the digester tank on a daily basis. The quantity of the fertilizer that will be taken out of the digester tank is the same as the amount of feedstock that will be fed into the digester tank. Also the frequency of the extraction will be the same as the loading rate. The digestate can be distributed in a mud-like fluid or it can be dried and sold as dry fertilizer in order to improve its saleable qualities. The estimated liquid fertilizer is 8,86 m^3 per day, if dewatered the dry fertilizer will be 81318,26 kg per day.

2. Customer Segments

The three above mentioned value propositions have two different customer segments; one segment for the selling of the green electricity and the other segment for the selling of fertilizer. First het customer segment for selling the green electricity will be further explained. After this the customer segment for the other value proposition will be explained.

Green electricity

As the company is aspiring to follow a business model which involves wheeling, the main customer of the biogas business will be a private off-taker who will purchase the produced electricity. It is recommended to seek a private off-taker that fits (most of) the following profile:

Green Image

In the case the company does not receive a grant, the electricity that will be offered to the off-taker will be one and a half times as expensive as what is currently being offered by Eskom, but it has the advantage of being generated from renewable sources. The company should therefore seek an off-taker who appreciates and values green electricity as a company that is committed to reducing its carbon footprint and is concerned with its impact on the environment, will be more willing to pay extra for their electricity if it is green.

Innovative and/or Previous Biogas Experience

Biogas is still in its early stages of development in South Africa. Only an estimated 300 biogas digesters are in operation in South Africa and just a fraction of these are of a commercial scale (Odendaal, 2013). This lack of experience often leads to scepticism of the technology and risk-averse companies will typically be reluctant to commit to such a progressive project. It is therefore recommended to look for an international company that has experience with biogas oversees and/or is particularly innovative and future-oriented and local innovative companies who are committed to high-end technologies.

High-end products and/or service provider

Companies that focus on cost-efficiency will typically be less willing to pay extra for their electricity. Instead, it is recommended to approach companies which provide products or services that are slightly more luxurious and aimed at the upper-class (e.g. organic food supermarkets). Such companies will most likely be more willing to spend extra on their utilities if it means that they can make their image more appealing to their customers.

Social Involvement

One of the distinct advantages of biogas compared to other renewable energy sources is that it has a high job creation potential; it is estimated to be five times higher than that of solar energy (Ruffini, 2013). This is especially relevant to the province of Gauteng, as the latest census showed an unemployment rate of more than 25 percent (Statistics South Africa, 2011). Furthermore, the biogas plant will provide opportunities for the population of Devon to develop skills and increase their living standards. As such, a company which places high value on community development and job creation could be more interested in supporting the project at hand.

Established Company in South Africa

At present time, the company does not yet have any experience in setting up commercial scale biogas digesters and biogas technology is still very unfamiliar in South Africa. As such it is recommended to seek a company which is well-known in South Africa and has a strong reputation. This will add credibility to the project and the company, and aid in gaining support from for instance legislative and financial institutions.

Located in the same municipality as the biogas plant

Before wheeling can take place, the company needs permission from the municipality in which the off-taker is located to sell electricity to the off-taker. However, a wheeling agreement will result in decreased revenues for this municipality as they lose a portion of their electricity sales and this could lead to reluctance. The biogas business can somewhat off-set this negative impact with advantages such as job creation, waste reduction and skill development, if the biogas business is located in the same municipality as the off-taker.

A close friend of the owner of the company, Mr. Ntoane, is asked to search for a suitable private off-taker. According to him this possible suitable private off-taker could be Woolworth. Woolworth is an organic food supermarket which could be interested in using green energy to reduce their carbon footprint and for positive stimulating of the market. Although Woolworth could be suitable the search for a private off-taker is still a work in progress. This is why nothing is certain yet and therefore conclusions should not be drawn too quickly.

Fertilizer

The customer segment for selling fertilizer will most likely be farmers in the neighbourhood of the company. They could pick up the fertilizer themselves at the Chicken Chain Farm and use it to stimulate their crops. The digestate is much better for the environment than chemical fertilizer and less expensive. At this point it is difficult to put a price on the fertilizer, because this depends on the quality which can only be tested after the production of biogas. A more elaborate explanation of the challenges and the action plan for selling the digestate as fertilizer can be found in Annex F.

3. Customer Relationships

Now the value propositions and the different customer segments are known the customer relationships can be further determined. Although there are different value propositions and different customers the relationships between them are all intimate personal relationships. This means that the relationship is based on human interaction (Osterwalder and Pigneur, 2010). Below the relationships for the different value propositions will be further explained.

Green electricity

It is highly recommended to seek an intimate personal relationship with the private off-taker from the very start. Taking biogas plants in South Africa that have already been commissioned as point of reference, it is expected that the company will have a long road to go until the biogas plant can be commissioned. During this time, many processes should partially take place in parallel, such as contracting suppliers, applying for licenses and the design of the digester. Throughout these processes it will be essential for the continuation of the project to have a private off-taker who is committed even though the contracts will most likely not be finalized yet at that point. Due to the novelty of the technology in South Africa, many institutions are hesitant to take the risk of getting involved in biogas projects. Having a committed off-taker gives the project credibility. As such, the company should pay special attention to their off-taker, keeping them informed and involved continuously throughout the process.

Once the biogas plant has been commissioned, the company should ensure that the plant is associated with the off-taker in order to deliver the image benefits that are promised in the value proposition. This can for instance be done by strongly promoting the biogas plant and highlighting the essential support of the off-taker during interviews, tours of the plant and other media-related activities.

Fertilizer
Since the farmers will collect their bought fertilizer at the Chicken Chain Farm this ensures an intimate personal relationship between the company and the costumer. The duration of the relationship depends on the costumer. Some costumer will buy only their fertilizer once from the company. Others will continue to buy for a couple of years. This will probably depends on the quality of the fertilizer and on the creation of awareness around biogas. When costumers decide to build their own biogas plant they won’t need the fertilizer of the company anymore.

4. Channels
Awareness of biogas should be created in the first place. Therefore, the company should reach out to potential off-takers personally and attempt to arrange a face-to-face meeting in which the project can be pitched. In this pitch a few important advantages of electricity created with biogas should be pitched to compare biogas with normal electricity, produced by ESKOM. Biogas electricity reduces CO2, reduces waste, gives the company a green image and there will be no load shredding anymore.

This will give the company a better chance at convincing the off-taker of the potential that the project and company hold, which will be especially important due to the fact that the company has not yet established itself as a professional biogas producing company. This approach will aid in establishing a personal relationship from the very start and increase trust building.

Together with the off-taker a way should be found to transport the electricity. One of the possibilities is to use the network of ESKOM. Another possibility can be to add own cables in the ground to transport electricity, so the company is not dependent on ESKOM, but this also depends on the distance between the farm and the company.

Once a committed off-taker has been found, the company should maintain a close relationship and communicate with the off-taker regularly through meetings, phone calls and emails. At this point it will be important to ensure that the off-taker remains confident in the business and the value that it is adding in order for the business to be sustained, off-takers for future projects to be attracted, and the company to expand. Together with them it’s possible to update through the internet, the website of the off-taker and other social media to show about the green image. Also future television interviews will be given about green energy in cooperation with the off-taker, to advertise for both of the companies.

5. Revenue Streams
In the situation that the company does not receive a grant, the electricity will need to be sold at a price of 1.87 ZAR/kWh in order to break even in 9 years, when no grant is received. The revenues of the business will consist of electricity sales to the electricity off-taker and fertilizer sales to farmers. The revenues are expected to amount to roughly 867k ZAR per year. Detailed information can be found in the next chapter.

6. Key Resources
In this section the resources will be discussed that will be essential to the successful implementation of the presented business model.

Material Resources
It is advised to hire a contractor for constructing the plant. In deliberation with the contractor the supply of the material resources will be chosen. A lot of those resources have already been advised by team 2 who made the first design of the digester. A few others can possibly be found cheaper by the contractor. It is important to note that financial institutions will typically

require the equipment to be guaranteed by the supplier(s) for a certain amount of time before agreeing to provide funding. It is therefore recommended to consult the relevant financial institution(s) before entering into contracts with suppliers.

Furthermore, a truck will be needed to transport the biomass to the biogas plant. This truck will be bought which can be seen in the financial plan. Also the tractor will be used, who is already in possession of the company and it is assumed that it will not need to be purchased.

Licenses

A number of licenses should be obtained in order to lawfully produce electricity from biogas. Since the legislative landscape in South Africa is quite challenging with regards to biogas, the company should hire an environmental legislation expert in order to ensure that the regulatory requirements of the business are met. An overview of the relevant regulations can be found in Section 9.2 and in more detail in Annex E – Legislation & Licensing.

Wheeling-specific contracts

Several contracts should be obtained in particular to make wheeling possible:

- Power Purchase Agreement (PPA) with private off-taker – contract guaranteeing a minimum electricity off-take.
- Biomass supply – contracts guaranteeing the supply of biomass.
- Eskom Distribution Connection and Use-of-System Agreement – allowing the use of the Eskom grid.
- Municipality wheeling permission – agreement allowing wheeling of electricity into the municipality in which the off-taker is located as well as use of the municipal grid.

As many financial institutions have specific requirements with regards to for instance the biomass supply and off-take contracts (e.g. duration of the contract), it highly advised to hire a legal consultant to draw up the necessary contracts.

Skills

Once the plant has been commissioned, the company should ensure skill development among her employees as operating a commercial scale biogas plant requires specialized knowledge. It is therefore recommended that the hired constructing company, who is experienced in operating biogas plants, is going to run the plant during the first one or two years during which time the company's employees can be trained, and eventually take over. The main operator should be trained to take over all these tasks after the two years.

This will increase the company's independence and human capital, and skill development in the region. This main operator can also train other local farmers in operating their own future biogas plant. In this way you create a system, which can be an example for a lot of biogas companies.

Human Resources

For the Human Resources the future plant on the Chicken Chain Farm has been compared with already operating plants like Morgan Abattoir, Bio2Watt and BOTALA. With the information from these companies we can compare it to the situation on the Chicken Chain Farm.

All these companies use one main operator. This person is the one who turns the buttons on the digester. This is based on the assumption that the plant will be mostly automated as is the case in typical commercial scale biogas plants. Concluding, after being commissioned, the Chicken Chain Farm needs one single operator.

If we compare the Chicken Chain Farm with these other companies, who own a plant, you can see one big difference. All these companies collect their feedstock at their own company. For example Bronkhorstspruit, they collect the dung from their 4000 cows, which are walking next to the digester. While the Chicken Chain Farm needs to collect the dung from other companies, drivers and collectors are needed.

The dung at the crawl of the Chicken Chain Farm will be collected by workers currently employed by the Chicken Chain farm, Mr. Tabang and Mr. Kabelo. A possible option is to add a concrete floor to the crawl. With most of the suppliers the collection of waste goes automatically. At a few farms the dung needs to be collected manually. If the suppliers got someone to collect the dung, then we need fewer employees to catch the dung. For nowadays we expect that there always must be a second employee who is going with the driver to collect the waste of the suppliers.

At last, the assumption is made that the management and administration of the farm will be done by Mr. Mofokeng, or by one worker who can work part-time on this work.

Financial Resources

Assuming that the company will not receive any grants, a 1.995 million ZAR working capital will be needed. It should be noted that this does not include a contingency budget and as such it is advised to reserve an additional amount. Funding institutions could be approached in order to obtain loans.

7. Key Activities

7.1 Biomass Collection and Transportation

The majority of Biomass is fresh manure in near liquid form. At the Kobus Louw abattoir in Leandra, the stomach and intestine contents are collected in a basin and vacuum sucked into a tanker. The advantage of this system is that minimal manual labour is involved. The vacuum pumped is placed outside of the tanker. The chance of blockage is relatively low as the liquid does not pass through it as demonstrated in the picture below.

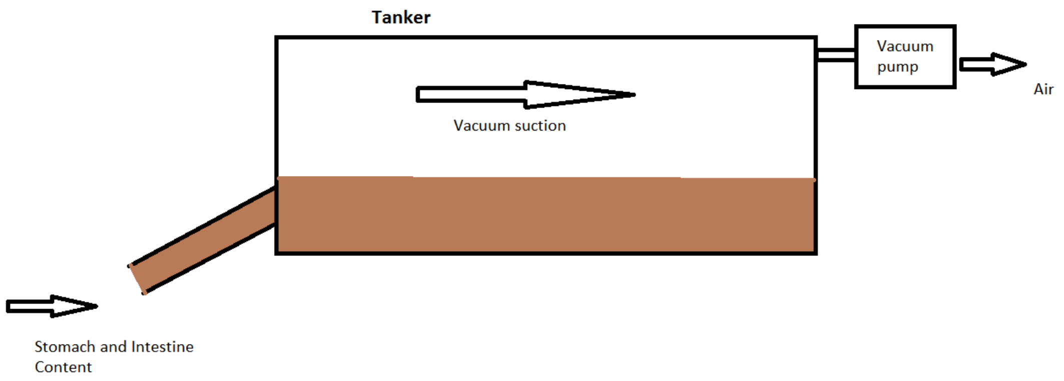


Figure 22 Vacuum Tank

About 22,5 tons of waste will be collected of which 2700 kg biomass and the rest is additional water. It would be practical to have two digester tanks. One tank located at the abattoir which will be filled up during the day. The other tank will be brought empty to Leandra to replace the full one. This way only one trip will be necessary. A trailer will need to be added to pick up the bags of condemned waste which will be picked up manually. At the plant these bags will have to opened and disposed of separately. Optionally biodegradable

plastic bags could be used. But the effects of biodegradable plastics on methane production would have to be tested first.
At Mampe's farm the waste is collected in a dam. Since it is fresh and there is a water source, this can also be vacuumed by the tanker. A borehole may need to be installed in case of a dry season. Picking up the sewage sludge at the STI will be just as practical. A total capacity of 32 000 l will be necessary for the tanker. This is based on the amount of water and waste to be collected at Mampe's farm, Leandra Abattoir and STI Devon.
At Devon abattoir the waste is collected in a tipper truck. This is of a much drier consistency than the waste at Kobus Louw. The tipper trailer will be added to the truck chain and brought to the farm. The waste is collected in the same way at Abdul's farm. It can be picked up once every two months.
At the prison, the food waste will be given in a sealed barrel. The prison workers advised giving a small reward (pack of cigarettes) to the convicts in exchange for helping loading the truck. The same trailer which contains the condemned matter can be used for the barrel. An empty barrel must be brought back the next day.

7.2 Electricity generation & feed-in

A steady biogas production and supply of electricity into the grid should be maintained in order to safeguard the company's revenue stream and contractual obligations. The running hours of the generator will be matched with the consumption hours of the off-taker. There is sufficient gas storage for the off hours.

7.3 Fertilizer delivery

An essential revenue stream is the fertilizer. First the fertilizer must be tested for contents and quality. Based on its chemical contents we can estimate its fertilizing potential and price. After emptying the slurry basin, the fertilizer will be dried and grinded. The fertilizer will be transported to the nearest fertilizer depot and sold from there.

7.4 Monitoring & maintenance of the digester

It will be important for the temperature and acidity of the digester to be maintained in a stable sweet spot. A computer will monitor the temperature of the digester. If it deviates more than one degree Celsius, the flow of the heat exchanger can be altered. Naturally more heat will be extracted from the CHP during the winter than during the summer. The remaining heat will be disposed of outside of the digester.
Regular tests of the digester slurry should happen to determine if the acid level is still within the good range. During the first months of running the gas should be tested for contents and quality. Hydrogen Sulphide levels should be closely monitored.
Maintenance of the digester will be done in cooperation with the contractor. Their expertise on biogas systems will be best in the case of damage repairs.

7.5 Promotion

The main value that the biogas business offers the private off-taker in the presented business model lies in image benefits. The company should therefore actively seek promotion not only to grow their own image, but also to ensure that the off-taker's involvement in the project becomes publically known.

The digester can be used to promote biogas which will raise the profile of sustainable energy solutions and that of the farm itself. Presentations, workshops and networking events (braais) can be held at the farm to demonstrate the working principle of the technology and bring farmers in contact with companies.

Social media should not be ignored as a means of promotion. It is a cost effective way of rapidly raising the corporate profile. A Facebook and Twitter page should be established to update the public on past and coming events.

8. Key Partnerships

In order to successfully implement the presented business model, several key partnerships should be established. More information on potential partners can be found in the list of "relevant stakeholders" in the stakeholder analysis in Annex A.

Private off-taker

As the company is striving towards a business model based on wheeling, it is essential to find a private off-taker who is interested in buying the generated electricity. Before setting up the agreement with the off-taker, the company should take into consideration the requirements of the financial institution at which they plan to apply for funding (e.g. required duration of the contract and minimum off-take). The win for the private off-taker is to have continuous green energy.

Biomass suppliers

The company should establish contracts with the biomass suppliers in order to provide security to the business. Before entering into agreements with the suppliers, the company should take into consideration the requirements of the financial institution at which they plan to apply for funding (e.g. required duration of the contract, quantity of biomass, technology requirements). The advantages for biomass suppliers in this whole story is that they get rid of their waste for free and that they can possibly learn from this example and make their own digester in the future.

Eskom

In order to feed electricity into the grid, the company should enter into an "Eskom Distribution Connection and Use-of-System Agreement" with Eskom. The advantage for ESKOM in this project is the money they receive for putting the electricity into the grid.

Municipality

The wheeling agreement will require the municipality in which the off-taker is located to allow electricity being wheeled in. As mentioned, the municipality will lose a portion of their revenues because the off-taker will purchase electricity from the company instead and as such they might be reluctant. However, should the off-taker and the biogas plant be located in the same municipality, there will also be particular advantages to the municipality such as waste reduction, CO_2 reduction, green energy, job creation and skills development and these advantages should be highlighted.

In the case that the off-taker and the biogas plant are located in different municipalities, the company could consider focusing on the fact that the amount of electricity fed into the grid is relatively low and will not reduce the municipality's revenues significantly, while building a green image for the municipality and promoting this in the media.

Furthermore, the company will need a connection and use-of-system agreement with the municipality in which the generator is located and other municipalities whose grid needs to be used (Eskom, 2012).

Government
Government companies can provide the Chicken Chain farm with grants for financing the project. They can also give advises about the project and how to promote it to other local farmers. They can also help with licensing. For the government a big advantage is to promote and create green electricity, get rid of waste, CO_2 reduction, job creation and creation of skills which can help the country to grow some biogas experts.

Finance instances
Finance instances can possibly be a partner in this biogas project. They can help the Chicken Chain Farm with some loans to finance the whole project. Therefore a lot of contracts need to be made, to give some security of a passing project. Their advantage is also the money and the green image.

Specialists
The company is recommended to consult several specialists as discussed in Section 10.6:

- Legal consultant
- Environmental legislation specialist

Furthermore, a research facility will need to be involved in order to conduct the specialist studies that are needed to obtain the relevant licenses.

Contractors
Not only will a contractor be essential for the design and construction of the biogas plant, it is advised to continue the partnership also after commissioning in order to bridge the knowledge gap related to the operation of the plant (see Section 10.6). Furthermore, the contractor should be involved in maintenance of the plant

As the company does not yet have experience with commercial scale biogas projects, it is recommended to seek a contractor who is familiar with such projects. This will not only add to quality of the plant, it will also increase the company's credibility as an aspiring commercial scale biogas producer when approaching potential off-takers and financial institutions. These companies can train a worker to become the main operator of this plant. For the contractors the big advantage is earning money with building, operating and maintaining of the plant.

9. Cost Structure

The investment costs can be broken down into four categories: R&D, construction, material costs and legal costs (licenses). In total, an investment of 3.506 million ZAR will be needed of which the breakdown can be found in the next chapter.

Recurring costs consist of biomass costs, operation, fuel costs and maintenance. The total yearly recurring costs are estimated at 482k ZAR per year, assuming that biomass will be provided for free. An extra 170k ZAR is taken into account for five yearly maintenance costs.

Business and finance

The economic feasibility and profitability of the biogas business are assessed by means of a financial analysis. This section is dedicated to the outcome of the financial analysis. The foundation for the financial analysis is laid by the cash flow statement. In the financial cost-benefit analysis the viability and profitability are assessed by calculating key economic indicators. The section concludes with a break-even analysis in which the leveled costs of electricity, also a key financial indicator, is determined to be able to compare between independent power producing businesses in South Africa. On top of that, the minimum required electricity sales price to meet the financial requirements set by the project owner is determined. It should be noted that the framework of the financial analysis is retrieved from (Romijn).

All amounts will be given in South African Rand (ZAR). When amounts are converted to ZAR, the following currency rates are used:
1 USD = 16.7 ZAR
1 EUR = 18.2 ZAR
(18 January 2016)

Cash Flow

The cash flow statement is an overview of the expected yearly cash in- and outflows arising from the implementation of the biogas business. The cash flows are distinguished into categories as can be seen in the figure below.

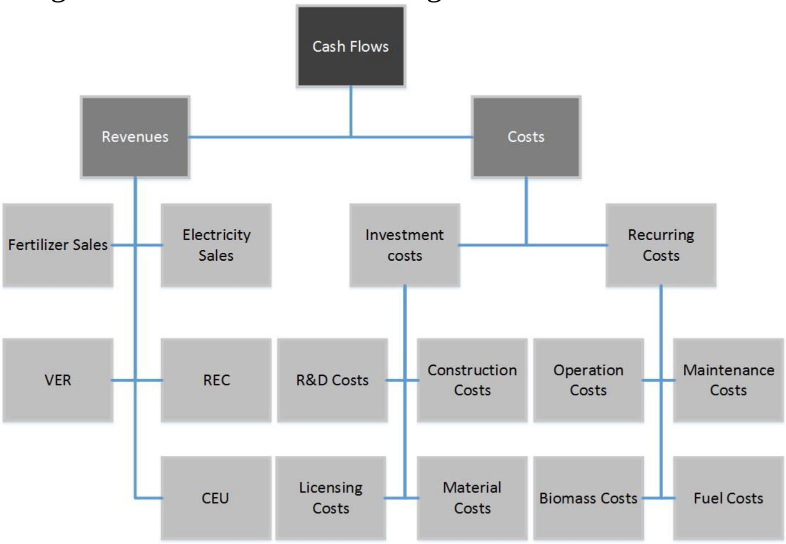


Figure 21 Cash flow overview

Cost Structure

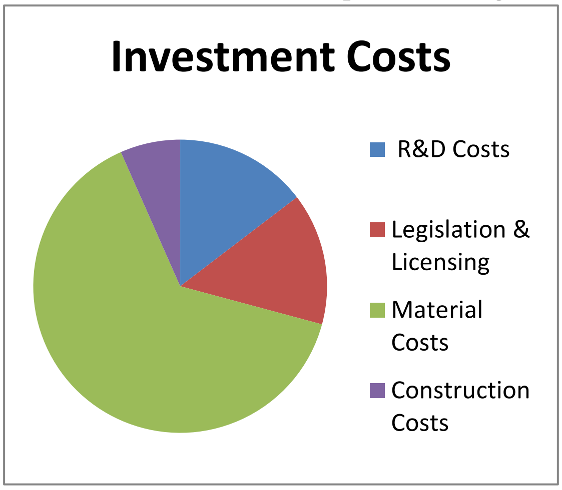
The investment costs can be broken down into four categories: R&D costs, construction costs, material costs, and legal (licensing). In total, an investment of 3.506 million ZAR will be needed of which the breakdown can be found below.

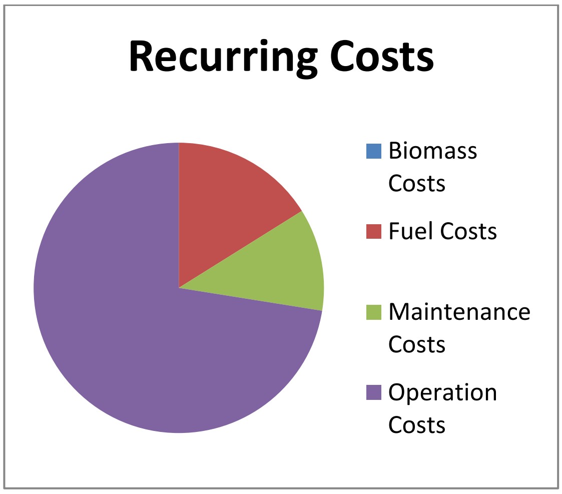
The recurring costs consist of biomass costs, operation costs, fuel costs, and maintenance costs. The costs are estimations made by the project team and are not accurate. Therefore, costs will be +/- 20% accurate.

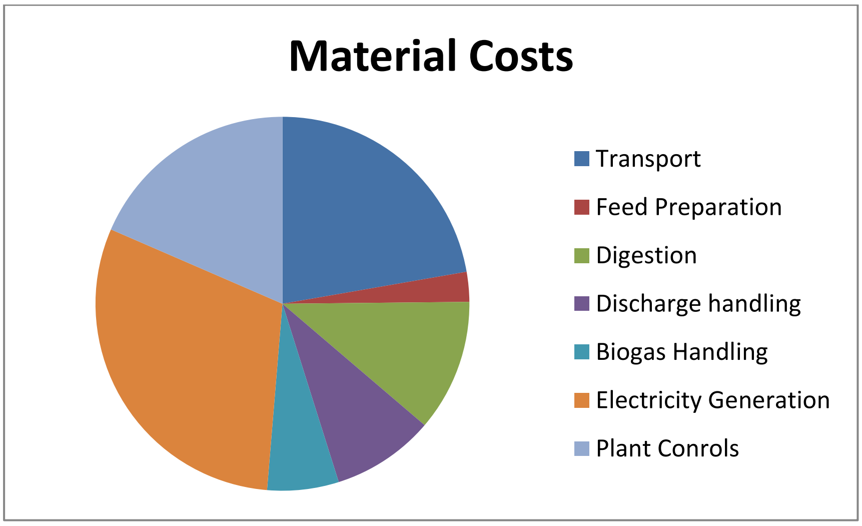
Table 14 Cost Structure

Category	Category Total	Sub-Category	Sub-Category Total	Cost Stream		Estimated Values
Investment Costs	ZAR 3 506 181	R&D Costs	ZAR 512 500	Team 1		ZAR 62 000
				Team 2		ZAR 5 500
				Team 3		unknown
				Team 4		unknown
				Pre-design and Feasibility		ZAR 45 000
				Design		ZAR 400 000
		Legislation & Licensing	ZAR 511 000	Total Costs		ZAR 511 000
		Material Costs	ZAR 2 250 681	Transport	4x2 Tipper Truck	ZAR 501 000
				Feed Preparation	Mixing Tank	ZAR 12 000
					Mixer	ZAR 17 000
					Pumping	ZAR 3 000
					Piping	ZAR 1 500
					Pasteurizer	ZAR 15 678
					Shredder	ZAR 8 900
				Digestion	Anaerobic Digester	ZAR 200 000
					Mixing System	ZAR 34 000
					Heat Exchanger	ZAR 6 000
					Flare	ZAR 16 700
				Discharge handling	Post fertilizer storage	ZAR 200 000
				Biogas Handling	Gas Treatment and Pressure boosting	ZAR 107 193
					External Gas Storage	ZAR 32 000
				Electricity Generation	Generator 120 kW + CHP boiler	ZAR 679 460
				Plant Conrols	Electricity Distribution and Manual Plant Controls	ZAR 66 250
					Reverse Feed-in grid	ZAR 350 000
		Construction Costs	ZAR 232 000	Construction – Labour Costs		ZAR 190 000
				Pour Concrete Crawl		ZAR 42 000
Recurring Costs	ZAR 394 412	Biomass Costs	ZAR -	Chicken Chain Farm		ZAR -
				Mr. Twala		ZAR -
				Mr. Abdul		ZAR -
				Prison Devon		ZAR -
				Sewage Treatment Installation Devon		ZAR -
				Devon Abattoir		ZAR -
				Mrs. Mampe		ZAR -
				Leandra Abattoir		ZAR -
		Fuel Costs	ZAR 69 000	Yearly Fuel Costs		ZAR 69 000
		Maintenance Costs	ZAR 14 912	Yearly Maintenance Costs		ZAR 14 912
			ZAR 169 865	Five Yearly Maintenance Costs		ZAR 169 865
		Operation Costs	ZAR 310 500	2x Biomass Truck/Tractor Driver		ZAR 200 000
				Chief Operator		ZAR 110 500

In the following pie charts the cost distribution is more clarified. Since material costs have a big share in the investment costs, an extra pie chart is given.







Revenue Streams

Table 15 Revenue Streams Electricity Sales @ 1.87/kWh

Category	Category Total	Revenue Stream	Total
Revenues	ZAR 782 192	Fertilizer Sales @ ZAR 150/ton	ZAR 70 172
		Voluntary Emission Reductions (VER)	ZAR -
		Renewable Energy Certifications (RECs)	ZAR -
		CO2 emissions utilisation (CEU)	ZAR -
		Electricity Sales @ ZAR 1.67/kWh	ZAR 712 021

Financial Cost-Benefit Analysis

Viability

The viability of the project is assessed by determining the payback period.

Payback Period

The payback period is an indicator to assess the potential investment for its viability. Informally speaking, the payback period is the time period required for the accumulated net cash flows to equal the initial investment. According BiogasSA – Mark Tiepelt currently the typical payback period for biogas plants in South Africa is longer than 10 years while a biogas plant is only attractive if the payback period is lower than 7 years.

Three key economic indicators are determined to assess the profitability of the biogas business: The net present value, the internal rate of return and the return on investment.

Net Present Value

The net present value is the difference between the present value of cash inflows and the present values of cash outflows. The so-called 'time preference' principle basically implies that cash flows in the future are worth less than present cash flows. To make the cash flows comparable across the different years they are therefore discounted in terms of the present value by multiplying it with a discount factor. The initial project investment is expected to be profitable, if the net present value is larger than zero.

$$NPV = \sum_{y=1}^{y=n} \frac{CF_{net_y}}{(1+r)^y}$$

Where, y represents the year,
CF_{net} The yearly net cash flow,
r The discount rate,
And n the lifetime of the plant.

In turn, the discount can be determined using:

$r = \frac{1+i}{1+p} - 1,$

where, i the market interest rate,
and p the inflation rate.

According to (Trading Economics, n.d.) and (inflation institution, n.d.) the market interest rate and the inflation rate 6% are 4,8% respectively. To include a certain level of risk the market interest rate is chosen to be 9%. Using the formula above it follows that the discount rate $r = 4{,}0\%$. Moreover, it is assumed that the lifetime is approximately $n = 20$ years.

Internal Rate of Return

The internal rate of return is an internal measure of the profitability of the biogas business. The internal rate of return is the interest rate for which the net present value equals zero. The investment is expected to be profitable, if the IRR is larger than the discount rate, which, as stated before, is equal to $r = 4{,}0\%$. The IRR cannot be calculated analytically and is for this reason determined by using the Excel tool.

Return on Investment

In essence, the return on investment is a measure of the efficiency of an investment. The ROI measures the amount of a return on an investment relative to the initial investment costs:

$$ROI = \frac{\sum_{y=1}^{n} CF_{net} - I_C}{I_C},$$

where I_c the cost of investment.

Key Indicators

To quantify the financial feasibility and profitability of the biogas business several key economic indicators are determined. It is assumed that 80% of the investment costs are refunded through a grant. For this scenarios the electricity sales price is increased up to the point that the key economic indicators satisfy the predetermined conditions: PBP < 10, NPV > 0 and IRR> $z_{discount} = 4$. The result is that the electricity price for when no investment costs are refunded is equal to +/- 1.87 ZAR/kWh. And when 80% of the investment costs are refunded the electricity price is equal to +/- 1.08 ZAR/kWh. A typical price for electricity is 1,47 ZAR/kWh. Hence, a sales price of 1.87 ZAR/kWh a potential off-taker will pay 27% more than usual and a sales price of 1.08 ZAR/kWh a potential off-taker will pay 27% less than usual. The accompanying key indicator values are listed in Table 16 and Table .

Table 16: Key Indicator Values for a Sales Price of 1.87 ZAR/kWh and no grant.

Key Indicator	Unit	Reference Value		Current Value
PBP	year	10		9.0
LCE	ZAR/kWh	1.24	6.21	1.69
IRR	-	3.99%		12.23%
NPV	ZAR	0		ZAR 2 089 814
ROI	-	15.00%		137.2%

Table 17 : Key Indicator Values For a Sales Price of 1.08 ZAR/kWh and 80% grant.

Key Indicator	Unit	Reference Value		Current Value
PBP	year		10	**9.0**
LCE	ZAR/kWh	1.24	6.21	**1.24**
IRR	-		0.0399	**10.44%**
NPV	ZAR		0	**ZAR 56 515**
ROI	-		0.15	**32.7%**

Break-Even Analysis

Leveled Cost of Electricity

As aforementioned the levelled cost of electricity provides a basis to compare independent power producing businesses in South Africa. It can be regarded at the cost at which the electricity has to be generated to break-even over the lifetime of the project. The LCE is determined by dividing the construction, operation, and maintenance costs by the electrical energy output of the plant over its lifetime. Although the levelled cost of electricity are location dependent they globally range between 1,24-6,21 ZAR/kWh according to Bart Frederiks.

$$LCE = \frac{\sum_{y=1}^{n} \frac{I_c + R_c}{(1+r)^y}}{\sum_{y=1}^{y=n} E_t/(1+r)^y}$$

where R_c the recurring costs,
And E_t the electricity generation in year y.

The yearly electricity generation is assumed to be relatively constant:

$$E_t = Q \cdot t_{full-load}$$

where Q the installed capacity in kW,
$t_{full-load}$ the annual full load hours.

It is assumed that the annual full load hours $t_{full-load}$ = 5680 hours. Regarding the time under operation per year it is assumed that the plant is taken out of operation 10 days per year, for instance for maintenance, and it runs 16 hours per day at 80 percent of its maximum capacity. Substitution of these values together with the installed capacity of 75 kW and the cash flow statement it follows that the levelized cost of electricity are 1.69 ZAR/kWh.

Conclusion

The section presents two possible scenarios: a scenario in which pricing is scaled to the event that a grant of 80% coverage is obtained and one in which this is not the case. In the case of reaching a PBP within a desired timeframe the sales price must be adapted to reach a certain target. In this case, electricity sales price for the scenarios with a grant of 80% coverage and no grant will be respectively 1.08 ZAR/kWh and 1.87 ZAR/kWh. The team recommends using the tools, which were created, in the event that changes are made to the investment scheme, which are also heavily technology dependent. The tables feature various options, which the project commissioner can choose from.

Follow-up plan

Short term plan: Set up an internship at the farm of Mr. Mofokeng

There is a list of important things which should be done on the short term and on the long term. After team 2 leaves the project needs a follow up team. For the short term the most important thing is to check/valorise the design. The first design is done by a team of students with limited time. The follow up team must examine whether the design can be tweaked for better efficiency. In the end the design must be revised and valorised by an expert.

The option of up-scaling the plant is still possible. The plant out-put and revenue can be expanded by adding more biomass suppliers. Due to time constraints certain suppliers in Devon were not considered in the business plan and design. An example would be the Springs Fresh Food Market which team 2 has visited within the last two weeks of their stay. This company produces an average of two tons of food waste a week. Based on the first estimations, the Fresh Food Market has passed the selection criteria as a biomass supplier. Due to lack of time this supplier has not been closely examined. The future team should examine the contents of the food waste and re-evaluate the profitability of the feed stock. Close attention should be paid of its effect on the balance of the C:N ratio. Optionally waste suppliers close to the Springs Fresh Food Market can be examined to see if they can make the trip more profitable. Other options which could still be examined are the prisons of Nigel and Modderbee, which were excluded because of the lack of profitability. If more biomass supply is found near these locations, it could possibly be profitable to collect.

Contracts with suppliers and off-takers need to be arranged. Most grants are only considered when contract with suppliers and off-takers are established for 5-10 years. For contracts with an off-taker Mr. Ntoane can be of some help as he has some business contact. A wheeling agreement is made in collaboration with Eskom and the municipality. In the case of government run suppliers, such as STI Devon, a contract should be made with the municipality.

Chicken Chain enterprises should start the process for obtaining licences immediately. These can take up to 24 months to obtain. In the case of abattoir waste being used as feedstock more licenses and regulations come in to play. In the feasibility report a list of all necessary licenses for this project are shown. Collaboration with Louise-Mari van Zuyl is advisable.

After the design is valorised a contractor should be found to construct and operate the plant. Possibilities include Biogas SA and Botala Energy Solutions, managed by Peet Steyn who has helped the team with his extraordinary advice.

An application for a grant via Innovation Hub in collaboration with Mr. Mofokeng is due. When Mr. Mofokeng receives the grant the price of electricity can be lowered and it can be easier to find an off-taker.

While the contractors are building the biogas digester, control programs must be written for the measurement and regulation of temperature, pH-value etc. in the digester. These systems can be programmed by a mechanical engineering student.

A continuous supply of students from different faculties is necessary to secure continuation in this project. These students should be from a chemical-, mechanical-, electrical engineering, microbiological and management background. They will provide free creative capital for prof. Mofokeng. In turn experience will be created and the knowledge capital of biogas in South Africa will increase.

After the contracts with suppliers are made, their biomass should be tested. The quality of this feedstock makes a lot of sense for the biogas yield. Therefore chemical and microbiology can test the quality in collaboration with testing institutes. Besides testing the individual biomass composition, yield of mixed feedstock must also be tested. An optimal combination of feedstock can be tested with the existing prototype at Mr. Mofokeng’s farm. This will increase the profitability of the future digester. This could also provide a valuable study for general biogas technology. Collaboration with Prof. Myer of UNISA could be useful in this case. Prof. Myer has been interested in setting up similar studies himself. The RMAA is also interested in testing biogas digestion with pure abattoir waste. This is an opportunity to look for stakeholders that have interest in the test result.

It is important to stay connected with the current network of stakeholders established by team 1 and 2. The existing network consists of various internal and external stakeholders. Most of who are enthusiastic about

advancing the biogas industry. Louise-Mari van Zuyl, for example, is invested in the relevant licensing. Another important person to maintain contact with is team 2's advisor in the Netherlands, Henri Spanjers. He is a biogas expert who is enthusiastic about advising students as long as they come with clear concise questions.
The National Biogas Platform is a meeting where a lot of people from the biogas industry discuss the problems, possibilities and future of biogas. At these meetings it is easy to get in contact with the major biogas companies and learn about their experiences in the realisation of biogas plants. There are different themes that are on the agendas of the working groups, which can be interesting to attend.
The perfect vehicle and route for picking up biomass on a daily base should be optimized. This point is only important when the supply of biomass is extended. The algorithm which is used is Dijkstra's Algorithm, which means that if you add more suppliers in different cities the whole route can change.
A re-evalution of the logistics of collection of manure is necessary. Team 2 has already researched and devised practical ways of collecting waste. It could still be useful to research more practical and efficient methods of collecting the waste, especially in the case of new suppliers. An improvement of collecting method can lead to improved recoverability of the waste. An example of re-evaluation could be the consideration of concrete floors in kraals or pumping all the biomass from a basin. It would be unfeasible for the workers to collect amounts of waste in the tons by had due to time and (human) energy constraints. Besides, a time slot for each supplier should be set for the collection of biomass. These times can be written down in the contracts with the suppliers.
A problem of the collected biomass is that it often contains inorganic solids. For example if the suppliers have cattle that stay in a kraal at night without a concrete floor, the manure will contain sand and stones. This can be separated to prevent clogging or damage of plant parts. A chemical engineer, mechanical engineer or an agricultural student can be very useful to find a separation method. It has been assumed that separation is not necessary/profitable at this scale. A cost-benefit analysis should determine the necessity of a separation mechanism.

Long term plan:

It can be interesting to try to arrange collaboration with local companies and university students. The students will gain experience in biogas technology. At the same time companies will have a cheap way of training and scouting new employees. Potentially such collaboration can increase interest among students.
Different universities should be visited together with Mr. Mofokeng to arrange a continuous supply of students at the farm. It can be an interesting option to supply Dutch students for the whole year to work together with local students for some transfer knowledge. If local students are used than the knowledge will stay in the country contrary to the case of using Dutch students. On this way you can really develop the country and develop the biogas industry.
A long term plan for biogas internships is also an important thing. One of the main goals of Mr. Mofokeng is to be an example for other farmers with making a biogas digester. When the digester is finished it is an interesting option to look at a plan for other farmers too. Team 2 is currently busy with it, but it can be more detailed. A plan can look like this:

- Find out stakeholders who are interested in student visits
- Find a team of local university students for a feasibility study and find out if there is a business case
- Find another team of local university students for designing a biogas digester
- Make a list of different studies that can be useful. Like mechanical engineers, chemical engineers, agricultural students, architecture students, electrical students and management students
- Arrange contracts with suppliers, off-takers and contractors.
- Build a digester
- Make a long term business plan

For the long term the waste water treatment works in Pretoria can be an interesting option to visit and collaborate. This company already got some plants, but is burning a lot of gas into the atmosphere. Therefore another project can be started over there to make electricity from this, now useless, gas. Because of the lack

of time the first two teams haven't visited the ARC, which is a well-known biogas institute. They can provide the following-up team with a lot of information about biogas plants, while they own a few plants.
Another interesting thing is to organise an event at the farm when the biogas digester is in operation to show (local) farmers about this phenomena. In this way you can stimulate them to make their own biogas digester on their own scale. With this event it's possible to create more knowledge about biogas and definitely for farmers it's an interesting option. They can create electricity or gas, get rid of their waste, reduce their electricity bills and get self-sustained.
After the digester is build the business model and also the business plan should be re-calculated/re-write. Some costs can become higher or lower and therefore the price of selling can be changed. Also if there is up scaling the business model should accord to this.
A possible future option can also be a cost-benefit analysis of feeding the cows more to compare it with the quality and quantity of the manure. If you feed them specific food than possibly the biogas yield can become higher. This is not a high priority, but can be an interesting thing for an agricultural student to look after.
In our opinion it's worth the effort to have a look at adding vegetables to the biogas plant to create a safer C/N ratio. With vegetables the C/N ratio will become higher which can increase the biogas yield and therefore also the electricity output. These students should also have a look at how suppliers can provide these vegetables during the whole year, so also in the winter. The most important for the digester is a continuous supply of biomass in the perfect ratios.

List of activities:

1. Checking /Valorisation of the design
2. Up scaling: Expanding of biomass suppliers to create more electricity
    a. Springs Fresh Food Market got an average of 2 tons of food waste a week
    b. Search for more Biomass suppliers in Springs to collect waste to make the trip more profitable
3. Contracts with suppliers must be signed. These should stipulate the amount of biomass and how to pick it up. In the case of the STI, go to municipality to create contracts
4. Find an off-taker in cooperation with Mr. Ntoane.
5. Obtaining all necessary licenses
6. Find a contractor and sign a contract (preferably Botala).
7. Find an operator for the first two years of the operation of the digester.
8. Grant applications and innovation hub
9. Write systems for measuring of temperature, pH-value etc.
10. Recruit students from different faculties. Evaluate which educational backgrounds these students require.
11. Testing program to study the effects of mixing different types of feedstock. Testing the quality of the various types of feed stock.
12. Testing Program for combinations of feedstock
    a. Looking at various combinations of feedstock. Use the feed stock of Mofokengs farm as a feed study. Another example of composition is 70% manure - 30% abattoir suggested by RMAA
    b. Find a institute for sponsoring
    c. Contact RMAA contacts about research. Find out if they are interested at testing for 100% abattoir waste.
    d. Also test the effect of adding more vegetables to the biogas plant (C/N ratio)
13. Investigate how to secure a continuous supply of vegetables during the year (including winter)
14. Maintain contacts with current network. So that the new team can use the existing network.
15. Keep updated with Louise-Mari van Zyl for the current licensing
16. Maintain contact with Henri Spanjers, advisor.
17. Visit working groups for the National Biogas Platform

18. Optimizing perfect vehicle and route for picking up biomass daily. Only necessary when supply of biomass is extended. Use Dijkstra's Algorithm.
19. Reflect on methods of waste collection
20. Devise method of separating organic from inorganic solids (e.g. Sand, stones)
21. Scheduling pick-ups at suppliers
22. Arrange a collaboration with local companies on the project/internship
23. Establish contacts at different universities in South Africa
24. Securing supply of Dutch students for the whole year to work in collaboration with South African students.
25. Write a long term plan for biogas internships
    a. Find out stakeholders who are interested in student teams (for example farmers)
    b. One team of students for a feasibility study
    c. One team of students for designing (these two do not necessarily need to be separated)
    d. Compose a team of students from useful fields
    e. Arrange contracts with suppliers, off-takers and contractors.
    f. Build a digester
    g. Make a long term business plan
26. Investigate the possibility of biogas production and electrification at the Pretoria Waterworks (Idea by Takatso). Design such a system if profitable.
27. ARC research and visiting of their plants
28. Organise event at the farm for more biogas knowledge
29. After the digester is built, re-calculate/re-write the business model and plan
30. Test the quality of gas after the first run of the digester
31. Optional: Make a cost-benefit analysis of feeding the cows more to compare it with the quality and quantity of the manure.

Table 2 Important stakeholders

Person	Company/Institution	Position
Takatso Mofokeng	Chicken Chain Farm	Project owner
Otto Kroesen	TU Delft	Dutch supervisor
Henri Spanjers	TU Delft	Biogas expert
Peet Steyn	Botala Energy Solutions	Adviser
Louise-Mari van Zyl	Cape EAPrac	Licensing
Mark Tiepelt	BiogasSa	Advise
Gerrit Oelofse	Devon Abattoir	Potential buyer
Napo Ntoane	Friend of Takatso	Adviser for potential customers.

Sustainability, development & culture

In this part of the report the content will be about development and cultural influences. First the contribution of the project to development will be described. After this there will be a reflection on the cultural differences. Last off all the relation towards civil society and the contribution to an effective business culture will be dealt with.

Contribution to development

The contribution to development of the project can be seen in different scales. First of all the production of biogas will contribute to a more sustainable South Africa. After all this is a production of green energy. By producing biogas the CO_2 emission will be reduced and people will re-use their waste instead of just throw it away.

A more local scale is the awareness creation of biogas by the project. During the stay of the team an event took place at a farm nearby Nigel. The team was asked to give a presentation about biogas to convince the local farmers of getting their own biogas plant for own use. All the farmers who came to the event were very enthusiastic and Mr. Mofokeng, who attended the meeting, proposed to ask the TU Delft for a follow up team which will design a general small scale biogas plant. This design should be easily adapted to the requests of other farmers, so these farmers can provide themselves with green energy and they won't be depending on Eskom.

This proposal brings us to the next scale of the contribution to development; the project itself. The team has made a business plan and a preliminary design of the commercial viable biogas plant for the Chicken Chain Farm and when the licensing is there and the contracts with suppliers, off-takers and constructors are made Mr. Mofokeng will be actually able to build this digester. The finishing of the biogas plant doesn't mean the finishing of a project in cooperation with Mr. Mofokeng. There are several other projects Mr. Mofokeng wants to start. For example the earlier mentioned project for other local farmers, but also a project in Pretoria where a lot of biogas is wasted by the sewage treatment. All these projects together again help the developing in South Africa.

The last scale is more from the point of view of the students who will join the project(s) in the future. The team experienced a great learning process during the process, but when the team will leave the country all the acquired knowledge will leave with them. To prevent this in the future, the team has suggested the involvement of local students in the project. This will be possible in combination with students from the Netherlands for a proper knowledge transfer. In this way the knowledge will stay in the country instead of leaving back to the Netherlands.

Cultural differences

If we compare South Africa with the Netherlands, we can say that there are many cultural differences. At Devon, where we stayed, we mainly had to deal with Afrikaners. The Afrikaners have been saying racist quotes about the black people to us. We have mostly given neutral answers and have not been choosing a side. We thought this was the most intelligent to do, so that those people couldn't judge us.

With our supervisor we firstly started with creating a proper relationship. We haven't been talking a lot about religion, because we had heard that choosing a particular religion can have unpleasant consequences. Thereby we have always respected the people which attended meetings with us and have always tried to have a conversation with the workers at the farm.

At a farmer meeting in Nigel the people started with a prayer, which we have been attending. In this case we respected on an effective way their culture. Thereby we have learned a few words from some local languages to break the ice at a conversation. In the South African culture it is common to ask random people how they are. Therefore we have always asked the people how they are doing and had a lot of small conversations with them.

Contribution to an effective business culture

Biogas is a relatively new concept of green energy in South Africa. There are a few upcoming biogas companies in the country, although it's still relatively new. Mr. Mofokeng will be an example for other farmers to start their own business to be self-sufficient. Old values will be maintained, but new green energy sources will be implemented. With combining new green energy technology with old traditional values for farmers a new movement can hopefully be created. Like using manure as fertilizer, while with biogas you can create fertilizer and even gas/electricity. In the old situation no money is made out of manure, while with biogas you can even make or safe money.

A business model will be given to the farmers so they don't have to start from scratch. With providing them this business model they can, in collaboration with students, make it fitting for their own situation. This business model will make the setup of a biogas plant easier to encourage the farmers to make a digester themselves.

Concluding, with the concept of biogas and our preliminary design and providing farmers with a business model a new movement can be created. It will be easier for farmers to setup their own plant and at this point they know about how much money they can safe with a biogas plant. This will all lead to a greener and cleaner South Africa.

Line of events

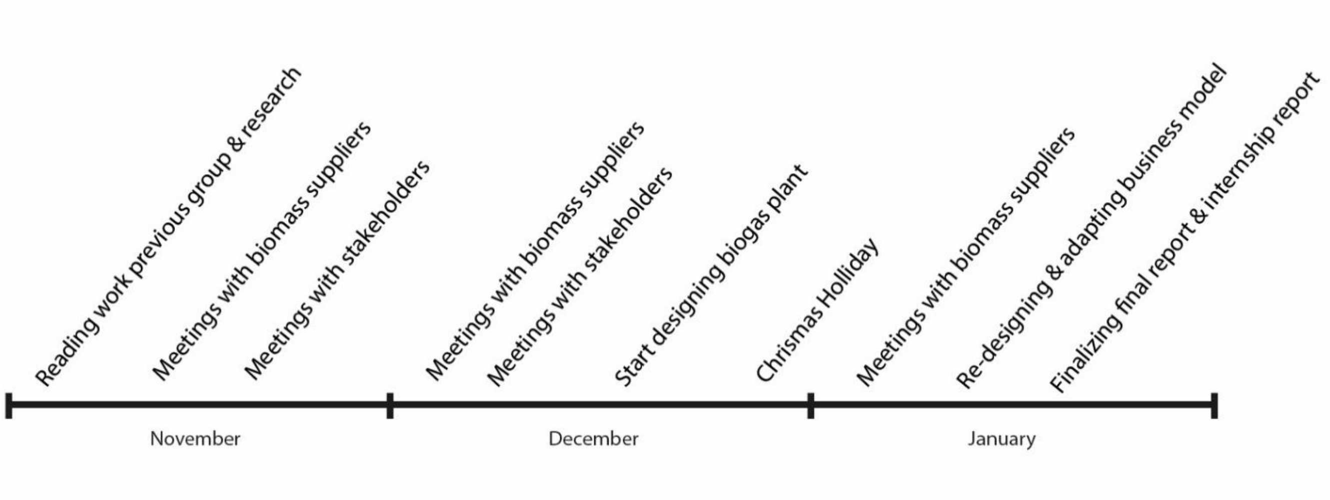


Figure 23 Line of main events

The figure above shows a summary of the main events of the internship. These events will be further explained in the following table.

Table 3 Detailed line of events

DATE	WHAT	WHO	HOW LONG	WHY
Thursday 5-11-2015	Arrival in Johannesburg/Devon	Steven, Yonis, Job, Eva	Staying until 27-01-2016	Mission of the project.
Friday 6-11-2015	Reading information of the previous group	Steven, Yonis, Job, Eva	As long as necessary	For better understanding of the project.
Saturday 7-11-2015	Reading information of the previous group Tour with workers of the farm to get the cows in the cradle	Steven, Yonis, Job, Eva Steven, Yonis, Job, Eva	As long as necessary Half an hour	For better understanding of the project. For better understanding of the business at the farm.
Sunday 8-11-2015	Preparing interview IDC	Yonis, Roxanne, Eva	Roxanne prepared the questions before we arrived. Yonis and Eva had to read them to make some comments. This took half an hour.	To be prepared for the meeting of tomorrow.
Monday 9-11-2015	Interview IDC – Tony Nkuna & Claren Chan	Yonis, Roxanne, Eva	The meeting itself was one hour, but it took place in Santon. This is why we needed four hours in total.	To get more information about the policy of ICD and their point of view about biogas.
Tuesday 10-11-2015	Interview Mamphe (pig farm)	Roxanne, Eva	45 minutes to drive from our farm to Mamphe and back because Mamphe was	To get information about possible supply of biomass and to get information about the

	Interview in Prison Devon Drive to Johannesburg	Steven, Job, Eva Steven, Yonis, Job, Eva, Len, Evan, Roxanne	not at her farm → always double-check! One hour for the meeting itself and two hours including the driving. One hour	differences for a lady to work in a men's world. To get information about possible supply of biomass. We accidently found out there are almost 300 cows at the prison, so there will be a follow up meeting. Tomorrow a part of our group will visit the biogas platform. For practical reasons we decided to drive to Johannesburg a day before the meeting.
Wednesday 11-11-2015	Biogas platform	Steven, Evan, Len, Roxanne	The meeting at the biogas platform took half a day. Therefore we had to prepare some questions together with the team and had to read some information about all the possible attendees	For some networking with other parties and for the idea behind the biogas business. There were some big companies attending and together we have been discussing about the future and the future plans of biogas.
Thursday 12-11-2015	Interview Sean Thomas Every interview has to be written down so you can look back at it sometime and use it in a report.	Roxanne, Eva Roxanne made the minutes and Eva made some comments.	45 minutes for the meeting itself and three hours including driving. As long as you need. It depends on the level of detail.	Sean Thomas is the founder of the biogas plant in Bronkhorstspruit and Bio2Watt. We wanted to know his experiences, difficulties, choices etc. Sean is a very secretive man. We asked some questions several times in different ways, but he still wouldn't answer. Be prepared for this kind of people and keep asking.
Sunday 15-11-2015	Every interview has to be written down. Most of the times	Everybody	As long as it takes to write everything down. This is different for	So you can look back at it some day or you can use it as a reference in

	you write the interviews down the same day as you take them, but sometimes you have to do it another day. Today we used to write down all the minutes which were not wrote jet. Write new project plan activities	 Yonis	every meeting and depends on the level of detail. As long as it takes	a report. We have been here sometime over a week now and we concluded that just building a biogas digester is not possible in three months. So we needed a way to make it possible even if no one of us will be at the farm anymore. This is why we want to include local students into the project in a way they can finish what we have started.
Monday 16-11-2015	Group meeting	Steven, Job, Yonis, Eva	Two hours	We needed a group meeting to discuss our project plan. Yonis has written a different version of the activities yesterday, and we need to discuss these activities. Also we needed to get really started with the project and had to plan the rest of the week.
Tuesday 17-11-2015	Everyone is working on the to do's we set up during the previous meeting: - Starting Logbook. - Put design plant previous group in computer. - Thinking about questions for the	 Eva	Hole day for everyone	Project continuity: Getting started, organized and getting information from the meetings. Minutes were made of the meetings at Morgan Abattoir and Red Meat Abattoir Association

	previous group. - Make notes of previous meetings. - Meeting Morgan Abattoir - Meeting Red Meet Abattoir Association - Calling/SMS prison Devon for follow-up meeting. - Meeting Morgan Abattoir - Meeting Red Meat Abattoir Association - Writing emails - research	 Steven Job Yonis		
Wednesday 18-11-2015	Meeting DBSA in Johannesburg – Eugenia Masvikeni Drawing digester Group meeting with Our group and the previous group.	Roxanne, Eva Eva All	One hour for the meeting itself and 4 hours in total with preparing and driving time. Rest of the day One and a half hours	To find out what we have to do to get funding from the Greenfund. The only problem is that there is no more Greenfund left and DBSA only gives loans to larger projects. So the rapport of the other group could have graphics. To transfer knowledge.
Thursday 19-11-2015	Meeting Prison Devon Meeting Sean Thomas Drawing digester	Job, Steven, Yonis Roxanne, Eva Eva	One hour for the meeting, two hours including the driving. 45 minutes for the meeting, three hours including the driving. Two hours	To get information over their possible biomass supply. Follow-up meeting and site visit. So the rapport of the other group could have graphics.
Friday 20-11-2015	Meeting DOE	Roxanne, Yonis, Job	One hour for the meeting, two hours including the driving.	??

	Meeting Takatso	Steven, Yonis, Job, Eva	One hour for the meeting, two hours including the driving.	To transfer the idea of our new project plan.
Monday 23-11-2015	Group meeting to do's: - Minutes Takatso - Minutes DBSA - Comments internship form - Little adjustments timetable - Comments internship form - Research - Comments internship form - Research - Comments internship form - Timetable adjustments - Research	Yonis, Job, Steven, Eva Eva Yonis Steven Job	Two hours Rest of the day	To fine-tune the new project plan after proposing this to Takatso and to define the project planning from now on. Project continuity.
Tuesday 24-11-2015	Meeting with Takatso	Yonis, Job, Steven, Eva	One hour and 50 minutes	Run thru of the final report of the previous group. And fine-tune the gabs we have to fill. Also we had the intension of sending the new internship form to Takatso and receive some feedback. But he had not read it jet.
Wednesday 25-11-2015	Meeting with Takatso	Yonis, Job, Steven, Eva	Half an hour.	Takatso showed us the boreholes at the farm. Unfortunately he was not able to open our internship form (we had to put it on his

	Group meeting To do's: - Reading of the final report - log - Making a working list of all the different areas we have to work on in the next weeks. - Reading of the final report - Reading of ARC manual - Reading of the final report - Reading of ARC manual - Reading of the final report - Reading of ARC manual	Yonis, Job, Steven, Eva Eva Job Yonis Steven	One hour. Rest of the day	computer directly) so we have not received any feedback jet. We had to discuss our next steps of the project. We made a list of new to do's and a list of people we have to interview. Project continuity.
Thursday 26-11-2015	To do's: - Reading Final report - Making minutes of the meeting with Takatso at the 25th. - Scheduling meetings for next week. - Research	Eva Steven Yonis	Full day	First steps of our own beginning of the project. We still have to read up on the literature and some of the documents of the previous groups. But after the meetings with Takatso, everything becomes clearer and now we know better which steps we have to take in the next weeks.

	- Research - Research	Job		
Friday 27-11-2015	Skype meeting with Bart Frederiks To do's: - Log - Editing movie of our time in SA Research, calling for appointments and preparing questions for meetings	Yonis, Job, Steven, Eva Eva Job, Steven, Yonis	One hour. For this Skype meeting we went to Johannesburg, so also a one hour drive can be counted in the process. Rest of the day (+/- 4 hours)	Bart Frederiks was the technical supervisor of the previous group. We thought he would be our supervisor also, but he has not enough time anymore. Therefore we had a skype meeting to ask some final questions, in order of a good knowledge transfer. Minutes will be made in Dutch. Project continuity.
Monday 30-11-2015	Meeting Morgan Beef	Job, Steven	1.5 hour including drive	Morgan Beef was considered a possible biomass supplier. We had a meeting in the office with the managing director. We got a tour at the property of Morgan Beef.
Tuesday 1-12-2015	Meeting STI Meeting Peet Steyn	Steven, Eva Yonis, Job, Steven,	One hour for the meeting, two hours including the drive. One and a half hour for	The meeting with the STI was about possible supply of biomass form the STI to the farm. We had to double-check where the used water goes to and what is being done with the waste after it is being burned.

	of Botala energy solutions	Eva	the meeting, 4 hours including the drive.	The meeting and site visit with Peet Stein was about knowledge transfer. Botala is a company which provides small scale biogas digesters. Takatso visited Peet once before and Peet gave him some advice. We went back to get more detailed advice about the design of the plant, the materials, the sizes and where they come from.
Wednesday 2-12-2015	To do's - Write minutes from Skype meeting with Bart, and Botala - Call possible suppliers for meetings - Start designing the digester	 Eva Steven Yonis, Job, Steven	Whole day	Project continuity.
Thursday 3-12-2015	Meeting Kobus Louw Meeting Mampe To do's: - Minutes - Design	Job, Yonis Steven, Eva Eva Yonis, Job	One hour for the meeting, one and a half hour including driving. One hour for the meeting, two hours including driving. Rest of the day	To get information over their possible biomass supply. To get information over their possible biomass supply. Project continuity.
Friday 4-12-2015	Meeting Takatso Waiting for Agriculture department	Yonis, Job, Steven, Eva Yonis, Job, Steven, Eva	One and a half hour One hour	To answer some questions of Takatso about the final report of the previous group. We had to tell them something about biogas, but they were

	Skype meeting with Otto	Yonis, Job, Steven, Eva	Half an hour	too late and we had to go to Johannesburg for our meeting with Otto. So we never saw them. Update about the project.
Monday 7-12-2015	Working on Design	Yonis, Job, Steven	Whole day	Fine tune excel sheet and research about design options
Tuesday 8-12-2015	Working on Design	Yonis, Job, Steven	Whole day	To finish deadline of preliminary design.
Wednesday 9-12-2015	Working on Design Minutes and log Meeting Mr. Ntoane	Yonis, Job, Steven Eva Yonis, Job, Steven, Eva	Whole day Whole day One hour	To finish deadline of preliminary design. Keeping track of everything what is said during meetings and what is done during our working days. To find out the possibilities of the off takers.
Thursday 10-12-2015	Working on Design and different systems Drawing design	Yonis, Job, Steven Eva	Whole day Whole day	To finish deadline of preliminary design. To finish deadline of preliminary design.
Friday 11-12-2015	Working on Design and different systems Drawing design	Yonis, Job, Steven Eva	Whole day Whole day	To finish deadline of preliminary design. To finish deadline of preliminary design.
Monday 14-12-2015	Working on Design and different systems Drawing design Bring the car to Nqobile's house.	Yonis, Job, Steven Eva Steven, Eva	Half a day Half a day One hour	To finish deadline of preliminary design. To finish deadline of preliminary design. Deadline was today. So it will be safe during our holiday and it will be in maintenance.
Tuesday 5-1-2016	Contacting Takatso after holiday.	Yonis	15 minutes	To wish him a happy new year & ask about

	Write down a 'to do' list for the next days. Pick up the car at Nqobile's house. Back to the farm	Steven, Yonis, Job, Eva Job & Eva Steven, Yonis, Job, Eva	15 minutes One hour One hour	his opinion of our first design and the event of the ARC. To make a proper start after the holiday. Otherwise we don't have a car (the car was in maintenance when we were on holiday). Back to work after our holiday
Wednesday 6-1-2016	Mail to Martin Myer To do's: - Reading ARC manual - Log - Design and business plan	Yonis Eva Job, Yonis and Steven	15 minutes Whole day	Answer on a previous mail. We asked him for help with a follow up team/team with will test different types of feedstock. Project continuity
Thursday 7-1-2016	Group meeting To do's: - Log - Internship-report - Reading ARC manual - Design and business plan	Steven, Yonis, Job, Eva Eva Job, Yonis, Steven	15 minutes Whole day	Heads up of yesterday and for today. Project continuity
Friday 8-1-2016	Group meeting To do's: - Internship-report - Log	Steven, Yonis, Job, Eva Eva	15 minutes Whole day	Heads up for the rest of the day. Project continuity

	- BMC - Log - Adapt design	Job Steven Yonis		
Monday 11-1-2016	Group meeting To do's: - Internship-report - Log - Adapting design; different systems and calculations - BMC cost structure	Steven, Yonis, Job, Eva Eva Steven, Yonis Job	15 minutes Whole day	Heads up for the rest of the day. Takatso called Yonis today and during the meeting Yonis gave the rest of the team a heads up of their conversation. New deadline: at the end of this week our new design has to be combined with the final report of the previous team. Project continuity
Tuesday 12-1-2016	Meeting Kobus Louw To do's: - internship-report - Adapting design; different systems	Job, Yonis Eva Steven, Yonis, Job	1,5 hour including drive Whole day	Follow up meeting to ask how the biomass will be collected. Project continuity
Wednesday 13-1-2016	To do's: - Adapting design; Different systems and flow chart	 Eva, Steven, Yonis, Job	Whole day	Project continuity
Thursday 14-1-2016	To do's: - Adapting design;	 Eva, Steven, Yonis,	Whole day	Project continuity

	Different systems and flow chart	Job		
Friday 15-1-2016	Guided tour Devon Abattoir To do's: - Adapting design; Different systems and drawings - Call Takatso to ask if we could postpone the deadline of the preliminary design, so we could finish it properly the next day.	Eva, Steven, Yonis, Job Eva, Steven, Yonis, Job Steven	1,5 hour including drive Rest of the day	For better understanding of the slaughter process and to find out how the abattoir waste can be transported to the Chicken Chain Farm. Project continuity. Today was the deadline to finish our preliminary design, but we needed one extra day to finish it.
Saturday 16-1-2016	To do's: - Adapting design; Different systems and drawings	Eva, Steven, Yonis, Job	Whole day	Project continuity and finishing our deadline.
Monday 18-1-2016	To do's: - Starting to adapt the business model after adapting the design and updating Ginger.	Eva, Steven, Yonis, Job	Whole day	Project continuity, we had set our next deadline on Friday. This is when we want to finish the merging of our final report with that of the previous group.
Tuesday 19-1-2016	To do's - Adapting business model -Meeting mr. Abdul	Eva, Steven, Yonis, Job Yonis, Steven	Whole day 20 minutes	Project continuity Supplier information
Wednesday 20-1-2016	To do's - Adapting business model	Eva, Steven, Yonis, Job	Whole day	Project continuity
Thursday 21-1-2016	To do's - Adapting business model	Steven, Yonis, Job	Whole day	Project continuity

	- Adapting design renders & internship report - short/long term internship plan -Meeting Springs Fresh Food Market	Eva Steven Job, Yonis, Steven	 45 minutes drive to Springs, 15 minutes meeting.	 Potential biomass supplier
Friday 22-1-2016	Short/long term internship plan Meeting with Takatso Mofokeng at the sewage treatment in Pretoria	Steven Steven, Yonis, Job, Eva	2 hours 5 hours, including drive	Project continuity In an earlier meeting with the sewage treatment Takatso found out that the treatment produces a lot of gas, but they just let it out in the open air. He wants to set up another project with the treatment to produce more electricity. Because we are at the end of our stay, Takatso knew we couldn't start this second project. He just wanted us to see the treatment. Afterwards we went to his house to meet his wife and to build up the relationship a little more.
Saturday 23-1-2016	To do's - Adapting business model, cost/benefit structure - Adapting design renders & internship report - Short/long term internship plan & explanation about the business case - Safety and security	 Job Eva Steven Yonis	Half a day	Project continuity

Monday 25-1-2016	Preparing presentation for biogas event. Biogas event for local farmers. To do's - Project after movie - Internship report - Long/short term internship plan.	Job, Eva, Yonis Yonis (presentation), Job, Steven, Eva Job Eva Steven & Yonis	One hour Two hour presentation and two hour drive. Rest of the day.	To give a proper presentation at the event. We were asked to give a presentation about biogas, what it is, why you should produce it and how it works. So local farmers would be convinced of building their own ones for personal use. → We heard two hours before the event where and how late the event was happening. This is why unfortunately one hour late. Project continuity
Tuesday 26-1-2016	To do's - Project after movie - Internship report - Long/short term internship plan - Final report	Job Eva & Steven Yonis Steven, Yonis, Eva, Job	Whole day	Project continuity / finishing the project.
Thursday 28-1-2016	To do's - Project after movie - Presentation	Job Yonis	Half a day	Project continuity / finishing the project.
Friday 29-1-2016	To do's - Presentation - Final report - Internship report	Job, Yonis, Steven, Eva Job, Yonis, Steven, Eva Job, Yonis, Steven, Eva	Whole day	Project continuity / finishing the project.

Problems

The line of events during the project is described above for every relevant day. During the stay of the team in South Africa the project didn't always went fluently. Below the different problems will be described and in the next section will describe the way the team dealt with these problems.

1. As written in the adapted scope, the team found it very important to involve local universities in the project. Before our departure to South Africa, the team had spoken to Mr. Mofokeng. He wanted to promote biogas at the universities, so we would convince them to include biogas technology in the syllabus. The team even wanted to bring this to the next level by searching for a follow-up group at the same universities. The only difficulty would be the timing for approaching the universities, because the team would arrive in the examination period and this wouldn't be the easiest time to set up some meetings. This bad timing soon turned out to be not the biggest problem for the team. This would have been the strikes at universities. Mr. Mofokeng and the team itself contacted different universities but they all had problems with their students. The students in South Africa were striking; they even set their lecture halls on fire, because they don't want to pay their student fees anymore. They believe that it is too expensive and the government is not doing any good with it in the end. The worrying about contacting the universities at the right time was nothing compared to the strikes.
2. The team also had some little problems with the different interpretations of time in South Africa and in the Netherlands. The first time the team was exposed to this was during an appointment with one of our possible biomass suppliers. Two of our team members were supposed to meet a farmer, but when they arrived at the farm this farmer appeared to be in Johannesburg instead of the farm.

   The second time something similar happened was at the Chicken Chain Farm. It was Friday and the team had plans to go to Johannesburg during the morning. Around noon a skype meeting was scheduled with our supervisor in the Netherlands and around nine o'clock Mr. Mofokeng would visit the farm to discuss some points of the final report of the previous group. In between the two appointments two men of the department of agriculture would come to visit the farm. Mr. Mofokeng asked us to wait for them, so we could tell something about biogas. In the beginning the men were supposed to arrive at ten, but when they still weren't there at half past ten Mr. Mofokeng decided to call them. They told him they just left but still had to drive for more than an hour. The team had to get to Johannesburg in time for our appointment with our Dutch supervisor, so that's why we had to leave the farm before the men arrived.

   The last and most imported one the team had such an accident was right before the biogas event the same departure of agriculture was organizing. The team heard two hour for the event where they had to go and at which time the event would start. This time, the team had to drive one hour and still had to prepare the presentation they were supposed to give. This is the reason why the team couldn't make it in time themselves.
3. The last problem which will be described is not really a problem itself but it gave some little struggles with the assurance of some aspects of the final report. In the Netherlands the team had proposed to find biomass suppliers, off-takers and constructors and to make contracts with them. When the team arrived in South Africa we heard Mr. Mofokeng wanted to make contracts himself with the suppliers and constructors and he had asked a good friend to find an off-taker. This is why the team couldn't be certain about the exact amount of biomass, the exact costs of the construction and the exact selling price of the electricity.

Solutions

1. Regrettably the strikes didn't stop during our stay, they even got worse. When we heard that the universities Mr. Mofokeng approached were bothered by strikes Yonis le Grand made contact with an old family friend who worked at Vaal University of Technology in the hope we would have more luck with this one. Unfortunately the summer Holliday put us on hold and when it was over we heard from Mr. Mofokeng that the strikes had also started at this university. The only thing we could do was making a short term & long term internship plan. In this plan we put a list of acquired students and actions for finishing the project. Hopefully the next group of (Dutch) students will have more luck with contacting the universities.

2. The problem of different the interpretation of time was tackled different every time.

   The fist example we had to reschedule the meeting. Furthermore, we planned on double checking every meeting from that moment.

   The second example didn't have a real satisfying solution. The team had to be in time for their own skype meeting, so Mr. Mofokeng stayed at the farm to welcome the men form the departure of agriculture.

   At last the example of the biogas event. Unfortunately we were the ones who ran late that day, because we were informed too late. During the week we had called Mr. Mofokeng several times to ask about time and place, but he also didn't knew until the actual date. Although the team ran late, the event was a great success and hopefully this made up for the lost time.
3. The fact that the team didn't know all the exact previous mentioned aspects didn't mean that the team didn't know anything at all. We have made some proper assumptions about the possible biomass supply, because we got a lot of information from enthusiastic possible biomass suppliers. Mr. Mofokeng does only have to confirm and make proper contracts with them. The lack of contracts with constructors will not be that bad. The team found lots of information on the internet and the final price for constructing will not make that great of a difference. At last the absence of an off-taker. This will probably cost some more trouble. The change for receiving grands is much higher when there is an off-taker involved. This is why it is necessary to find one as soon as possible. Since the team didn't have this task, we didn't find a solution for this problem. We did make some appointments with Mr. Ntoane, the friend of Mr. Mofokeng who was given the task to find an off-taker. In that way the team could follow the searching progress. The follow-up team should keep this in mind when they proceed with the project and they should keep in contact with Mr. Ntoane as well.

Self-reflection

The team

During the stay in South Africa the team was functioning very well. This also could have been said during the preparing time in the Netherlands when the team found themselves working very effective. Before the team left the members decided to divide the different main actions. This is why Steven Roerink and Eva ten Velden were supposed to focus their attention towards the management- and marketing aspects of the project and Job Seuren and Yonis le Grand should have had their concerns mainly with the technical aspects of the project. This dividing soon was less effective than thought at the beginning. Mainly because the project owner asked a design before a business plan. This is why Steven joined Job and Yonis with the research of the different systems of the biogas plan and Eva her concerns moved towards the drawings of the design. After the preliminary design was finished every team member choose his or her own subjects of the business model to correct and expand. Although the originally division of the tasks couldn't be kept, all team members focussed on different subjects so the efficiency wouldn't be lost.

In the first two weeks not only our team was present at the farm, but also the previous team. The previous team was finalizing their final report and this gave us time to adjust and make a start with the project. We could ask everything we needed to and that is why we had a proper handover.

Relation between the team and the project owner

The relationship between our team and the project owner Mr. Mofokeng has always been a good one. Before the team came to South Africa we had several skype-meetings with Mr. Mofokeng and also with the previous team. During these skype-meetings we discovered that the relationship between the previous team and Mr. Mofokeng had deteriorated from informal to formal during their stay, because of some practical issues. Both parties talked around each other and in the end the project owner was not quite satisfied with the results of the previous team. This is why next to the actual project we also got the task, from our Dutch supervisor Otto Kroesen, to restore the good relationship with the project owner and students from the University of Technology Delft. In that way it would be possible to send another group of students next year.

Mr. Mofokeng is very open minded about a new group of students, so that is way our relationship with him was good form the start. During our stay we always kept in touch with him and called him several times to tell him about our progress. In that way he knew what to expect of us and it was possible for him to add something when he wanted to. As mentioned before our professional relationship with Mr. Mofokeng was good, but also besides the project our contact was really great. The team got a very warm welcome and met several members of his family.

The team and the South African culture

Although South Africa was, a long time ago, a colony of the Netherlands there are a lot of culture differences to be dealt with. The three main differences will be further explained.

The first cultural difference is the fact that the people in the Netherlands are more individual and more direct than the people in South Africa. When you approach someone you are, most of the time, supposed to ask this person how he or she is doing before you ask the question you were approaching this person for. Dutch people are always straight to the point, so this is why the team had to keep the South African tradition in mind when they wanted to ask something. On the other hand, the people in South Africa are more diverse than in the Netherlands. Most of them are very open and truly interested in how you are doing, but sometimes people are more like the Dutch and they want you to keep your distance. This is why you always have to be prepared for all types of people.

The second and most practical cultural difference is the way people handle time. In the Netherlands you schedule everything way up ahead including time and place. While in South Africa it won’t be noticed when time and place still have to be arranged at the actual date of the appointment. A good example will be the event about biogas for local farmers. First of all took this event place two days before we would leave the country. Originally it would have taken place in the beginning of January, but because of the lack of rain it was postponed. A week before the event we heard the date, but time and place still had to be confirmed. During the week the actual date of the event changed and still we didn’t know the time and place. This is the reason the team decided to focus on the deliverables of the project instead of the presentation, because our deadline was approaching. The morning of the event we finally heard where we had to go and at what time. This meant that we had to prepare a presentation and drive from Johannesburg to Nigel within two hours. Unfortunately in the end we ourselves couldn’t make it in time, but the event was a great success. When the team left Johannesburg we were a bit sceptic about the amount of farmers who would show up at such short notice, but apparently this is the way which works the best in South Africa because the room was packed.

The last and probably most relevant cultural difference with the team had to deal with during the project was the difference between black and white people. Although the Apartheid is officially over for more than twenty years, there are still some aspects to be seen because of the Apartheid. Especially the white people in Devon are very racial and during meetings with them they often showed it without embarrassment. The project owner is one of the black farmers in the region and during the previous mentioned event for local farmers were only other black farmers invited. This is because Mr. Mofokeng wants to help his type of people, since there is still some kind of racism. His mentorship of black farmers is a sign of collectivism, because his interest of the group is bigger than that of him as an individual. The mentorship is an example of the fact that black people still have the feeling they aren’t equal to the white people. However, there are also examples for the fact that black people do have the same rights nowadays. The government has a new policy to empower more black people. Enterprises which are owned by at least 51% by black people, are regarded as black-owned (Southafrica BEE, 2016). Furthermore, it is sometimes easier for black people to receive grands than for white people. Either way, there are still differences between the races in South Africa but it is not only the white people who receive preferential. The team had to keep this in mind during our stay in the country, but we never had problems with these differences.

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