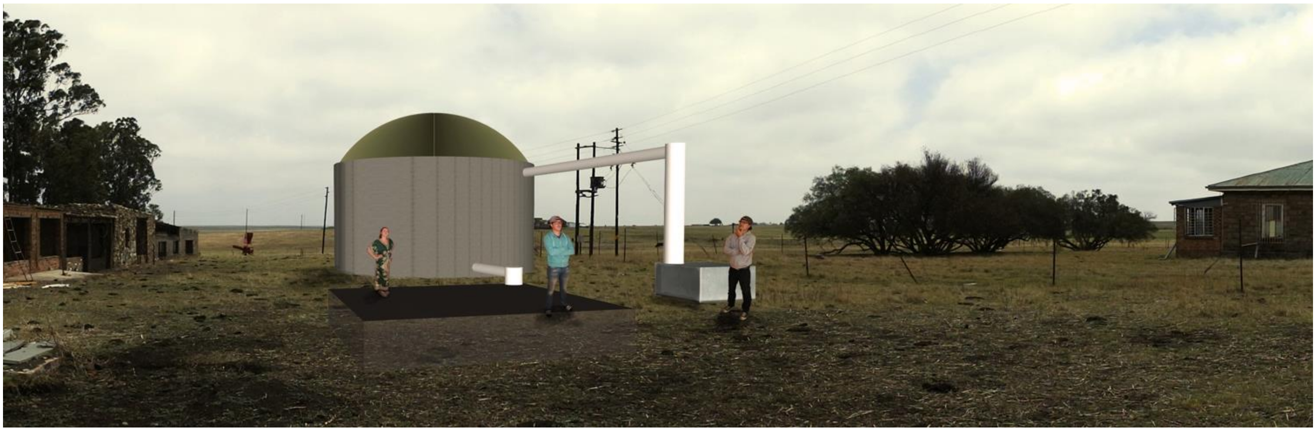
Final Project Report

Research towards a commercially viable and sustainable biogas business in the municipality of Devon, South Africa



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Devon, January 6, 2016

Acknowledgements

Firstly, we, the team, express our sincere gratitude to the initiator Takatso Mofokeng and supervisor Otto Kroesen, and their contributions and feedback, without whom this project would not have existed.

We would also like to pay special thanks to the significant contributions made by independent advisor Bart Frederiks and show our appreciation to him for his continuous support and technical advice.

In our endeavor two stakeholders situated in South Africa eagerly assisted us, and contributed significantly to our findings. We thank Mark Tiepelt, CEO and founder of BiogasSA, and Louise-Mari van Zyl, managing director and principal consultant at Cape EAPrac for their extraordinary support and contributions.

Besides, our special thanks, goes to the follow-up team and their feedback on the report. In particular we thank Eva ten Velden for her contributions to the visualization of some of the plant components and the ground plan.

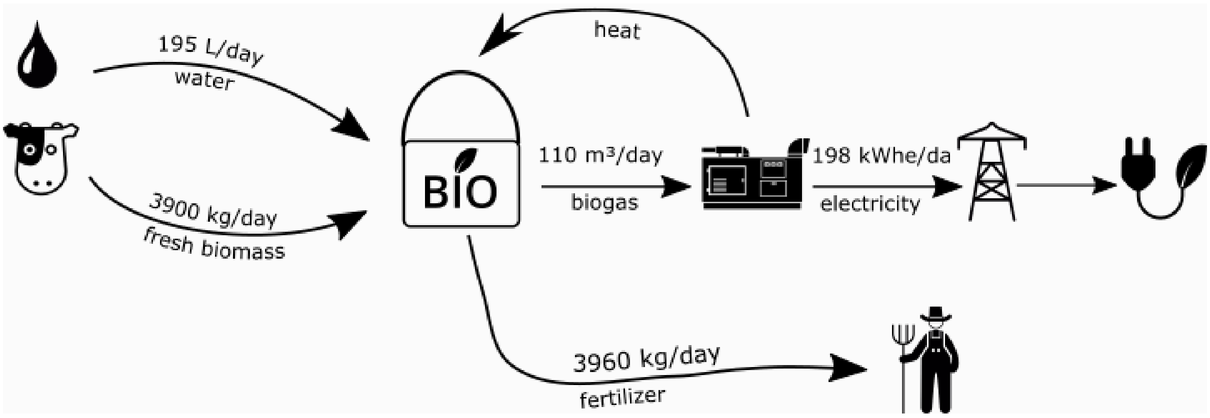
We also place on record, our sense of gratitude to all, who directly or indirectly, assisted in this project.

Abstract

The work conducted, intends to showcase the feasibility of an commercial electricity producing biogas business in Devon, while providing future follow-up teams with the necessary knowledge to successfully continue this endeavor.

The team captured many aspects relevant to the respective business environment, featuring an overview on the legislation and the required licenses for this business, a financial analysis, an analysis of the energy potential and the dimensioning of the most relevant power plant components, as well as a dynamic stakeholder analysis. In doing so, the team developed two comprehensive tools which can be utilized to perform financial analysis and aid in the plant design and determine the energy potential. The knowledge acquired was obtained by involving several key players of the South African biogas industry, including CEOs, consultants, and freelancers, but also extensive literature research of state of the art knowledge in biogas. Below a flow chart on the daily operation of the biogas installation can be found.

The power plant's input is composed of 3900 kg/day of fresh biomass, supplemented with an additional 195 L/day of water. The digester produces 110 m^3 of biogas per day, which can be combusted in an engine to produce kinetic energy. Thermal energy in turn is recuperated to heat the digester and keep it within a desired temperature interval. The plant is capable of producing 198 kWh of electricity per day and also produces 3963 kg of wet fertilizer per day.



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3 List of Symbols

Symbol	Quantity	Unit	Abbreviation Unit
α	Angle	Degrees	°
$\Psi_{consumption}$	Specific Fuel Consumption	Liters per Kilometers	L/km
η	Efficiency	-	-
η_{tot}	Power Cycle Efficiency	-	-
η_{gen}	Generator Efficiency	-	-
ρ_{slurry}	Slurry Density	Kilograms per Cubic Meter	kg/m³
ρ^0_{BG}	Biogas Density under STP conditions	Kilograms per Cubic Meter	kg/m³
A	Surface Area	Square Meters	m²
c_{diesel}	Specific Diesel Costs	Zuid Afrikaanse Rand	ZAR/L
c_{BM}	Specific Biomass Costs	Zuid Afrikaanse Rand	ZAR/kg
C_{fuel}	Fuel Costs	Zuid Afrikaanse Rand	ZAR
C_{tot}	Total Costs	Zuid Afrikaanse Rand	ZAR
C_{rec}	Recurring Costs	Zuid Afrikaanse Rand	ZAR
$C_{purchase}$	Purchase Costs	Zuid Afrikaanse Rand	ZAR
CF_{net}	Yearly Net Cash Flow	Zuid Afrikaanse Rand	ZAR
$C:N$	Carbon to Nitrogen ratio	-	-
d	Distance	Kilometers	km
$e_{energy,BG}$	Specific Energy Content Biogas	Kilowatt-Hour per Cubic Meters	kWh/m³
$e_{energy,fuel}$	Specific Energy Content Fuel	Kilowatt-Hour per Liter	kWh/L
E	Energy	Kilowatt-Hour	kWh
E_{BM}	Biomass Energy Potential	Kilowatt-Hour	kWh
E_{fuel}	Fuel Energy Potential	Kilowatt-Hour	kWh
$E_{electric,daily}$	Electric Energy	Kilowatt-Hour	kWh
$E_{thermal}$	Thermal Energy	Kilowatt-Hour	kWh
E_t	Electricity Generated	Kilowatt-Hour	kWh
F	Force – Weight	Newton	N
f_{load}	Load Factor	-	-
g	Gravitational Constant	Meter per Square Seconds	m/s²
Δh	Height difference	Meters	m
h_0	Reference height	Meters	m
h	Height	Meters	m
h_{slurry}	Height Slurry Level	Meters	m
I_C	Investment Costs	Zuid Afrikaanse Rand	ZAR
$K_{ecological}$	Ecological Indicator	Kilogram per Kilometer	kg/km
k	Heat Transfer Coefficient	Watt per Meter-Kelvin	W/mk
LHV	Lower Heating Value	Kilowatt-Hour per Kilogram	kWh/kg
m	Mass	Kilograms	kg
m_{BM}	Mass Biomass	Kilograms	kg
$m_{BM,daily}$	Mass Daily Available Biomass	Kilograms	kg
m_{BG}	Mass Biogas	Kilograms	kg
$\dot{m}$	Mass Flow	Kilograms per Second	kg/s
$m_{selected}$	Selected Biomass Specific Source	Kilograms	kg
$m_{selected,total}$	Total Mass Selected Biomass	Kilograms	kg
m_{water}	Mass Water	Kilograms	kg
$m_{additionalwater}$	Mass Additional Water	Kilograms	kg
$m_{dryfertilizer}$	Mass Dry Fertilizer	Kilograms	kg
$m_{wetfertilizer}$	Mass Wet Fertilizer	Kilograms	kg
$m_{recoverable}$	Recoverable Mass Biomass	Kilograms	kg
MC_{target}	Target Moisture Content	-	-
N	Number	-	-
p	Pressure	Pascals	Pa
p_0	Standard Pressure	Pascals	Pa
p_{max}	Maximum Pressure	Pascals	Pa
$P_{electric}$	Installed Electrical Capacity	Kilowatt	kW
p_{atm}	Atmospheric Pressure	Pascals	Pa

$Q_{ecological}$	Ecological Criterion	-	-
$Q_{ecological,total}$	Ecological Criterion Total	-	-
$\dot{Q}_{digester}$	Heat Loss Digester	Kilowatt	kW
$r_{feed-in}$	Feed-in Tariff	Zuid Afrikaanse Rand per Kilowatt-Hour	ZAR/kg
R_{tot}	Total Revenues	Zuid Afrikaanse Rand	ZAR
$R_{electricity}$	Electricity Revenues	Zuid Afrikaanse Rand	ZAR
$R_{fertilizer}$	Fertilizer Revenues	Zuid Afrikaanse Rand	ZAR
$S_{gasholder}$	Safety Factor Gasholder	-	-
t	Thickness	Meters	m
t_{daily}	Operational Duration per Day	Hours per Day	h/day
$t_{maintenance}$	Period of Maintenance	Days	days
$t_{full-load}$	Full Load Duration	Hours	h
$t_{storage}$	Gas storage Duration	Hours	h
$T_{i,min}$	Inside Minimum Temperature	Degrees Celsius	°C
$T_{0,min}$	Outside Minimum Temperature	Degrees Celsius	°C
U	Voltage	Volts	V
ΔV	Variable Volume	Cubic Meters	m^3
$V_{daily,BG}$	Volume Daily Biogas Yield	Cubic Meters	m^3
$V_{liquid,fertilizer}$	Volume Liquid Fertilizer	Cubic Meters	m^3
$V_{gasholder}$	Volume Gasholder	Cubic Meters	m^3
$V_{cylinder}$	Volume Cylinder	Cubic Meters	m^3
x_{DM}	Mass Fraction Dry Matter	-	-
$x_{recoverable}$	Recoverable Mass Fraction Biomass	-	-
$x_{massfraction}$	Mass Fraction Selected Component	-	-
$Y_{specific}$	Specific Biogas Production	Cubic Meters per Kilogram	m^3/kg
y	Number of the Year	-	-
$z_{inflation}$	Inflation Rate	-	-
$z_{discount}$	Discount Rate	-	-

4 List of Abbreviations

Acronym	Description
ACED	African Clean Energy Developments
AEL	Air Emissions License
ARC	Agricultural Research Council
BASE	Bertha African Social Enterprise
CCFE	Chicken Chain Farming Enterprise
CHP	Combined Heat and Power
CSIR	Council for Scientific and Industrial Research
DAFF	Department of Agriculture, Forestry and Fisheries
DBSA	Development Bank of Southern Africa
DEA	Department of Environmental Affairs
DM	Dry Matter
DoE	Department of Energy
DTI	Department of Trade and Industry
EEP	Energy and Environment Partnership
EIA	Environmental Impact Assessment
ESKOM	South African Electricity Supply Commission
GIZ	Geselleschaft für International Zusammenarabeit
GHI	Global Horizontal Irradiation
IDC	Industrial Development Corporation
IDS	Innovative Development Solutions
IRR	Internal Rate of Return
ISCW	Institute for Soil, Climate and Water
LCE	Levelized Cost of Electricity
MC	Moisture Content
MHI	Major Hazardous Installation
NBP	National Biogas Platform
NEMA	National Environmental Management Act
NERSA	National Energy Regulator South Africa
NPV	Net Present Value
NRF	National Research Foundation
PBP	Payback Period
REIPPP	Renewable Energy Independent Power Producer Procurement Programme
ROI	Return on Investment
S&EIR	Scoping and Environmental Impact Reporting
SABIA	South African Biogas Industry Association
SABS	South African Bureau of Standards
SADC	South African Development Community
SAIREC	South African International Renewable Energy Conference
SALGA	South African Local Government Association
SANEDI	South African National Energy Development Institute
SAWIC	South African Waste Information Centre
WML	Waste Management License
WUL	Waste Use License
WULA	Water Use License Act
ACED	African Clean Energy Developments

5 Introduction

To date, biogas has shown significant potential as a renewable energy source, mainly in Europe and Asia. Not in the least due to the production of energy in the form of fuel, heat and electricity, the transformation of organic waste into high quality fertilizer, the generation of employment and the reduction of environmental problems such as soil contamination. Hence, it is remarkable that there are approximately only a few hundred biogas installation installed in South Africa at present (Ruffini, SA not using its biogas potential , 2013). Especially, considering the substantial opportunity of biogas from agricultural activities in combination with the proven state of the technology.

One of the few who has seen and taken advantage of the potential of biogas is the Chicken Chain Farming Enterprise, henceforth denoted as CCFE. The CCFE is based on a farm in Devon, a settlement located in the province of Gauteng, South Africa, and has the ambition to make the farm self-supporting in its energy supply. In this endeavor, the farm is not connected to utilities infrastructure and exploits locally available renewable sources. In the autumn of 2014 a team of two students from the Delft University of Technology in the Netherlands realized a prototype biogas installation and enlarged the solar photovoltaics system, which provide the farm with its respective minimum gas and electricity demand. The water demand is covered by the supply from two boreholes and the collected rainwater.

After the success of the prototype biogas installation, Takatso Mofokeng, Managing Director of the CCFE, has plans to develop a commercial biogas business located on the Chicken Chain farm. Hereto, a project is initiated by Takatso Mofokeng in cooperation with Otto Kroesen, assistant professor at Delft University of Technology. By means of the project, Takatso Mofokeng's journey towards the development of a biogas business will be studied and supported. Hereby, the main aim is to explore, design, construct and start up a commercially viable and sustainable biogas business in Devon, South Africa.

In order to carry out the project two teams of in total seven students will travel to the location working together on its completion. The first one of whose work is set in the timeframe of August 15 to December 5, 2015. The second project team continues the first team's work, in the period November 5, 2015 until January 27, 2016.

The previously published *Project Report* and *Mid-Term Project Report* lay the foundation for the *Final Project Report,* which provides its reader with an in-depth understanding of the first two phases of the project, the exploration phase and the design phase, executed by the first team. To start, the objectives and corresponding methodology that are defined for the exploration phase and the design phase are elaborated upon. Secondly, the scope is discussed. Thirdly, the project organization is explained. The findings with regard to the two phases start with an overview on the legal and environmental requirements which the plant has to meet. Together with the resource availability this leads to the energy potential. The specific business model is explained with the use of Osterwalder's Business Model Canvas. Hereafter, the plant design is given. The financial aspects are discussed by means of a financial analysis. The report concludes with a summary and an implementation roadmap for the construction- and startup phase of the project.

It should be noted that the contents of and substantive references to Annex A – Stakeholder Analysis until Annex E – Legislation & Licensing are for internal use only, since the specific sections are not checked with the interviewees at the time of writing. Moreover, references used in the calculations tools can be found in the respective tools or requested from the authors.

6 Objectives & Methodology

As aforementioned the project's goal is to develop a commercially viable and sustainable biogas business in Devon, South Africa. In order to accomplish this goal, it is broken down into three objectives.

1. Determine the feasibility of running an electricity-producing biogas business in Devon, South Africa.
2. Construct a business plan by balancing the exploitation of business, technical, social and ecological opportunities in Devon, South Africa.
3. Design the biogas system based on the prior technology choices, as well as the previously determined design parameters.

To be able to convert the three objectives into activities, they are in-turn broken down into sub-objectives. In this section the breakdown of the objectives into tasks is explained together with the corresponding methodology to pursue the objectives.

6.1 Objective I

Objective I is broken down into seven sub-objectives. To start, the stakeholders are identified and the extent to which they can contribute to the execution of the project is assessed. The appropriate stakeholders are subsequently addressed to determine the legislation, which includes licensing and regulation enforcement, around the electricity-producing biogas business. Moreover, the potential biomass supply is determined by contacting the biomass suppliers in the surrounding area of Devon. Next, the location characteristics including soil and climate conditions, the availability of water, and the characteristic features of the current electricity distribution and transportation infrastructure are determined. Based on the biogas production potential and the location characteristics, the most suitable technology for the biogas system is identified. In parallel, potential customers and their energy demand are determined. Research on this regard has to be completed by the second team. Finally, the financial feasibility and profitability of the electricity-producing biogas business is assessed by performing a financial analysis.

Objective |

Determine the feasibility of running an electricity-producing biogas business in Devon, South Africa.

TABLE 1: THE SUB-OBJECTIVES OF OBJECTIVE I.

Stakeholders

- O: Identify the stakeholder and assess the extent to which they can contribute to the execution of the project.
- M: Perform a stakeholder analysis. First, identify stakeholders by means online research and interviews with stakeholders. Next, define the stakeholders' position in the context of the project. Perform an actor network analysis.

Legislation

- O: Determine the legislation which affects independent power production in Devon.
- M: Contact industry experts, identified in the stakeholder analysis, for inquiries regarding legislation and licensing.

Suppliers

- O: Determine the minimum, maximum and average daily availability, the type and composition and the costs of the biomass and the supporting infrastructure at each supplier's location.
- M: Contact/Visit the identified suppliers. Compile a supplier-specific questionnaire.
- O: Make a preliminary selection of biomass suppliers.
- M: Define ecological and economical selection criterion. The biomass suppliers are selected or rejected on the basis of their score on the criteria.
- O: Determine the maximum biogas production potential according to the biomass suppliers.
- M: Develop an Excel tool, which generates the biogas production potential using the relevant data from the selected biomass suppliers as input.

Location

- O: Determine the soil and climate conditions and the extent to which they will influence the biogas production.
- M: Perform a soil & climate assessment. First, identify the relevant characteristics by literature and online research. Next, assess the relevant characteristics.
- O: Determine the limitations that the current electricity distribution and transportation infrastructure has on the production capacity of the biogas system.
- M: Perform an energy audit in which the energy management of the Chicken Chain farm is investigated. That is, the energy supply, demand, storage capacity and infrastructure. Hereby, the electricity infrastructure is included.

Customers

- O: Identify potential customers of biogas by-products and determine their demand pattern.
- M: Contact relevant stakeholders identified in the stakeholder analysis. Create an overview on potential customers and their demand patterns and requirements.

Technologies

- O: Identify technologies and select the most suitable technology.
- M: Identify potential technologies by online and literature research. Define the technological boundary conditions. Select the most suitable technology using the technological boundary conditions and advice from industry experts.

Financial feasibility

- O: Identify possible financial incentives available to the biogas business.
- M: Contact relevant stakeholders, including financial and governmental institutions, to identify funding opportunities and financial requirements.
- O: Perform a cost-benefit analysis with and without funding opportunities to showcase the feasibility and profitability of the project.
- M: Perform a cost-benefit analysis as a part of the financial analysis to assess the feasibility and profitability of the biogas business.

6.2 Objective II

Objective II is broken down into various sub-objectives, which lay the foundation for the construction of a business plan. The development of a business model, which balances the exploitation of financial, technical, social, and ecological opportunities, gives guidance to set up a sustainable business. After this step has been conducted the previously conducted stakeholder analysis requires revision in the form of an actor network analysis and leads up to the analysis of the competition. The financial plan highlights the cost and revenue streams in order to stay competitive in the energy market and is followed up by a risk-management assessment until the delivery of the project. Moreover, an operation and management plan will be developed. In order to reach out to funding opportunities and investors, the business plan will be tailored to specific content, which can be published. Despite the fact that their completion is crucial for the construction of a business plan the last three objectives are not addressed due to time constraints. Hence, the business plan will have to be completed by the second team.

> *Objective | |*
>
> *Construct a business plan by balancing the exploitation of business, technical, social and ecological opportunities in Devon, South Africa.*

TABLE 2: THE SUB-OBJECTIVES OF OBJECTIVE II.

Business Model

- O: Construct a business model, which balances the exploitation of business, technical, social and ecological opportunities.
- M: Construct a business model using the Osterwalder Business Model Canvas according to the wishes of the project owner and the findings of the feasibility study. Moreover, alternative business models and alternative strategies are defined.

Actors

- O: Define the nature of the relations between the relevant stakeholders.
- M: Due to time constraints the sub-objective is not addressed.

Competition

- O: Analyze competition, to which extent they pose a threat to the biogas business.
- M: Due to time constraints the sub-objective is not addressed.

Financial Plan

- O: Develop a financial plan to demonstrate and predict current and future cash flows as well as investment conditions.
- M: Develop a financial plan on the basis of the financial analysis, which includes a cost-benefit analysis.
- O: Identify possible financial incentives available to the biogas business.
- M: Due to time constraints the sub-objective is addressed to a limited extent. Financial stakeholder are contacted without positive outcomes in terms of potential financial support.

Risk-Management

- O: Develop a strategy to mitigate potential risks documented in a risk-management plan.
- M: Due to time constraints the sub-objective is not addressed.

Operation and Maintenance

- O: Develop an operation and management plan.
- M: Due to time constraints the sub-objective is not addressed.

Business Plan

- O: Write a business plan.
- M: Due to time constraints the sub-objective is not addressed.

6.3 Objective III

Objective III is broken down into four achievable sub-objectives and includes determining the specification of the system components, which leads up to the selection of these based on a catalogue of criteria. After global dimensioning is finished, a layout of the facility can be created, laying the foundation for the construction of the plant. The exact costs of all system components will be tracked in order to update the financial plan. A model of the entire system components will be created in order to determine the system's operating conditions.

> *Objective |||*
>
> *Design the biogas system based on the prior technology choices, as well as the previously determined design parameters.*

TABLE 3: THE SUB-OBJECTIVES OF OBJECTIVE III.

Specifications

- O: Determine the technical specifications of the system components.
- M: Develop an Excel tool that, besides the potential biogas yield, generates the basic dimensions and sizes of the components using the data from the biomass suppliers as input.

System Components

- O: Select possible system components based on previously determined criteria including: availibility & cost, risks involved and make-or-buy decisions.
- M: Contact contractors for advice on this aspect of the design.

Layout

- O: Construct the layout of the facility.
- M: Draft a two- and three dimensonal outline of the layout of the biogas.

Model & Simulation

- O: Create a model and simulate the system in operation in order to determine the operational conditions.
- M: Define an one-dimensional model the heat demand of the plant is estimated.

7 Scope

The first project team's tasks include the conduction of a feasibility study, the development of a business plan as well as the design of the respective biogas system, see Figure 1.

FIGURE 1: PROJECT FLOWCHART.

The aim of the feasibility study is to showcase the feasibility of a sustainable and commercially viable electricity-producing biogas business in Devon, South Africa. It analyses the political, legal, economical, technological, socio-cultural and environmental framework from multiple angles and aims to demonstrate the feasibility by means of a cost-benefit analysis. The team advices to keep an open view in this phase of the project. For instance, regarding the location and the end product of the biogas installation. By considering multiple scenarios the probability to be able to define a feasible scenario increases. What's more, the most promising scenario, in terms of selection criteria defined by the project owner, can be selected and optimized. Nevertheless, the project owner decided that the designated location of the biogas installation is the Chicken Chain farm. Moreover, the primary end product of the biogas installation is electricity that is fed into the grid.

The biogas system design is limited to the global design parameters, i.e. the target input and output of the system, as well as the dimensioning of all relevant system components and their specifications. The results are incorporated in the lay-out of the biogas plant. These parameters set the foundation to model and simulate the technical system in the future.

8 Project Organization

This section gives its reader an insight in the project's organization. Hereto, the background of each team member and their role in the project are discussed, see also Figure 2.

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 will supervise the 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 the first supervisor of Roxanne's master theses project and will advise the team of students on the business development side with a particular focus on the socio-cultural context.

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, however, he will also be involved in various 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 various 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.

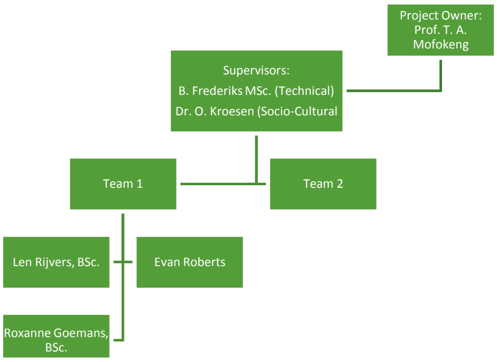


FIGURE 2: ORGANOGRAM OF THE PROJECT ORGANIZATION.

9 Legal and Environmental Boundary Conditions

This section provides the reader with an overview on the legal and environmental landscape and the accompanying boundary conditions it imposes on the biogas business.

9.1 Environmental Boundary Conditions

9.1.1 Air Temperature

The air temperatures in Devon in particular fluctuates significantly, influencing the digester temperature, and consequently the microbiology. A full analysis of the air temperatures in Devon can be found in Annex C – Soil & Climate Assessment. In this report the team utilized the average daily air temperature marking lower quartile in order to mark a pessimistic yet realistic temperature, for several calculations. Find the relevant values listed in Table 4 below.

TABLE 4: KEY TEMPERATURES USED IN THIS REPORT.

Description	Value	Unit
Outside Air Temperature (Lower Quartile)	16	°C
Outside Air Temperature (Upper Quartile)	22	°C

9.1.2 Borehole Water

The biogas digester's water supply will be fed by boreholes. Currently, there are 5 boreholes in place at the farm, 2 of which are in use. The two boreholes average a daily supply of 2255,88 L each. As the project owner wishes to keep the farm's water supply separately, the maximum daily availability of water for the digester can be estimated. The relevant data can also be found in Table 5. A more in-depth analysis of the water supply can be found in Annex D – Energy Audit.

TABLE 5: BOREHOLE WATER DATA.

Description	Value	Unit
Maximum Daily Water Supply	6767	L/day

9.1.3 Precipitation

Precipitation, influences the ground water level, in turn influencing the grass's water content. This variation in moisture influences the moisture content (MC) in the manure, which will be one of the main substrates in the digester. As the MC in the digester must be kept at a certain level due to technical constraints, the dung's fluctuating MC can be taken into consideration in order to determine the required daily additional amount of water supply. Due to time constraints, this kind of analysis is not included in the presented report. A full analysis, of the annual precipitation in Devon can be found in Annex C – Soil & Climate Assessment for further reference. Some relevant aspects are listed in Table 6 below.

TABLE 6: DATA ON PRECIPITATION IN DEVON.

Description	Value	Unit
Annual Precipitation	877	mm

9.2 Legal Boundary Conditions

This section gives an overview of the relevant legislation in the case of the inclusion of abattoir waste. In most cases in the case of the exclusion of abattoir waste, a Basic Assessment (BA) by the authorities is acceptable, which entails a duration of approximately 6 months. In the case of the inclusion of abattoir waste in the biogas digester's substrate mix a scoping and environmental impact reporting (S&EIR) is necessary, which entails a duration of approximately 12 months. A more elaborate description of the relevant legislation and licenses can be found in Annex E – Licensing & Legislation. This area will have to be pursued by an expert, however, till completion. The required licenses for the inclusion of abattoir waste can be found in Table 7.

In order to lawfully generate and distribute electricity into the grid, the biogas plant needs to be registered with the National Energy Regulator South Africa (NERSA) and obtain generation and distribution licenses. As there is no data available on the time that it will take to obtain such a license, it will be estimated at the default value of 2 years, with the expectation that it will at least be obtained within that time frame.

TABLE 7: REQUIRED LICENSES INCLUDING ABATTOIR WASTE.

Legislation	License	Assessment Type	Minimum Timeframe	Cost Estimation
National Environmental Management: Waste Act NEM:WA	Waste Management License (WML)	S&EIR	12 months	ZAR 198.000
National Environmental Management: Air Quality Act	Air Emissions License (AEL)	S&EIR	12 months	ZAR 198.000
National Environmental Management Act (Activity 28)	Environmental Authorization (NEMA)	S&EIR	12 months	ZAR 198.000
National Water Act 36	Water Use License (WULA)	No information	12 months (estimation)	No Information
Electricity Regulation Act (ERA)	Electricity Generation License	No information	24 months (estimation)	No information

10 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.

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.

10.1 Customer Segments

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 three 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.

At this point it is not advised to sell the digestant as fertilizer and as such the private off-taker will be considered the only customer segment. A more elaborate explanation for this decision can be found in Annex F.

10.2 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 the main value thus lies in the improved image that the off-taker will enjoy.

10.3 Channels

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. 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.

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.

10.4 Customer Relationships

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.

10.5 Revenue Streams

In the situation that the company does not receive a grant, the electricity will need to be sold at a price of 4.97 ZAR/kWh in order to break even in 6.1 years. The revenues of the business will consist of electricity sales to the off-taker and are expected to amount to roughly 487k ZAR per year. Detailed information can be found in Chapter 13.

10.6 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 who will supply all of the material resources that are needed for the biogas plant (e.g. tanks, generators) and construct it. 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 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 to hire a company experienced in operating biogas plants 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. This will increase the company's independence and human capital, and skill development in the region.

Human Resources
After being commissioned, the plant will be operated by a single operator. This is based on the assumption that the plant will be mostly automated as is the case in typical commercial scale biogas plants. As mentioned, the plant should be run by an external company specialized in operating biogas plants throughout the first one or two years. This makes it possible to hire only one operator during that time, as the operating company will be expected to provide replacement in case the operator falls ill. Once the company takes over operation of the plant, the company should consider hiring multiple operators who work in shifts to ensure the availability of at least one operator at all times.

Due to financial constraints and considering the small scale of the plant, it will be assumed that biomass collection and transportation will be done by workers currently employed by the Chicken Chain farm.

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.

10.7 Key Activities

Several key activities should be undertaken in order to deliver the value that is presented in this business model.

Biomass collection & transportation

Biomass should be collected on a daily basis and transported to the biogas plant with a truck.

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.

Fertilizer delivery

As mentioned in Section 10.1, it is not recommended to sell the digestant as fertilizer at this point. Instead, it is suggested to provide the fertilizer to the biomass suppliers as a compensation for their support. The frequency with which the fertilizer will be delivered to the biomass suppliers should be agreed upon with each supplier.

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.

10.8 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).

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).

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.

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, 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).

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.

10.9 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 1.995 million ZAR will be needed of which the breakdown can be found in Chapter 13.

Recurring costs consist biomass costs, operation, fuel costs and maintenance. The total yearly recurring costs are estimated at 146k ZAR per year (assuming that biomass will provided for free).

The cost structure can be found in more detail in Chapter 13.

11 Energy Potential

This section is dedicated to the energy potential of the future biogas installation. The team developed a comprehensive Excel Tool to which generates the output of the plant: fertilizer, biogas and in turn electricity, for a given biomass supply. To start, the basic theory behind anaerobic digestion is explained. Hereby, the focus lies on the parameters that influence this process. Next, the relevant data, the input, obtained from the potential biomass suppliers is discussed. Moreover, the economic and ecological criterion on which the biomass suppliers are selected, using the relevant data as input, are elaborated upon. Hereafter, the iterative process in which the substrate input is determined by combining the biomass from the selected biomass suppliers in such a way that the, previously discussed, parameters are optimized is described. Hereby, the team considered a scenario including abattoir waste and a scenario excluding abattoir waste. Further calculations, e.g. plant design, will only be performed for the scenario excluding abattoir waste. As abattoir waste is not deemed feasible as substrate under the prevailing regulatory conditions in the South African biogas industry. More information can be found in the section Legislation and Licensing. The section concludes with the plant's output.

11.1 Theory

11.1.1 Bio-chemistry

The fermentation of biomass is based on a series of four phases of degradation, namely hydrolysis, acidogenesis, acetogenesis, and methanogenesis. As all four phases are closely linked with each other the process can be grouped in two stages.

Hydrolysis and Acidogenesis

During hydrolysis carbon hydrates, proteins and fats are broken down into short-chained sugar, amino acids, fatty acids, and glycerin. The degradation continues with the acidogenesis process, in which short-chained acids and alcohols, as well as CO_2 and H_2 are formed (Steinhauser, 2008).

Acetogenesis and Methanogenesis

The processes of acetogenesis and methanogenesis continue with the formation of carbonic acids, alcohols and acetate resulting in CH_4, CO_2, and H_2O in parallel to which sulphate and nitrate are reduced to H_2S and NH_3, NH_4^+ respectively (Steinhauser, 2008).

Process Parameters and Environmental Requirements

The processes described submit to specific environmental requirements, i.e. temperature, pH value and the C:N ratio. According to Steinhauser (Steinhauser, 2008) the following parameters must meet the conditions in the Table 8 below. A more detailed description of the parameters can be found on the next page.

TABLE 8: ENVIRONMENTAL REQUIREMENTS (STEINHAUSER, 2008).

Parameter	Hydrolysis/Acidogenesis	Methane Formation
Temperature	25-35 °C	Mesophilic: 32-42 °C
C:N Ratio	10-45	20-30
Dry Matter (DM) Content	<40 m% DM	<30 m% DM

11.1.2 Biomass Composition

Parameter: Dry Matter

In this report biomass is modelled to be composed of fresh and dry matter. The fraction of water within the biomass defines the moisture content (MC). The dry matter (DM) — the other part of the biomass — is made up of so called volatile solids and inorganic solids. The volatile solids can be converted into biogas after digestion, and the inorganic solids remain solids in the slurry and are discharged, see also Figure 3. Many literature values indicate the specific biogas yield of a particular substrate per dry matter and are the values used in this work. The DM values used in this work can be found in Table 9. Hereby, it should be noted that these values are based on a calculation method using several literature values. In-depth information and references can be found in the developed Excel tool.Table 9: Dry Matter content (DM) of various biomass sources. Moreover, the moisture content is an important factor when determining the necessary additional water input of the digester. More elaborate descriptions can be found in the section Water Input.

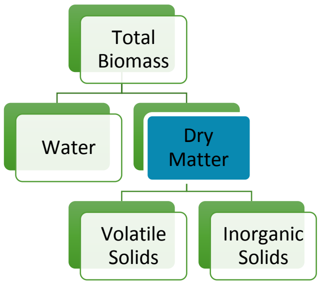


FIGURE 3: COMPOSITION OF BIOMASS.

TABLE 9: DRY MATTER CONTENT (DM) OF VARIOUS BIOMASS SOURCES.

Substrate	DM Content in mass %
Slaughterhouse Waste	16
Stomach-/Intestine Content	15
Cattle Excreta	16
Chicken Excreta	25
Pig Excreta	11
Sewage Sludge	9,0
Sheep Excreta	22
Blood	13

Parameter: C:N Ratio

In order for the necessary bio-chemical processes to take place the C:N ratio of the substrate should be in the range of 15:1-30:1 (Steinhauser, 2008). This is only an indication as nitrogen can be bound in lignin structure (crucial part in the cell structure). A too low C:N ratio leads to an increased ammonia production and an inhibition of methane production. A too high C:N ratio indicates a lack of nitrogen, which leads to an inhibition of protein formation, the necessary energy and structural material metabolism of the microorganisms.

TABLE 10: C:N RATIO OF VARIOUS BIOMASS SOURCES.

Substrate	C:N Ratio
Slaughterhouse Waste	2,5
Stomach-/Intestine Content	15
Cattle Excreta	17
Chicken Excreta	7,8
Pig Excreta	12
Sewage Sludge	11
Sheep Excreta	16
Blood	3,0

11.2 Supplier Selection

11.2.1 Critical Data Acquisition

This chapter introduces the relevant data the team takes into consideration to determine the biogas potential in the surrounding area of the Chicken Chain farm.

Type of Livestock & Biomass

It is critical to know the type of livestock present at the respective farm or location in order to make projections of dung composition and dung yield per day. Some of the biomass may be considered hazardous. It is important to be aware of this from a legal, economic, socio-cultural and technical perspective, e.g. abattoir waste might be considered hazardous which entails legislative implications.

Number of Livestock

It is necessary to acquire the number of livestock present at the respective farms. The team takes three values into consideration to make projections for a potential dung yield per day namely a minimum, an average, and a maximum value.

Average Weight of Livestock

The team collects the average weight of the livestock present at the respective farms. Typical literature values indicate dung yield per animal by matters of livestock weight (LSU), which equals 500kg of live weight (Kossmann). This value enables the straightforward and reliable projection as to how much dung is available.

Weight of Biomass Supply
In several cases the team can rely on values given in terms of weight of the biomass supply. Biomass sources such as abattoirs know how much waste they need to dispose of. In the case of the Chicken Chain farm the team will perform measurements to verify literature values giving more weight to their projections.

Composition of Biomass
The composition of the biomass is of great importance to make projections for the potential biogas yield of a respective substrate, and to plan the dry to water ratio of the substrate input. The relevant data includes determining the:

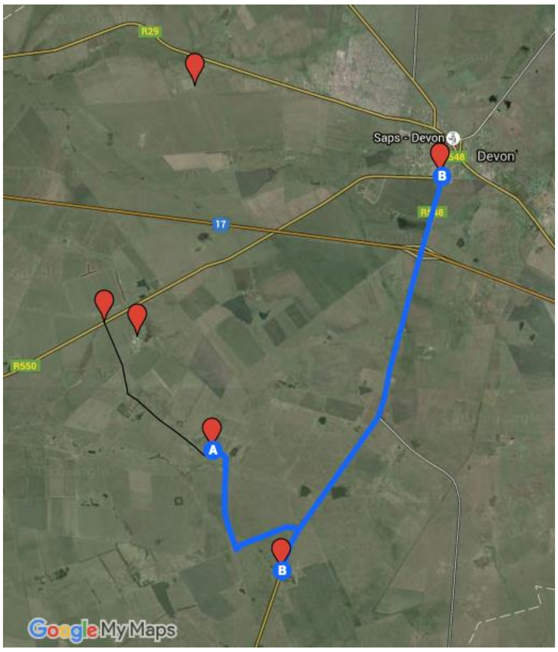
- Total water;
- Total dry matter;
- Volatile matter;
- Inorganic matter.

Current Use of Biomass
It is of great relevance to Mr. Mofokeng's biogas start-up to know what the suppliers currently do with the biomass they produce. The following possibilities exist:

- The biomass is considered a waste-product and needs to be disposed of;
- The biomass is reused for composting;
- The biomass is not used at all (none).

Distance
The distance by means of road needs to be determined for transportation cost calculations. Google Maps was used to make measurements virtually, as can be seen in Image 1.

IMAGE 1:SCREEN SHOT OF A GOOGLE MAPS DISTANCE CALCULATION.



11.2.2 Supplier Selection Tools

The team takes two supplier selection methods for quick and easy decision-making into consideration:

- The ecological criterion;
- The economical criterion.

Both criteria are based on a biomass-to-distance ratio, which enables the team to make preliminary supplier choices before the optimization of the substrate input is executed.

Ecological Criterion

The ecological criterion is used to determine if the potential energy that can be generated from the biomass of a certain supplier, is greater than the amount of energy (from fuel) that is needed to transport the respective biomass to the biogas plant. If this is not the case, the plant would never be ecologically sustainable when supplied by the respective supplier. The ecological quotient is a function of the potential biomass energy, E_{BM}, the daily biomass supply, m_{BM}, on the fuel energy, E_{fuel}, and the distance, d, and should be larger than 1 in order to make sense from an ecological perspective. In order words:

$$Q_{ecological} = \frac{E_{BM}\,(m_{BM})}{E_{Fuel}(d)} > 1$$

where,

$$E_{BM} = m_{BM} \cdot Y_{specific} \cdot e_{energy,BG},$$

and,

$$E_{Fuel} = 2 \cdot d \cdot \Psi_{consumption} \cdot e_{energy,fuel}.$$

The inequality gives an indication to what extent a supplier should be taken into consideration from an ecological perspective if the quotient of biomass to distance $\frac{m_{BM}}{d}$ is greater than the indicator $K_{ecological}$.

$$\frac{m_{BM}}{d} > 2 \cdot \frac{\Psi_{consumption} \cdot e_{energy,fuel}}{x_{DM} \cdot Y_{specific} \cdot e_{energy,BG}} \equiv K_{ecological}$$

The parameters for energy equations are given in Table 11.

TABLE 11: RELEVANT PARAMETERS FOR THE CALCULATION OF THE BIOGAS AND FUEL ENERGY CONTENT.

Parameter	Description	Value
$Y_{specific}$	Specific biogas production [m^3/kg]	See Table 19
$e_{energy,BG}$	Specific energy [kWh/m^3]	Biogas: 6,0
$\Psi_{consumption}$	Specific fuel consumption [L/km]	Truck: 0,26
$e_{energy,fuel}$	Specific energy [kWh/L]	Diesel: 11

Values for specific combinations $K_{ecological}$ using safe estimations, applying a safety factor of 3, can be found in Table 12 (goodyear, 2015) (IOR Energy – Engineering Conversion Factors, 2015)

TABLE 12: POSSIBLE VALUES FOR $K_{ecological}$ WITH A SAFETY FACTOR OF 3.

Specific case for $K_{ecological}$	Value
Slaughterhouse Waste	41
Stomach-/Intestine Content	59
Cattle Excreta	98
Chicken Excreta	53
Pig Excreta	182
Sewage Sludge	139
Sheep Excreta	44
Blood	45

The indicator K can be improved by a safety factor S, whose meaning is an indication of the ratio of the two energy contents. This means that if $S = 2$, the potential biogas energy is twice as large as the fuel energy. This would imply that biomass-distance quotients for slaughterhouse waste of $K_{ecological} < 42{,}8$ are required to meet the ecological criterion.

The ecological quotient can be extended to a total quotient:

$$Q_{ecological,total} = \sum_{i=1}^{n} Q_{ecological,i} = \sum_{i=1}^{n} \frac{E_{BM,i}\,(m_{BM})}{E_{fuel,i}(d)} > 1$$

for a total of n-suppliers, giving a good overall indicator for the ecological selection of biomass suppliers. The quotient also enables straightforward calculation of the CO_2-emissions emitted during transport in order to calculate the plants carbon footprint.

Economical Criterion

The economical quotient indicates whether or not the revenues of the biogas plant will outweigh the associated costs if a certain biomass supplier is taken into account. It gives a financial indication based on the quotient of all revenues, R_{tot} composed of electricity revenues, $R_{electricity}$, and fertilizer revenues, $R_{fertilizer}$, as well as all dominant costs C_{tot} composed of fuel costs for transportation, C_{fuel}, and purchasing costs, $C_{purchase}$. The inequality is formulated as:

$$\frac{R_{tot}}{C_{tot}} = \frac{R_{electricity}+R_{fertilizer}}{C_{fuel}+C_{purchase}} > 1,$$

where,

$$R_{electricity} = m_{BM} \cdot Y_{specific} \cdot c_{energy,BG} \cdot \eta_{total} \cdot r_{feed-in},$$

$$R_{fertilizer} = (m_{BM} - m_{BG}) \cdot c_{BM},$$

$$C_{fuel} = 2 \cdot d \cdot \Psi_{consumption} \cdot c_{diesel},$$

and,

$$C_{purchase} = m_{BM} \cdot c_{BM}.$$

This implies that:

$$\frac{m_{BM}}{d} > 2 \cdot \frac{\Psi_{consumption} \cdot c_{Diesel}}{x_{DM} \cdot Y_{specific} \cdot c_{energy,BG} \cdot \eta_{total} \cdot r_{feed-in} + \frac{m_{BG}}{m_{BM}} \cdot c_{BM}} \equiv K_{economical}$$

for,

$$Y_{specific} \cdot c_{energy,BG} \cdot \eta_{total} \cdot r_{feed-in} + \frac{m_{BG}}{m_{BM}} \cdot c_{BM} > 0.$$

The inequality is an indicator to what extent a supplier should be taken into consideration from an economical perspective if the quotient of biomass to distance $\frac{m_{BM}}{d}$ is larger than the indicator $K_{economical}$. Values for the cost and revenue equations can be extracted from Table 13. In addition it is assumed that the biomass from the suppliers will be acquired for free, $C_{purchase} = 0$. Moreover, as aforementioned, for now it is not advised to sell the fertilizer, hence $R_{fertilizer} = 0$.

TABLE 13: RELEVANT PARAMETERS FOR THE CALCULATION OF THE COST AND REVENUE STREAMS (STEINHAUSER, 2008) (GOODYEAR, 2015).

Parameter	Description	Value
$\boldsymbol{Y_{specific}}$	Specific biogas production [m^3/kg]	See Table 19
$\boldsymbol{e_{energy,BG}}$	Specific energy [kWh/m^3]	6,0
$\boldsymbol{\eta_{total}}$	Product of engine and generator efficiency	0,30 (estimate)
$\boldsymbol{c_{feed-in}}$	Feed-in tariff [ZAR/kWh]	1,5
$\boldsymbol{\frac{m_{BG}}{m_{BM}}}$	Ration of mass of biogas to total biomass input	$\rho^0 \cdot Y_{specific} =$ 0,36 ($\rho^0 =$ 1,2)
$\boldsymbol{\Psi_{consumption}}$	Specific fuel consumption [L/km]	0,26
$\boldsymbol{c_{Diesel}}$	Diesel price [ZAR/L]	11
$\boldsymbol{c_{BM}}$	Specific cost of biomass [ZAR/kg]	0,18

Values for specific combinations $K_{economical}$ using safe estimations can be found in Table 14.

TABLE 14: POSSIBLE VALUES FOR $K_{economical}$ EXCLUDING PURCHASING COST, INCLUDING A SAFETY FACTOR $S = 3$.

Specific case for $K_{economical}$	Value
Slaughterhouse Waste	63
Stomach-/Intestine Content	74
Cattle Excreta	80
Chicken Excreta	67
Pig Excreta	99
Sewage Sludge	101
Sheep Excreta	61
Blood	78

The indicator K can be improved by a safety factor S, where S determines the minimum ratio of revenue to costs. This means that if $S = 3$ the revenues will be, under the aforementioned assumption, twice as high as the costs involved. Naturally, this is only an estimation.

11.3 Definition of Substrate Input

11.3.1 Boundary Conditions

In this study three boundary conditions define the substrate input. The overall C:N ratio, $\mathrm{C{:}N}$, the target moisture content, MC_{target}, and the recoverability of the biomass from the location indicated as a recoverable fraction, $x_{recoverable,i}$, where i is the respective substrate. Here, recoverability refers to the fraction of biomass that can be collected at the specific location. The literature value found in Deublein and Steinhauser's *Biogas from Waste and Renewable Resources* was adapted based on Bart Frederiks' expert opinion. The recoverability of cattle excreta is based on the time the cattle spend in the stable daily. A typical abattoir can only provide waste on work days when animals are being slaughtered. If one assumes 5 days in operation per week and 20 national holidays the recoverable fraction can be estimated as such.

TABLE 15: LOCAL PARAMETERS DEFINING THE SUBSTRATE INPUT.

Parameter	Symbol	Value
C:N ratio	$C{:}N$	15-30
Target Moisture Content	MC_{target}	10%
Recoverability	$x_{recoverable,i}$	-Cattle Excreta: 50% -Abattoir: 66%

11.3.2 Biomass Input

The recoverable mass of biomass $m_{recoverable,i}$ can be calculated by multiplying the daily available supply of the respective biomass source $m_{BM,daily,i}$ and the recoverability factor:

$$m_{recoverable,i} = \sum_{i=1}^{n} m_{BM,daily,i} \cdot x_{recoverable,i}.$$

In order to determine the substrate input, taking the overall C:N ratio into consideration, a fraction of each source must be chosen. The selection process is an optimization problem, as the total selected biomass accumulated must have a C:N ratio within the previously defined C:N ratio. The following assumption is made:

$$m_{selected,total} = f(C{:}N),$$

and,

$$C{:}N = \sum_{i=1}^{n} C{:}N_i \cdot x_{massfraction,i},$$

where $C{:}N_i$ is the substrate specific C:N ratio and $x_{massfraction,i}$ is:

$$x_{massfraction,i} = \frac{m_{selected,i}}{m_{selected,total}}.$$

Due to the relatively low amount of possibilities an iterative optimization approach was chosen to meet the conditions. Additionally, the team decided to include a possibility with, scenario 1, and without the abattoir, scenario 2, as the necessary legislation elongates the project and entails additional costs.

11.3.3 Water Input

In order for a biogas digester to be stirred a certain moisture content must be sustained. If the moisture content MC which can be calculated as such:

$$MC = \frac{\sum_{i=1}^{n} m_{selected,i} \cdot (1 - x_{DM,i})}{\sum_{i=1}^{n} m_{selected,i}},$$

is smaller than the target moisture content MC_{target}, additional water must be added to the digester. The additional water can be calculated as:

$$m_{additionalwater} = MC_{target} \cdot m_{selected,total} - m_{wetmatter}.$$

11.4 Resource Availability Summary

The biomass resources of this biogas system originate from an array of sources in the surrounding area of the farm.

11.4.1 Biomass Resources Available On-Site

Currently, approximately 600 kg of cattle dung are available on sight under the conditions that the cattle spend 50% of the day (night-time) in their stable.

TABLE 16: AVAILABLE RESOURCES ON SITE.

Source	Type	Daily Quantity [kg/day]
Chicken Chain Farm	Cattle Excreta	600

11.4.2 Biomass Resources from other Sources

Currently, there are several external sources that can be drawn upon to include in the biogas digester mix. Twala, Abdul and Kobus Louw, farm owners in the surrounding area can provide cattle excreta under the conditions that the cattle spend 50% of their time in the stable. The Devon abattoir can provide waste on work days only. Averaged out over the year the daily supply can be calculated, if 66% days in the year are considered work days.

In chapter Biogas Yield, the team demonstrates two possibilities to produce biogas. One with and one without the inclusion of the abattoir. The reason this distinction is made, are the difficulties in technology, investment and legislation this would entail. This distinction is also made in the cost benefit analysis in the section Financial Cost-Benefit Analysis.

TABLE 17: SELECTED RESOURCES FROM OTHER SOURCES. SCENARIO 1 REFERS TO THE CASE INCLUDING ABATTOIR WASTE. SCENARIO 2 REFERS TO THE CASE EXCLUDING ABATTOIR WASTE.

Source	Type	Daily Quantity [kg/day]	Distance [km]
Twala	Cattle Excreta	180	1
Devon Abattoir (only scenario 1)	Slaughterhouse waste	294	4
Devon Abattoir (only scenario 1)	Stomach-/intestine Content	2756	4
Devon Abattoir (only scenario 1)	Blood	343	4
Abdul	Cattle Excreta	1020	4
Kobus Louw Farm	Cattle Excreta	2100	6

11.4.3 Water Resources

The required additional water supply, calculations in Water Input, can be provided by installing more solar power pumps.

TABLE 18: OVERVIEW OF WATER DEMAND AND SUPPLY.

Description	Value	Unit
Additional Water – Including Abattoir	222	L/day
Additional Water – Excluding Abattoir	195	L/day
Available Water per Pump	2255	L/day

Conclusively, this means that one additional solar powered pump should be installed for both scenarios, under the assumption that the yield is in the same order of magnitude as the other pumps installed at the farm so far.

11.5 Biogas Plant Output

11.5.1 Biogas Yield

The daily volumetric biogas yield $V_{daily,BG}$ depends on the selected mass of biomass $m_{selected,i}$, the dry matter fraction $x_{DM,i}$, and the specific biogas yield $Y_{specific,i}$, where i is a specific source of n selected sources. The specific values for $Y_{specific,i}$ can be found in:

$$V_{daily,BG} = \sum_{i=1}^{n} m_{selected,i} \cdot x_{DM,i} \cdot Y_{specific,i}.$$

TABLE 19: SPECIFIC BIOGAS YIELD OF DIFFERENT SUBSTRATE TYPES.

Substrate	Specific Biogas Yield in m^3/ton of Dry Matter
Slaughterhouse Waste	419
Stomach-/Intestine Content	358
Cattle Excreta	188
Chicken Excreta	294
Pig Excreta	215
Sewage Sludge	294
Sheep Excreta	315
Blood	576

11.5.2 Electricity

The electric energy depends on a series of parameters listed in Table 20. The team estimates that the plant will be running continuously for a fraction of the day, with the exception to some dedicated maintenance days in the year under a specific load.

TABLE 20: PARAMETERS AFFECTING THE ELECTRICITY PRODUCTION

Parameter	Symbol	Value	Unit
Lower Heating Value	LHV	6,0	kWh/m^3
Generator Efficiency	$\eta_{generator}$	0,3	-
Days under Maintenance Annually	$t_{maintenance}$	20	days
Operation per Day	t_{daily}	16	h
Average Load Factor per Day	f_{load}	0,8	-

The electricity, which can be produced depends on the potential thermal energy $E_{thermal,daily}$ of the biogas yield. Based on the lower heating value LHV and a generator efficiency $\eta_{generator}$ the thermal and electric energy can be calculated as:

$$E_{thermal,daily} = V_{daily,BG} \cdot LHV,$$

and,

$$E_{electric,daily} = E_{thermal} \cdot \eta_{generator},$$

respectively.

The installed electrical capacity is based on the annual full load hours, $t_{full-load}$, and average daily full-load hours, $\bar{t}_{full-load}$. See equations below:

$$t_{full-load} = (365 \text{ days} - t_{maintenance}) \cdot t_{daily} \cdot f_{load},$$

$$\bar{t}_{full-load} = \frac{t_{full-load}}{365}.$$

The recommended installed electrical capacity (or total generator power) can then be calculated

$$P_{electric} = \frac{E_{electric,daily}}{\bar{t}_{full-load}}.$$

11.5.3 Fertilizer

An potential future revenue stream is the slurry output of the digester, which can be used as fertilizer. The volume of liquid fertilizer, $V_{liquidfertilizer}$, and the mass of dry fertilizer, $m_{dryfertilizer}$, can be calculated as shown in the equations below:

$$V_{liquidfertilizer} = \frac{V_{input} \cdot \rho_{slurry} - V_{daily,BG} \cdot \rho_{BG}^{0}}{\rho_{slurry}},$$

$$m_{dryfertilizer} = V_{liquidfertilizer} \cdot \rho_{slurry} \cdot (1 - MC_{target}).$$

All parameter can be found in Table 21 below.

TABLE 21: PARAMETERS REQUIRED TO DETERMINE THE AMOUNT OF FERTILIZER.

Parameter	Symbol	Value	Unit
Slurry Density	ρ_{slurry}	1000	kg/m^3
Biogas Density under STP	ρ_{BG}^{0}	1,2	kg/m^3

11.5.4 Plant Outputs

Scenario 1: Abattoir waste included

TABLE 22: PLANT OUTPUTS INCLUDING ABATTOIR WASTE.

Description	Value	Unit
Annual Electricity Production	95.058	kWh/a
Installed Power	22	kW
Liquid Fertilizer	5	m^3/day
Dry Fertilizer	458	kg/day

Scenario 2: Abattoir waste excluded

TABLE 23: PLANT OUTPUTS EXCLUDING ABATTOIR WASTE.

Description	Value	Unit
Annual Electricity Production	72.257	kWh/a
Installed Power	16	kW
Liquid Fertilizer	4	m^3/day
Dry Fertilizer	396	kg/day

12 Plant 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. The plant design is based on the scenario excluding the abattoir waste. The main reason is that the legislative landscape for biogas plants that handle abattoir waste is relatively non-transparent and ever changing. In turn, this leads to uncertainty in terms of finances and time. Nevertheless, future developments in the aforementioned landscape might lead to a stronger position for biogas plants including abattoir waste.

12.1 Components

This chapter highlights the team's proposed main specifications of the individual components this power plant will feature: the biogas digester, a gasholder dome, the scrubbing system (although this was not explored in detail, due to time constraints) and the generator.

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.

TABLE 24: KEY GEOMETRICAL DATA OF THE PROPOSED DIGESTER DESIGN.

Description	Value	Unit
Digester Volume	246	m^3
Slurry Volume	123	m^3
Buffer Volume	123	m^3
Radius	3,4	m
Thickness	0,15	m
Digester Height	6,8	m
Slurry Level	3,4	m

Input and Output
The input and output of the biogas digester is based on a mass balance as visualized in Figure 4.

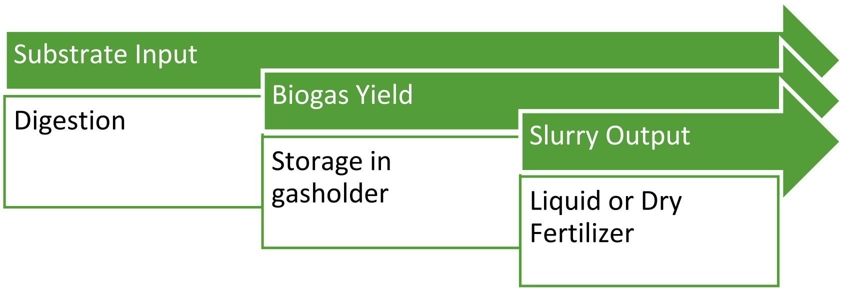


FIGURE 4: FLOW-CHART DEMONSTRATING THE SUBSTRATE CONVERSION INTO 2 PRODUCTS.

Table 25 shows the most important input and output values. The calculations of these values can be found in Energy Potential.

TABLE 25: INFLOW AND OUTFLOW VALUES OF THE DIGESTER.

Description	Value	Unit
Substrate input	4,1	m^3/day
Liquid fertilizer output	4,0	m^3/day
Dry fertilizer output	396	kg/day
Biogas yield	110	m^3/day

12.1.1 Gas Storage

Functional Requirements
The gas will be stored separately. It is designed to hold approximately 12 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 26.

TABLE 26: PARAMETERS THE GAS STORAGE IS DESIGNED FOR.

Description	Value	Unit
Biogas Storage Capacity	12	h
Maximum pressure difference	5	Mbar
Volume	66	m^3

12.1.2 Slurry Basin

This basin, which will act as an overflow tank, in which the slurry can be stored in temporarily post-digestion. As the fertilizer will not necessarily be picked up daily, it can be stored for a certain amount of time. In this case the team chose seven days — weekly pick-ups — approximately one fourth of the retention time. The global geometrical design parameters, with exception to the thickness can be found in Table 27.

TABLE 27: : GEOMETRICAL DESIGN PARAMETERS OF THE SLURRY BASIN, INCLUDING.

Description	Value	Unit
Volume	29	m^3
Side A	5,4	m
Side B	5,4	m
Depth	1,0	m

12.1.3 Scrubber

The approximate content of 0,5 vol.% of H_2S in the gas will be reduced to a concentration of 0,05 vol.% of H_2S, to prevent corrosion downstream the installation (Steinhauser, 2008). The gas treatment system must handle a flow rate of approximately 4,8 $\frac{\mathrm{m}^3}{\mathrm{h}}$.

12.1.4 Generator

The team recommends installing a generator of the power of 16 kW. This CHP engine, will also provide the digester with the heat required to maintain a digester temperature of 32°C to 42°C. The global generator design parameters, can be found in Table 28.

TABLE 28: GENERATOR DESIGN PARAMETERS.

Description	Value	Unit
Energy Anually	72.257	kWh
Full-load Hours Annually	4416	h
Average Daily Duration	16	h
Average Load Factor	80	%

12.1.5 Biogas Digester

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. The tables below demonstrate the conditions the digester will be operating at, the proposed geometry, and the input and output (mass balance).

13 Financial Analysis

The economic feasibility and profitability of the biogas business are assessed by means of a financial analysis. An Excel tool, developed by the team, aids in performing the 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 levelized 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).

13.1 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 Figure 5.

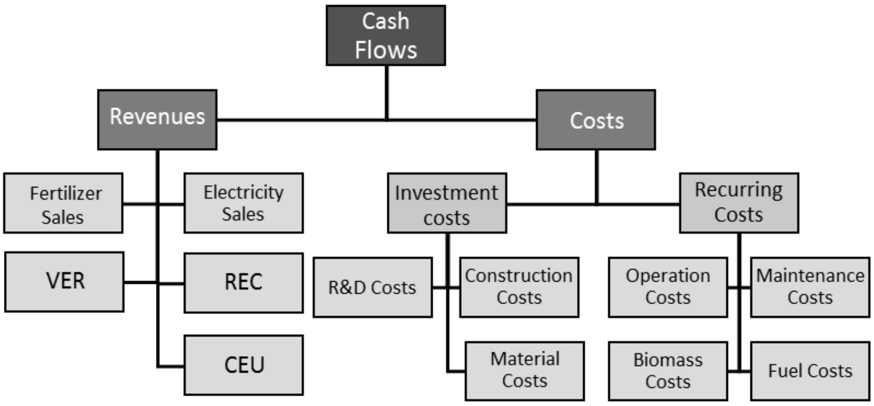


FIGURE 5: CATEGORIZATION OF THE CASH FLOWS.

The cash flow statement is constructed by inventorying the cash flows together with the time when the in- or outflow takes place. In doing so, multiple industry stakeholders are contacted with the request to draw up a quota for the future installation.

The resulting cash flows can be found in Table 29 and Table 30 .

TABLE 29: REVENUE STREAM BIOGAS BUSINESS AT A GENERAL SALES PRICE OF 1,47 ZAR/KWH.

Category	Category Total	Revenue Stream	Total
Revenues	103864,32	Fertilizer Sales	**0**
		Voluntary Emission Reductions (VER)	**0**
		Renewable Energy Certifications (RECs)	**0**
		CO2 emissions utlisation (CEU)	**0**
		Electricity Sales	**103864,32**

Table 30: Cost Stream Biogas Business, Scenario excluding abattoir, 16 kW Installed Capacity.

Category	Category Total	Sub-Category	Sub-Category Total	Cost Stream	Estimated Values
Investment Costs	ZAR 1.995.611	R&D Costs	ZAR 507.000	Team 1	ZAR 62.000
				Team 2	ZAR 0
				Team 3	-
				Team 4	-
				Pre-design and Feasibility	ZAR 45.000
				Design	ZAR 400.000
		Legislation & Licensing	ZAR 511.000	Total Costs	ZAR 511.000
		Material Costs	ZAR 745.611	CHP Engine	ZAR 153.139
				Gas Treatment Equipment	ZAR 121.702
				Gas Storage	ZAR 68.867
				Mixers, Pumps, Piping	ZAR 68.835
				Plant Controls - Electricity Distribution	ZAR 66.250
				Heated (mesotherm) Concrete CSTR	ZAR 266.818
				Truck	-
		Construction Costs	ZAR 232.000	Construction - Labour Costs	ZAR 190.000
				Pour Concrete Kraal	ZAR 42.000
Recurring Costs	ZAR 146.204	Biomass Costs	ZAR 0	Chicken Chain Farm	-
				Twala	-
				Kobus Louw	-
				Abdul	-
		Fuel Costs	ZAR 20.792	Chicken Chain Farm	-
				Twala	-
				Kobus Louw	-
				Abdul	-
		Maintenance Costs	ZAR 14.912	Yearly Maintenance Costs	ZAR 14.912
			ZAR 38.285	Five Yearly Maintenance Costs	ZAR 38.285
		Operation Costs	ZAR 110.500	Feedstock Truck Driver	-
				Chief Operator	ZAR 110.500

13.2 Financial Cost-Benefit Analysis

13.2.1 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 a the electricity price for which this conditions are met is equal to 2,55 ZAR/kWh. A typical price for electricity is 1,47 ZAR/kWh. Hence, a potential off taker has to be willing to pay a price that is 73% higher than usual. The accompanying key indicator values are listed in Table 31.

TABLE 31: KEY INDIDACTOR VALUES FOR A SALES PRICE OF 2,55 ZAR/KWH.

Key Indicator	Unit	Reference Value	Current Value
PBP	year	10,00	9,8
LCE	ZAR/kWh	1,24-6,21	2,40
IRR	-	3,99%	11,4%
NPV	ZAR	0	ZAR 145.339
ROI	-	15,00%	92,7%

13.3 Break-Even Analysis

Levelized Cost of Electricity

As aforementioned the levelized cost of electricity provide 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 levelized 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 $t_{full-load} =$. Regarding the time under operation per year it is assumed that the plant is taken out of operation 20 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 16 kW see Biogas Plant Output, and the cash flow statement it follows that the levelized cost of electricity are 4,00 ZAR/kWh.

13.4 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. The tables feature various option, which the project commissioner can choose from. 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.

Research Limitations

As is the case for research in general, the feasibility study is inherent to certain limitations. The main limitations to which the research is subjected are listed below. The team strongly recommends where possible to take into account the limitations in further research.

- Timeframes and costs on licensing & regulations are not always known as a result of the ever changing and instable regulative landscape of the South African biogas industry.
- For now the feasibility of the scenario excluding the abattoir substrate is considered. The main reason is the, aforementioned non-transparent and ever changing regulative landscape of the South African biogas industry. This is especially the case for biogas installations which process abattoir waste.
- No sensitivity analysis is performed in the financial analysis. Together with the partially inconsistent and incomplete data this makes that it is highly recommended to do a sensitivity analysis and gather more data in the future to increase the accuracy and reliability of the financial analysis.
- There is a relatively small (<10) number of commercial scale biogas projects in South Africa. First, there are no commercial projects which operate on the same scale as the one researched in this work, which makes it impossible to compare between similar projects. Second, the industry is in its infant stage which entails among others a non-streamlined legislative landscape, a lack of data on the substrates, no proven technology for South Africa.
- No data was available on the time needed to execute specialist studies which are required to obtain the necessary licenses.

14 Implementation Roadmap

In this chapter, an implementation roadmap will be given which can be used to implement the biogas business according to the results given in this report. An overview can be seen in Figure 6.

14.1 Preparation

First and foremost, it will be important to validate the findings of the presented feasibility study by a company specialized in biogas production in South Africa. The reason for this is not only to increase the reliability of the results and confirm that the chosen technology is suitable, but also to provide the company with credibility when approaching prospective partners. It should be emphasized that as the company is not yet perceived as an established biogas expert, it is at this point particularly important to build a reputation and gain credibility. This can be done by involving a company which has experience in conducting feasibility studies for biogas projects in South Africa.

Secondly, the company should formally establish herself by registering under South African law. Furthermore, the company profile should be defined in order to present a consistent image to external stakeholders.

Once the feasibility study has been validated, the company can proceed with formulating a business plan based on the business model given in Chapter 10 and conduct risk analysis. The activities must be designed according to the requirements that the feasibility study yields.

Finally, the company should put together a project team. This team should at least include:

- **Contractor** – it is advised to involve two companies for this: one company which is specialized in the design of biogas plants (and who could potentially also validate the feasibility study) and one contracting company which can construct, operate and maintain the plant after receiving training from the first company. A similar structure is for instance also used by the Bio2Watt plant in Bronkhorstspruit by working with both Bosch Munitech and CombiGaS. It is however also an option to seek a company that is specialized in both construction and biogas technology.
- **Legal consultant** – to draw up the necessary contracts with for instance biomass suppliers and the private off-taker.
- **Environmental legislation specialist** – to guide the company through the legislative requirements of the biogas plant.

The reason that it is important to set up the project team at such an early stage is that it will again contribute to the credibility of the company when approaching for instance potential off-takers.

Activities:

- *Validate Feasibility Study*
- *Formally register company*
- *Formulate business plan*
- *Contract project team*

14.2 Legislation & Licensing

In Section 9.2, the licenses that are expected to be needed for the biogas business have been discussed. An overview can be seen in Table 32. However, as the regulatory process for biogas plants in South Africa is still not streamlined, it is difficult to predict the exact legislative requirements for the business. It is therefore highly advised to consult an environmental legislation specialist in order to ensure full compliance with the South African law.

TABLE 32 MINIMUM EXPECTED REQUIRED LICENSES

Legislation	License	Assessment Type	Minimum Timeframe
National Environmental Management: Waste Act NEM:WA	Waste Management License (WML)	BA	8 months
National Environmental Management: Air Quality Act	Air Emissions License (AEL)	BA	8 months
National Environmental Management Act (Activity 28)	Environmental Authorization (NEMA)	BA	8 months
National Water Act 36	Water Use License (WULA)	No information	26 months (estimation, see minutes Johann van Niekerk)
Electricity Regulation Act (ERA)	Electricity Generation License	No information	24 months (estimation)

Before the WML, AEL and WUL can be granted, it will typically be required to conduct specialist studies such as ground water pump tests and microbiological tests on the slurry. These specialist studies will aid the respective authorities in assessing the impact that the biogas facility will have on the environment. The extra time needed for the specialist studies will be estimated at 2 months and this has been included in the timeframes presented in Table 32. It should however be noted that no data was available to validate this estimation.

Activities:

- *Apply for licenses:*
    - *Waste Management License (WML)*
    - *Atmospheric Emissions License (AEL)*
    - *Water Use License (WUL)*
    - *Environmental Authorization (NEMA)*
    - *Electricity Generation License*

14.3 Contracts & Agreements

Part of the implementation of the biogas business that has been described in the presented report consists of obtaining contracts and agreements with relevant stakeholders. This process will be described in this section (excluding contracts relating to the members of the project team as described in Section 15.1).

14.3.1 Biomass Suppliers

Once the feasibility study has been validated, the company should approach the selected biomass suppliers and start contracting them.

14.3.2 Private Off-taker

Once the interested biomass suppliers (and thereby the electricity generation potential) have been determined, the company is formally registered, business plan is finalized and the project team has been appointed, the company can start approaching potential off-takers. It is recommended to seek companies that fit the profile given in Section 10.1. This can already be done before the aforementioned steps are finished and the company could consider using the help of university students for this. Nonetheless, it is not advised to approach potential off-takers before finalizing the mentioned steps.

As soon as an interested off-taker has been found, the company can start working towards a Power Purchase Agreement (PPA). It should however be expected that the finalization of this agreement will most likely not happen until a much later stage due to the many fundamental uncertainties that will still be present at this point (e.g. funding, licensing), making it unlikely that the off-taker will sign an agreement.

14.3.3 Municipality

As mentioned in Chapter 10, the company should establish a connection and use-of-system agreement with the municipality in which the biogas plant is situated and a use-of-system agreement with the municipality in which the off-taker is located. The time that it will take to reach such agreements will strongly depend on the municipalities and as there is no data available on the time that it will take to obtain such a license, it will be estimated at a default value of 2 years, with the expectation that it will at least be obtained within that time frame.

14.3.4 Eskom

The company should have obtained a license from NERSA including wheeling approval and (connection and) use-of-system agreements with the relevant municipalities before applying for a generation and distribution agreement with Eskom (Eskom, 2012). As such it will also be necessary to have found the private off-taker at this point, since that will determine the municipality into which the electricity will be wheeled.

As there is no data available on the time that it will take to obtain such a license, it will be estimated at a default value of 2 years, with the expectation that it will at least be obtained within that time frame.

Activities:

- *Find interested private off-taker*
- *Contract private off-taker*
- *Determine interested biomass suppliers*
- *Contract biomass suppliers*
- *Connection & use-of-system agreement with the municipality in which the biogas plant is located*
- *Use-of-system agreement with the municipality in which the off-taker is located*
- *Set up generation & distribution agreement with Eskom*

14.4 Funding

Before entering into contracts with the biomass suppliers or negotiating with a prospective private off-taker, the company should contact the financial institutions at which it intends to apply for funding as these institutions often have requirements related to these contracts. As an example, the requirements of the IDC can be found in Annex B.

It is advised to at least finish the activities listed in Section 15.1, contract the biomass suppliers, find a committed private off-taker, and initiate the licensing process before applying for funding. The reason for this is that although the specific requirements might differ per financial institution, they will all require a degree of security that the project will be executed successfully and that the project will be viable. This security can be provided to a large extent by completing the aforementioned steps.

Once the application has been handed in, typically a process of back-and-forth communication with the institution will follow in order to reach a funding agreement. In the case of the Bio2Watt plant in Bronkhorstspruit and the IDC, this took 11 months (see minutes IDC in Annex B).

In any case, funding applications should be handed in before commencing construction as financial institutions will not give refunds for costs made before the application.

Activities:

- *Enquire about application requirements at financial institutions*
- *Apply for funding*
- *Reach agreement(s) with financial institution(s)*

14.5 Design & Construction

As soon as the project team has been assembled, the contractor specialized in biogas technology can start designing the biogas plant. As these kinds of companies are experienced in this, it is expected to take 2 months.

Construction can start as soon as the application(s) for funding have been handed in and building permits have been acquired. Furthermore, it is highly advised to not start construction before there is reasonable certainty that the required licenses will be granted.

The construction period will be estimated at one year.

Activities:

- *Design the biogas plant*
- *Construct the biogas plant*

14.6 Start-up

Once the plant is commissioned, it is advised to hire the contractor to operate the plant for the first one or two years. During this time, the company can train her own employees to take over.

It is advised to hire the contractor who built the plant to take care of maintenance during the first 3-5 years of operation.

Activities:

- *Operation by contractor*
- *Operation by company*
- *Maintenance by contractor*

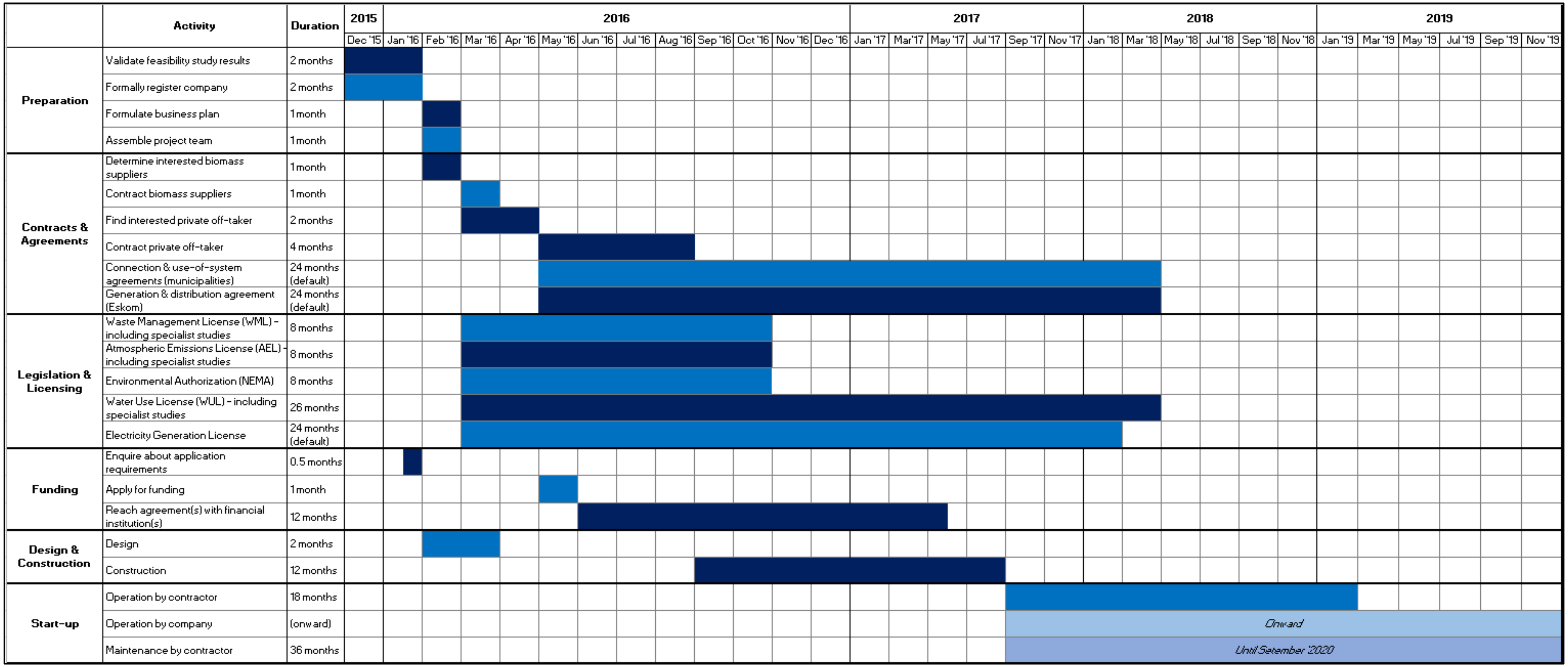


FIGURE 6: IMPLEMENTATION ROADMAP.

Annex A — Stakeholder Analysis

This chapter provides an insight in the general stakeholder analysis executed by team 1. The main goal of the stakeholder analysis is to develop a fruitful cooperation between the project team and the stakeholders. Moreover, varying perspectives from all sectors and elements from the community affected are identified, unforeseen risks are exposed, and the credibility of the future business is increased. To start, the stakeholders involved in one way or another are identified. Moreover, the stakeholders are categorized on base of their relevance in the course of project. The most important aspects of the relevant stakeholders and the nature of their interrelations are discussed in more detail at the end of this section.

A.1 Identifying Stakeholders

The aim of the first step of the stakeholder analysis is to identify stakeholders that are (potentially) involved in one way or another in the project. In doing so, several methods are applied, namely: brainstorming, online research, and consulting organizations and individuals met during the project. Identifying stakeholders is a dynamic process, which means that stakeholders can be added or removed from the list in the course of the project.

A.2 Categorizing Stakeholders

Once the stakeholders are identified, the following characteristic features of the stakeholders are determined:

- Core Activities
- Partnerships

Moreover, the stakeholders are categorized on the base of the nature of their relevance in the project. The team distinguishes between:

- External Stakeholders:
    - Biomass Suppliers
    - Contractors
    - Customers
    - Governments & regulators
    - Financial Institutions
    - Network and Consultancy Services
- Internal Stakeholders

In Table 33 an overview, in alphabetical order, of the identified stakeholders, whether they are relevant or not and the category they belong to can be found. Moreover, per stakeholder a more in-depth description of the characteristic features is given together with the status quo on the activities (to be) undertaken in the stakeholder analysis.

TABLE 33: OVERVIEW OF THE STAKEHOLDERS AND THE CATEGORY THEY BELONG TO.

#	Stakeholder	Category
1	AFASA	Networks & Consultancies
2	African Clean Energy Developments (ACED)	Networks & Consultancy Services
3	AGAMA BiogasPro	Networks & Consultancies
4	Agri SA	Networks & Consultancies
5	Agricultural Research Council (ARC)	Networks & Consultancy Services
6	Along Environtechnology – Mr. K. Guo	Contractors
7	ARC Biomass Suppliers	Biomass Suppliers
8	B. Frederiks MSc. - Supervisor (Technical)	Internal Stakeholders
9	Berks Engineering	Contractors
10	Bertha Foundation	Financial Institution
11	Bio2Watt Pty Ltd	Networks & Consultancy Services
12	BiogasSA	Contractor
13	BioPower – Mr. F. Ciliers	Networks & Consultancies
14	BOTALA Energy Solutions – Mr. P. Steyn	Networks & Consultancies
15	Brookfields Beef Pty Ltd	Biomass Supplier

16	Chicken Layer Devon	Biomass Supplier
17	Clean Energy Africa	Financial Institution
18	Cooperative Atteridgeville	Networks & Consultancy Services
19	Council for Scientific and Industrial Research (CSIR)	Network & Consultancy Services
20	Cova Advisory - Mr. T. Chipfupa	Networks & Consultancy Services
21	Department of Agriculture, Forestry and Fisheries (DAFF)	Government & Regulators
22	Department of Energy (DoE)	Government & Regulators
23	Department of Environmental Affairs (DEA)	Government & Regulators
24	Department of Minerals and Energy (DME)	Governments & Regulators
25	Department of Trade and Industry (DTI)	Government & Regulators
26	Development Bank of Southern Africa (DBSA)	Financial Institution
27	Devon Meat Wholesalers - Mr. Gerrit	Biomass Supplier
28	Dr. O. Kroesen - Supervisor (Socio-Cultural)	Internal Stakeholders
29	Dresser-Rand	Contractor
30	E. Roberts – Team member 1	Internal Stakeholders
31	E^2 - Social Entrepreneurship	Financial Institution
32	Electricity Supply Commission (ESKOM)	Customer
33	ENER-G Systems	Contractor

34	Energy and Environment Partnership (EEP)	Financial Institution
35	ENSafrica	Contractor
36	EnviroServ	Contractor
37	Geselleschaft für International Zusammenarabeit (GIZ) - Mrs. S. Giljova	Networks & Consultancy Services
38	Grain SA	Networks & Consultancies
39	Industrial Development Corporation (IDC)	Financial Institution
40	Innovation Hub	Networks & Consultancy Services
41	Innovative Development Solutions (IDS) Foundation	Financial Institution
42	Institute for Research in Waste and Resources Management (I-WARM)	Networks & Consultancy Services
43	Institute for Soil, Climate and Water (ISCW)	Networks & Consultancy Services
44	International Energy Agency (IEA)	Networks & Consultancy Services
45	Johannesburg Water SOC Ltd (JW)	Networks & Consultancy Services
46	Karan Beef	Biomass Supplier
47	Kruger Feedlot	Biomass Suppliers
48	L. Rijvers BSc. - Teammember Team 1	Internal Stakeholders
49	Leandra Abattoir – Mr. K. Louw	Biomass Suppliers
50	Lesedi	Contractor
51	Leslie Abattoir	Biomass Supplier

52	Michiel and Onno - Predecessors	Networks & Consultancy Services
53	Morgan Beef Feedlot	Biomass Suppliers
54	Morgan Beef/ Abattoir	Networks & Consultancy Services
55	Mr. A Hattingh – Piggery Farmer	Biomass Suppliers
56	Mr. Abdul - Neighbouring Farmer	Biomass Supplier
57	Mr. B. Smut – Farmer	Biomass Suppliers
58	Mr. D. Bruinsma	Networks & Consultancies
59	Mr. J. van Niekerk - Consultant Legislation	Networks & Consultancy Services
60	Mr. Kabelo - Employee Chicken Chain Farm	Internal Stakeholders
61	Mr. Meyer – Dairy Farmer	Biomass Suppliers
62	Mr. Napo– Consultant Chicken Chain Farm	Networks & Consultancies
63	Mr. R. Tsele – Neighbouring Farmer	Biomass Suppliers
64	Mr. Twala - Neighbouring Farmer	Biomass Supplier
65	Mr. X - Employee Chicken Chain Farm	Internal Stakeholders
66	Mrs. L. Marie van Zyl – Consultant on Legislation	Networks & Consultancies
67	Mrs. Mampe - Neighbouring Farmer	Biomass Supplier
68	Mrs. N. Mofokeng - Consultant Funding	Networks & Consultancy Services
69	Municipality of Devon	Government & Regulators

70	NAFU	Network & Consultancy Services
71	National Biogas Platform	Networks & Consultancy Services
72	National Energy Regulator of South Africa (NERSA)	Government & Regulators
73	National Research Foundation (NRF)	Networks & Consultancy Services
74	Nissan	Customers
75	Nova Institute	Networks & Consultancy Services
76	Prison of Devon	Biomass Suppliers
77	Prof. T.A. Mofokeng - Project Owner	Internal Stakeholders
78	R. Goemans – Team member Team 1	Internal Stakeholders
79	Re-energise Africa	Contractor
80	Renen Renewable Energy Solutions	Networks & Consultancy Services
81	Rossgro - Mr. L. Smalle	Biomass Supplier
82	SASOL	Network & Consultancy Services
83	Sewage Treatment Installation Devon	Biomass Supplier
84	South African Bureau of Standards (SABS)	Contractor
85	South African Development Community (SADC)	Networks & Consultancy Services
86	South African Local Government Association (SALGA)	Networks & Consultancy Services
87	South African National Energy Development Institute (SANEDI)	Networks & Consultancy Services

88	South African Waste Information System (SAWIC)	Government & Regulators
89	South African Weather Services	Networks & Consultancies
90	Southern African Biogas Industry Association (SABIA)	Networks & Consultancy Services
91	Sunshine Chicken Abattoir	Biomass Supplier
92	TBR Consulting	Networks & Consultancies
93	Team 2	Internal Stakeholders
94	University of South Africa - Prof. Dr. M. Myer	Networks & Consultancy Services
95	XERGI	Contractor

A.3 Internal Stakeholders

A more detailed description of the background of the stakeholders and their role in the project can be found in the chapter *Project Organization*. The other internal stakeholders are elaborated on below.

- **B. Frederiks MSc. – Supervisor (Technical)**
- **Dr. O Kroesen – Supervisor (Socio-Cultural)**
- **E. Roberts – (Team member) Team 1**
- **L. Rijvers BSc. – (Team member) Team 1**
- **Prof. T.A. Mofokeng (Project Owner)**
- **R. Goemans BSc. – Team member Team 1**
- **Team 2**

Mr. Kabelo - Employee Chicken Chain Farm

Kabelo works at Takatso's farm and manages the cattle. He also feeds the prototype digester on daily basis. His relevance is to show as the project progresses, but he can provide insightful cultural information.

Mr. X - Employee Chicken Chain Farm

Mr. X works at Takatso's farm and manages the cattle. He also feeds the prototype digester on daily basis. His relevance is to show as the project progresses, but he can provide insightful cultural information.

A.4 External Stakeholders

A.4.1 Biomass Suppliers

ARC Biomass Suppliers

Takatso, the project owner, discounted the biomass suppliers provided by the ARC.

Brookfields Beef Pty Ltd

The company is located in Springs, 43 kilometres from Devon. Hence, the supply of biomass by this company will not be cost effective and the company is left out of consideration as potential biomass supplier.

Chicken Layer Devon

The chicken layer farm in Devon, located next to the sewage treatment installation, is a small-scale farm that owns six poultry runs. The chicken dung from two of these poultry runs is used as fertilizer for the vegetables that grow nearby the farm. The chicken dung from the other four poultry runs can be used as feedstock for the biogas system. Hence, the farm is a potential biomass Supplier.

Status quo:

Date	Action
25-8-2015	Meeting at the facility. Minutes were created.

Devon Meat Wholesalers; Abattoir Devon – Mr. Gerrit

The Abattoir in Devon is the nearest abattoir to the Chicken Chain Farm. On average 6000 cattle and 2000 lambs are slaughtered each month. Currently, the offal; blood, water, and intestines, is an undesirable by-product. This opens up opportunities for the use of the offal as feedstock for the biogas system. In other words, the Abattoir in Devon is a potential biomass supplier

Status quo:

Date	Action
21-8-2015	Meeting at the facility. Minutes were created.
10-11-2015	Follow-up meeting. Minutes were created.

Karan Beef

Karan Beef is among the largest suppliers of beef and beef products in South Africa. Their feedlot accommodates 120.000 head of cattle, making it the largest in South Africa, which makes the company a biomass supplier. However, the feedlot is located 76 kilometers from Devon. Moreover, the company has advanced plans for a biogas plant. Hence, they have no significant role in the project.

Mr. Twala - Neighbouring farmer

Twala is a neighbouring farmer of the Chicken Chain Farm. The livestock farm owns approximately 30 cattle for the production of meat. The cattle dung can be used for the production of biogas, which makes Twala a potential biomass supplier

Status quo:

Date	Action
21-8-2015	Meeting at the facility. Minutes created.

Mr. Abdul - Neighbouring farmer

Abdul is a neighbouring farmer of the Chicken Chain Farm. The cattle dung can be used for the production of biogas. Hence, Abdul is a potential biomass supplier

Status quo:

Date	Action
16-9-2015	Meeting at the facility. Minutes were created.

Mrs. Mampe - Neighboring farmer

Mampe is a neighbouring peasant woman. Her farm is located in Devon, 14 kilometres from the Chicken Chain farm. Together with her daughter she runs the farm on which currently 84 pigs, 10 cows and 130 sheep are kept. In the future, end 2015, the number of livestock will grow up to approximately 170 pigs, 1500 piglets, 130 sheep and 50 cows. As the manure is currently collected in a dam, the farm is a potential biomass supplier. Hereby, it should be noted that the farm is looking into the realization of their own biodigester. The energy output of this biodigester should then be used for a heating system for the new-born piglets and to supply the electricity and gas demand of the farm.

Status quo:

Date	Action
16-9-2015	Meeting at the facility. Minutes were created.

Prison Devon

The Devon prison has approximately 250 inmates (Oct 2015). The food waste is given to a farmer as pig feed. The waste is processed by two separate sewage plants.

Status quo:

Date	Action
25-10-2015	Meeting at the facility. Minutes were created.

Rossgro – Mr. L. Smalle

Rossgro is a family owned business which is specialized in the poultry industry of South Africa. The company is active in Mpumalanga, Gauteng and Limpopo. Their core business include egg production, layer hen rearing, broiler production, and specialized animals feed products (Rossgro, n.d.). Annually the company produces about 5000 tons of chicken manure. Half of this quantity is sold as compost, whereas the other half is used as high quality cattle feed. Despite the fact that the chicken manure is currently not used as feedstock for a biogas system and the reservations of the company regarding biogas, opportunities to use the chicken manure as future might arise in the future. Hence, Rossgro is a potential biomass supplier.

Status quo:

Date	Action
2-9-2015	Meeting at the facility. Minutes were created.

Sewage Treatment Installation Devon

The sewage treatment installation in Devon, located next to the chicken layer, collects the waste-water from the township of Devon. The waste-water is subsequently cleaned by means of various steps. In the final step, the water, which now only contains organic impurities, is collected in four drying basins. The organic waste that remains in the basins is then burned., The organic waste can be used as feedstock for a biogas system, what makes the sewage treatment installation a potential biomass supplier. However, there is no data available on the amount and quality of the feedstock available, which turns the Sewage Treatment Installation Devon into a high-risk supplier.

Status quo:

Date	Action
26-08-2015	Meeting at the facility. Minutes were created.
24-10-2015	Meeting at the facility. Minutes were created.

Sunshine Chicken Abattoir

The Sunshine Chicken Abattoir located in Delmas is in the chicken slaughtering industry and therefore a potential biomass supplier.

A.4.2 Customers

Electricity Supply Commission (Eskom)

The South African Electricity Supply Commission, henceforth denoted as Eskom, is the largest South African electricity public utility. Their core business is electricity generation, transmission, trading and distribution (Eskom, Company Information, n.d.). Hence, the company is assigned to the category of customers. Due to their dominant position, they are involved, in one way or another, in almost every transaction on the electricity fet. Eskom's partnerships include partnerships with (Eskom, Defining material items in partnership with stakeholders, n.d.): *National Energy Regulator South Africa (NERSA)*, *Department of Trade and Industry (DTI)*, *World Bank*, and *Water and Environmental Affairs.*

Status quo:

Date	Action
27-10-2015	Contacted via email. No response so far..

A.4.3 Contractors

BiogasSA

BiogasSA is a company, which provides biogas solutions for rural and domestic applications, but has also been contracted to produce a commercial biogas plant (0,4 MW) at the Morgan Abattoir in Springs. The company is also a co-founder of the SABIA, whose first chairman Mark Tiepelt is also the managing director of BiogasSA. The company poses to be relevant for this project as a case study for commercial biogas systems of which technical data can be extracted also.

Partners include*: SABIA, Schumann Tank & Stahlbau GmbH, Xergi, Wieferink.* (BiogasSA).

Status quo:

Date	Action
19-10-2015	Meeting with CEO Mark Tiepelt at SAIREC. Minutes were created.

Dresser-Rand

Dresser-Rand produces rotating equipment solutions such as compressors and turbines. The company can be viewed as a contractor for biogas applications. It also has provided the company WEC, with co-generation motors for their biogas facility at the Johannesburg Waterworks.

ENSafrica

ENSafrica is one of South Africa's biggest law firms, which partnered with Bio2Watt in one of their biogas plants. ENSafrica could be a relevant partner in this project. *Bio2Watt* (ENSafrica).

Status quo:

Date	Action
21-10-2015	Contacted via Email. No answer.

ENER-G Systems
ENER-G systems provides business with energy services and sustainable technologies to help them generate, buy and manage their energy. In the field of anaerobic digestion the company manages projects from conception through feasibility to construction and final completion. Hence, the company might be contacted for advice on managing the realization of the biogas business. Moreover, the company offers multiple funding options (ENER-G, n.d.).

Status quo:

Date	Action
21-10-2015	Contacted via Email. No answer.

EnviroServ
EnviroServ specializes in waste management specifically collection, treatment, and disposal. EnviroServ's treatment technologies can be beneficial to a biogas application in this project. (EviroServ).

Status quo:

Date	Action
21-10-2015	Contacted via Email. Contact: Kevin Guo. Provided valuable information regarding cost estimations.

Lesedi
Lesedi is an engineering, procurement and construction company. The company has experience in the execution of turnkey engineering projects operating in the South African Power Industry (Lesedi, n.d.). The Lesedi Biogas Project (LBP) planned to build the largest open-air feedlot manure-to-power plant at the Karan Beef feedlot in Heidelberg South Africa. No information can be found on the current status of the project. For the rest, there are no knows biogas project in which the company is involved in. Hence, the company is not taken into consideration any further.

Re-energise Africa
Re-energise is a South African company focusing on the bioenergy, energy efficiency, and recycling sectors. Their expertise lies in gas treatment, a crucial process when it comes to biogas systems. (Re-Energise).

Status quo:

Date	Action
21-10-2015	Contacted via Email. Answer from Tarik Höppener. "Scale of this plant is too small for the company."

South African Bureau of Standards (SABS)
The South African Bureau of Standards (SABS) is a business services provider for management system certification, product testing and certification, and standardization. The business could pose to be relevant towards the project completion phase. (SABS).

XERGI
The company XERGI designs and builds biogas plants. It also supports in operation and maintenance but still functions as a contractor and not the owner of plants. The company has experience all over Europe and has now been contracted by the company BiogasSA to support in the design of a biogas system for Morgan Abattoir. It's activities are limited in relevancy, but can function as a good external source if information. Partners Include: *BiogasSA* (Xergi).

A.4.5 Financial Institutions

Bertha Foundation
The Bertha African Social Enterprise (BASE) fund provides capital for launching and scaling businesses that have the potential to affect widespread (environmental) impact" (Foundation, n.d.). The foundation has invested in the Bio2Watt holding and may play a significant role in the financing of the biogas business.

Clean Energy Africa
Clean Energy Africa is an investment firm developing and investing in alternative energy opportunities, and thus a financial Institution. They provide equity funding to invest in new projects, and possibly in the farm's biogas business project.

Development Bank of Southern Africa (DBSA)
The Development Bank of Southern Africa, also known as the DBSA, is a state owned entity with "the purpose of accelerating sustainable socio-economic development and improve the quality life of life of the people of the Southern African Development Community (SADC) by driving financial and non-financial investments in the social and economic infrastructure sectors" ((DBSA), n.d.). The DBSA is a development financial institution that has shown strong commitment to biogas initiatives in the past (Academy, 2013). Therefore, the DBSA can be involved in the project as financial partner. The DBSA's partnerships include partnerships with the *Southern Africa Development Community (SADC)* and the *World Bank.*

E² - Social Entrepreneurship
E² is a philanthropy that provides venture capital financing to business and social entrepreneurial ventures that are likely to have a high impact in alleviating poverty and/or joblessness in South Africa. As a funder E² can be a valuable stakeholder for the success of the business model. (ESquared).

Energy and Environment Partnership (EEP)
The Energy and Environment Partnership (EEP) aims on eradicating poverty thought economically, socially, and environmentally sustainable development. It primarily addresses the challenges of energy poverty, energy security and energy related global and local environmental impacts in an integrated way and from a regional perspective. It functions on a bottom-up approach by providing partial (or co-) financing for projects related to renewable energy sources. The partnership's donors include the Ministry of Foreign Affairs of Finland, the UK Department for International Development, and The Austrian Development Agency. One of the Partnership's success stories includes supporting the company Bio2Watt in its endeavour to construct a commercial biogas plant in Bronkhorstspruit, with an installed capacity of 3,5 MW. It is possible for companies to apply for EEP funding on the partnership's webpage. Possible conditions for funding can be requested as well. Partners include: *Bio2Watt.*

Industrial Development Corporation (IDC)
The Industrial Development Corporation, henceforth denoted as IDC, is a national development finance institution set up to promote economic growth and industrial development ((IDC), about the IDC, n.d.). In doing so they, among others, provide finance for industrial development projects and use their industry expertise to drive growth in priority sectors. As green and energy saving industries are among these priority sectors ((IDC), Sectoral focus areas in line with governement's , n.d.), the IDC is a financial Institution which might be addressed for financial incentives. The IDC's partnerships include partnerships with ((IDC), Partners, n.d.): *Department of Trade and Industry, Economic Development Department*, *Centre for Development and Enterprise*, *National Economic Development and Labor Council*, *Small Enterprise Finance Agency*, *Small Enterprise Development Agency*, and the *National Empowerment Fund.*

Status quo:

Date	Action
27-9-2015	Email sent.
9-11-2015	Meeting. Minutes created

Innovative Development Solutions (IDS) Foundation
The Innovative Development Solutions (IDS)-Foundation was founded to support African organizations that aim at poverty alleviation and sustainable development in rural areas. The foundation fund raises in particular for household biogas applications to enable people to cook on gas instead of wood. Projects have been conducted near Kruger National Park. The Foundation could be of potential benefit to the project as it is knowledgeable on a niche biogas application and is well aware of the social added value and constraints. (IDSFoundation).

A.4.6 Governments & Regulators

Department of Agriculture, Forestry and Fisheries (DAFF)
The Department of Agriculture, Forestry and Fisheries (DAFF) strives to advance food security and agrarian transformation in the agricultural sector through innovative, inclusive and sustainable policies and programs. Relevancy, partners (DAFF, kein Datum). In terms of legislation this government body is relevant for this biogas enterprise.

Department of Energy (DoE)
The Department of Energy's purpose is to regulate and transform the sector for the provision of secure, sustainable and affordable energy. It is in charge of passing relevant acts and legislations, as well as initiating programs and projects for specific energy sources (mostly renewable). It also is the initiator of the national biogas platform, facilitated by the company GIZ. In the case of the project the DoE is relevant for the project to gain knowledge on acts, policies and regulations for the biogas sector and could provide contacts to the national biogas platform and GIZ. Partners include: *GIZ, REN21, SANEDI.* (DoE).

Department of Environmental Affairs (DEA)
The Department of Environmental Affairs (DEA) seeks to facilitate environmental cooperative governance across all spheres of government to provide geographically referenced environmental information for decision-making. The department has branches in climate change and air quality, and chemical and waste management, for which it issues licenses as can be seen in the case of BiogasSA's plant at the Morgan Abattoir in Springs. The department will be relevant when applying for necessary licenses to run a biogas plant. (DEA).

Department of Trade and Industry (DTI)
The Department of Trade and Industry, or DTI, is the part of the South African government which responsibility for the commercial- and industrial policy. Hence, the DTI falls under the category *Government and Regulators*. The DTI group includes various subordinate agencies, which perform specific functions. These agencies are classified in three clusters, namely (Wikipedia, Department of Trade and Industry (South Africa), n.d.):

Finance and small business development agencies

Regulatory Agencies

Specialist services agencies

As the project's aims to develop a commercially viable biogas business, the DTI is in all likelihood involved in the financial issues and the regulations concerning the biogas business.

Status quo:

Date	Action
18-09-2015	Met with former deputy director-general Tumelo Chipfupa to discuss grant possibilities. See minutes

Municipality of Devon
The municipality of Devon must be involved in the wheeling agreement with a potential customer, as they are both buyers and sellers of electricity provided by ESKOM

National Energy Regulator of South Africa (NERSA)
The National Energy Regulator of South Africa, also known as the NERSA, is a regulatory authority who's mandate is to regulate the electricity, piped-gas and petroleum pipelines industries ((NERSA), n.d.). Hence, the NERSA is a *government and regulators* party that will play a role in, among others, issuing the licenses and setting the pertinent conditions with regard to the generation and trading of energy products, including electricity and biogas. Obviously NERSA is involved in numerous partnerships.

A.4.7 Networks & Consultancies

African Clean Energy Developments (ACED)

African Clean Energy Developments henceforth denoted as ACED, is a South African registered company dedicated to the development of renewable energy projects in, among others, South Africa. ACED's renewable energy portfolio comprises mainly wind and solar energy projects. Therefore, their contribution to the project is in all probability limited to share information on the start-up of commercial renewable energy projects. The ACED's partnerships include partnerships with ((ACED), n.d.): *Nedbank* and *Industrial Development Corporation (IDC).*

Agricultural Research Council (ARC)

The Agricultural Research Council (ARC) seeks to develop the agricultural sector by conducting research with partners and developing human capital. The ARC has researched biogas for cooking and lighting applications the quantity of which seems quite low, however. (ARC).

Status quo:

Date	Action
21-10-2015	Contacted Peter Britz via phone and mail. So far no response.
11-11-2015	Met Mr. Britz at NBP meeting and initiated email contact.

Bio2Watt Pty Ltd

The company Bio2Watt Pty Ldt is an industrial-scale biogas waste-to-energy company in South Africa. It currently runs and operates a commercial biogas plant located in Bronkhorstspruit, Gauteng (4MW), powering BMW's Rosslyn production line and is constructing a second plant in Malmesbury, Western Cape (3-4MW). The company can provide added value to the project as a consultant in biogas as well as a case study for biogas companies in South Africa.

Partners include: IDC, Bosch Holdings, Barloworld Power, Norfund, The Bertha Foundation, EEP, ENSafrica. (Bio2Watt, kein Datum).

Status quo:

Date	Action
—	Contacted via mail and phone.

BioPower – Mr. Francois Ciliers

BioPower Corporation and its various solutions are aimed at assisting Government and municipalities in their endeavor to achieve the objectives as set out in the Medium Term Strategic Framework.

Status quo:

Date	Action
—	Contacted via mail and phone.

BOTALA

Botala Energy Solutions is one of the first engineering companies in South Africa providing turnkey biogas plants of all sizes. The head office of the company is located in Johannesburg, South Africa.

Status quo:

Date	Action
16-11-2015	Contacted via mail.

Council for Scientific and Industrial Research (CSIR)

The CSIR is one of the leading scientific and technology research, development and implementation organizations in Africa. Constituted by an Act of Parliament in 1945 as a science council, the CSIR undertakes directed and multidisciplinary research, technological innovation as well as industrial and scientific development to improve the quality of life of the country's people. They are a key researcher of microbial biosciences, knowledge which is crucial in the operation of a biogas digester.

Cova Advisory – Mr. T. Chipfupa

Tumelo is director of Cova Advisory. His current business is to help other businesses with applications to the Department of Trade and Industry (DTI). One of his current clients is the Phulosong Cooperative. In his previous job he worked for the Department of Trade and Industry for about 15 years. His job responsibilities at the DTI comprised allocating grants, financial incentives, and investments. Hence, Tumelo can advise the project team on these topics during the start-up of the biogas business.

Status quo:

Date	Action
18-09-2015	Met with former deputy director-general Tumelo Chipfupa (friend of Takatso's) to discuss grant possibilities. See minutes

Geselleschaft für International Zusammenarabeit (GIZ) – S. Giljova

The "Deutsche Gesellschaft für Internationale Kooperation (GIZ) GmbH" is a company that specialized in international development. It is owned by the German Federal Government. Within South Africa GIZ operates in several sectors, aiding specifically in governance and administration, climate change and energy, and HIV/AIDS, but also runs several bilateral projects in South Africa, and pan-African and regional projects. GIZ's involvements in climate change and energy programs in South Africa include the "South African-German Energy Programme" (SAGEN), the "Climate Support Programme" (CSP) and the "Skills Development for Green Jobs" (SfGJ). Moreover, GIZ has been contracted by the Department by the Department of Energy to facilitate and coordinate the National Biogas Platform of South Africa. Hence, GIZ is crucial in the information gathering process on legislation and the biogas industry in its entirety in South Africa (GIZ, 2013). The partners of GIZ include: *Department of Energy (DoE)*, *Department of Environmental Affairs (DEA)*, *National Energy Regulator South Africa (NERSA)*, *Department of Trade and Industry (DTI)*, *Research institutions, e.g. South African National Energy Development Institute (SANEDI), Financing institutions, e.g. Industrial Development Corporation (IDC), Local governments, e.g. South African Local Government Association (SALGA).*

Status quo:

Date	Action
14-09-2015	Met with Sofja Giljova. Minutes created.

Innovation Hub
The Innovation Hub is a science and technology park located in Tshwane established by the Gauteng Provincial Government through its Department of Economic Development (DED). The Innovations Hub's mission is to promote the socio-economic development and competitiveness of Gauteng through innovation (Africa, n.d.). The so-called *Green and sustainable development* project, one of the innovation programs of the Innovation Hub's programs stimulates and supports R&D commercialization and innovations in priority sectors of the green economy, to be incorporated into the Gauteng economy. Moreover, the *Climate Innovation Centre* supports innovation by offering a full suite of financing and capacity building services (Hub, n.d.). Hence, the Innovation Hub might assist the team to guide and support the farms journey towards the biogas business. The Innovation Hub is involved in partnerships with, among others: *Council for Scientific and Industrial Research (CSIR)*, *South African Bureau of Standards (SABS)*, *The National Research Foundation (NRF)* and the *Agricultural Research Council (ARC).*

Status quo:

Date	Action
27-10-2015	Received outline.

Institute for Research in Waste and Resources Management (I-WARM)
The establishment of an Institute for research in Waste and Resources Management (I-WARM) is currently only a plan. Hence, this stakeholders is in the course of the project not taken into account.

Institute for Soil, Climate and Water (ISCW)
The institute for Soil, Climate and Water, henceforth denoted as ISCW, is one of the ten Agricultural Research Council institutes. The national research mandate of the ISCW is to promote the sustainable use and management of the agricultural natural resources soil, climate and water. In doing so, knowledge is generated on agricultural natural resources and agro-ecosystems. In addition, the research is applied in the form of innovative technology development and technology transfer. In the context of the project, this R&D institute can be contacted for their expertise and information on the national resources ((SASSCAL), n.d.).

International Energy Agency (IEA)
The IEA is an autonomous organization that seeks to ensure reliable, affordable and clean energy for its 29 member countries and also non-member countries. They do so by focusing on energy security, economic development, environmental awareness and engagement worldwide. Even though South Africa is not a member of the IEA, the IEA also works with non-member countries on jointly holding topical workshops, cooperating on surveys, holding training activities and helping experts and organizations join the IEA network.

South Africa is participant of the Energy Technology Initiatives (ETI), which is an independent group of experts, enabled by the IEA.

Johannesburg Water SOC Ltd (JW)
Johannesburg is an independent company that provides water and sanitation services to the residents of Johannesburg. The City of Johannesburg is its sole shareholder (Water, n.d.). They're biogas installation is operated by WEC.

Status quo:

Date	Action
28-09-2015	Meeting with WEC representative Jason Giford. Minutes were created.

Mr. J. van Niekerk – Consultant Legislation
Johann van Niekerk has more than 17 year experience in legislation in the field of feedlots, biogas, animals waste and abattoirs. For this reason he can be consulted on the legislation regarding starting a biogas business. Johann was involved in the biogas plants of Morgan Abattoir and Karan Beef in the role of main consultant.

Status quo:

Date	Action
18-09-2015	Meeting. Minutes were created.

Mrs. Louise-Marie van Zyl
Mrs. Louise-Marie van Zyl is the managing director and principal consultant at Cape EAPrac - Environmental Assessment Practitioners. She is also actively involved in the National Biogas Platform.

Status quo:

Date	Action
7-10-2015	Meeting. Minutes created.
16-10-2015	Email contact.

Mr. Napol – Consultant
Mr. Napol, is the owner of a small scale airplane company providing flight services in southern Africa. Used to work for Toyota, and has contacts with Nissan. He advises Takatso Mofokeng on marketing matters.

Status quo:

Date	Action
09-2015	Received call. Agreement to talk again after Oct 14.
10-2015	Contacted. Agreed to meet after Nov 6.
14-11-2015	Meeting. No minutes yet (18-11-2015)

Mrs. N. Mofokeng – Consultant Funding
Nqobile Mofokeng is the wife of one of the three sons of prof. T.A. Mofokeng. She has fulfilled several financial job roles at, among others, KPMG, SAB and BP. Due to her financial expertise she is involved in the fundraising for the project.

Status quo:

Date	Action
17-09-2015	Meeting. Minutes were created.

National Research Foundation (NRF)

The National Research Foundation, or NRF, is an intermediary agency between the policies and strategies of the Government of South Africa and South Africa's research institution. Only a small portion of the NRF's activities is allocated to research, whereas a larger portion of their activities is allocated to funding of academic research. As this stakeholder cannot directly contribute to the successful completion of the project, it is not taken into account in the course of the project.

NOVA Institute

The NOVA institute is an non-profit company based in South Africa. NOVA develops and promotes solutions for low-income households in South Africa. By doing so, they aim to improve the quality of life of households. NOVA has been involved in several small-scale biogas projects. The financing of these projects is partially covered by selling so-called Voluntary Emission Reductions (VERs), also known as Carbon Credits. NOVA can provide the team with their expertise and information this method of financing (NOVA, NOVA institute, n.d.). The NOVA institute has partnerships with:*The Department of Environmental Affairs and Tourism (DEAT)*, *The Council for Scientific and Industrial Research (CSIR)*, *Carbon Trading Organizations*, *The University of Pretoria*, *The Department of Minerals and Energy (DME).*

Status quo:

Date	Action
10-09-2015	Meeting. Minutes were created.

Phulosong Cooperative Atteridgeville

The Phulosong Cooperative is a cooperative of 13, mostly unemployed, members with diverse backgrounds. The cooperation is involved in diverse activities, for instance cleaning the Zoo and sewing by the women. Moreover, they are currently exploring the possibility to start-up a biogas system at the local sewage treatment facility in order to provide low-cost electricity and in increased capacity to compensate for Eskom's load shedding. Given the overlap of this initiative and the project of the Chicken Chain farm, sharing knowledge and social resources can be beneficial for both parties.

Status quo:

Date	Action
22-08-2015	Meeting. Minutes were created.

Renen Renewable Energy Solutions

Renen is a company specialized in renewable energy solutions. Their products include solar PV, anaerobic domestic biogas digesters, generators, and solar collectors. Moreover, the company offers services like feasibility studies and project management. Hence, the company might be consulted for their view on, the feasibility of, the project (Renen, n.d.). Renen's partnerships include partnerships with: *AGAMA Energy* and *Development Bank of Southern Africa (DBSA).*

Morgan Abattoir

The Morgan Abattoir is an abattoir as a part of the Morgan Group, which has ventured into biogas. They currently have a biogas installation, which in the future will be able supply the abattoir with a baseload of 100kW of electricity. The lessons learned from the company can be applied in this project.

Status quo:

Date	Action
09-09-2015	Meeting. Minutes were created.
17-11-2015	Meeting. Minutes were created.

National Biogas Platform

The National Biogas Platform (NBP) was established as a key resolution of the 2013 National Biogas Conference. It is a collaboration between the public and private sectors and is facilitated and coordinated by the company GIZ. The platform aims to address the lessons learned from existing biogas projects, assess current and future regulatory requirements and reveal and bundle the financing options for the biogas projects. The NBP is an important stakeholder for developing business models for this biogas business as it unifies all required information for it.

Partners include: governmental departments (DOE, DEA, NERSA, the DTI), industries, ESOM, research (universities, SANEDI), financing institutions (DBSA, IDC, banks, donors), provinces and local government (SALGA, provincial authorities, municipal representatives). (BNP).

Status quo:

Date	Action
11-11-2015	Attended Platform meeting

Michiel and Onno – Predecessors

Michiel and Onno designed and constructed the present prototype at Takatso's farm. Their handwritten notes are currently at the farm and they could share information on the process and reasoning behind the current design.

Southern African Biogas Industry Association (SABIA)

The Southern African Biogas Industry Association, henceforth denoted as SABIA, is a network that represents the interest of the members of the biogas industry in South Africa. Over thirty parties from the biogas industry are member of SABIA ((SABIA), n.d.), including *Bio2Watt* and *BiogasSA.*

Status quo:

Date	Action
19-10-2015	Meeting with CEO Mark Tiepelt at SAIREC. Minutes were created.
—	Contacted via email

South African Development Community (SADC)
The South African Development Community, or SADC, is a regional economic community comprising 15 member states including South Africa. Its goal is to further socio-economic cooperation and integration and integration as well as political and security cooperation among its member states (Wikipedia, Southern African Development Community, n.d.). Is it expected that the SADC will not, directly, be involved in the project.

South African Local Government Association (SALGA)
The South African Local Government Association, or SALGA, is an autonomous association of 278 South African municipalities. This makes SALGA the voice and sole representative of the local governments. A joint program between SALGA and GIZ was established with the aim to support municipalities in assessing their biogas potential in their waste-water treatment (Association S. A., n.d.). This study might be used to reflect upon the feasibility study of the project.

South African National Energy Development Institute (SANEDI)
SANEDI is the acronym for the South African National Energy Development Institute. This R&D institute is a stated owned entity who's main function is to direct, monitor and conduct applied energy research and development, demonstration and deployment as well to undertake specific measures to promote the uptake of Green Energy and Energy Efficiency in South Africa ((SANEDI), n.d.). A typical embodiment is the Sustainable Energy Finance Tool. With this Tool potential financiers of the project can be identified.

South African Waste Information Centre (SAWIC)
The South African Waste Information Centre, also known as SAWIC, is developed by the Department of Environmental Affairs (DEA). Hence, SAWIC falls under the category *Government and Regulators.* SAWIC provides the public, business, industry and government with access and information on the management of waste in South Africa. Moreover, they provide users with access to the South African Waste Information System (SAWIS). The system is used by the government and industry to capture routine data on the tonnages of waste generated, recycles and disposed of in South Africa on monthly and annual basis ((DEA), n.d.). In the context of the project this information can be used to identify potential feedstock sources.

University of South Africa - Dr. Martin Myer
Dr. Martin Myer is a senior lecturer at the Department of Life and Consumer Sciences at the University of South Africa. He researches waste-to-energy with particular focus on anaerobic digestion of dairy manure & kitchen waste to produce biogas. In collaboration with the company Bioforsk he engages with rural communities to adopt bio digester technology in their daily living routine. From a technological perspective he presents a great opportunity to retrieve information necessary for the project, as well as from a social and environmental perspective.

Partners include: *Bioforsk, SABIA*)SABIA(.

Status quo:

Date	Action
17-09-2015	Meeting. Minutes were created.

Annex B – Minutes

The minutes of the meetings are listed below.

Mr. Abdul

Attendees
Abdul (Farmer)
Evan Roberts (team member)
Len Rijvers (team member)

Location & Time
Devon, 16:30-17:30 , 16-09-2015

Review History

Member	Action
Evan Robberts	R
Len Rijvers	O
Roxanne Goemans	

Symbol	Definition
	Not notified about existence
R	Reviewed, no comments
C	Reviewed, commented
O	Original author

Report

Logistics

- The farm of Abdul is located near Takatso's farm. It takes about 7 minutes to get from Takatso's farm to Abdul by car.

General

- The meeting with Abdul was scheduled at 15:00. When the team arrived at the farm Abdul was not present. A relative called Abdul and the meeting was rescheduled to 16:30. When they returned to the farm at 16:30 they had to wait for another 25 minutes.
- The manure at the farm is collected on used, partially, on the land.
- Only organic compost is used at the farm.
- Abdul hadn't heard of biogas before Michiel and Onno came to South Africa. He knows the working principle of a biogas digester.
- According to Abdul he has two silos, located near border of his property, which can be used as biogas digester.
- Abdul's son is responsible for the "logistics" of the farm. A "large" fuel tank was located on the farm during the visit of the team to the farm.

Feedstock

- On average the farmer keeps 183 cows for breeding. During the year this number fluctuates between a minimum number of 170 cows and a maximum number of 200 cows.
- Next to cows the Abdul also keeps sheep for breeding. On average there are 350 sheep at the farm. Two months a year this number increases up to 1300. After these two months the sheep are sold and slaughtered.

Chicken Layer Devon

Attendees

Takatso Mofokeng (project owner)
Roxanne Goemans (team member)
Evan Roberts (team member)
Len Rijvers (team member)

Location & Time

Devon, 14:00-15:00, 25-08-2015

Review History

Member	Action
Evan Roberts	R
Len Rijvers	O
Roxanne Goemans	

Symbol	Definition
	Not notified about existence
R	Reviewed, no comments
C	Reviewed, commented
O	Original author

Report

Logistics

- It took the team around 17,5 minutes, by car, to get from the farm to the chicken abattoir.
- Location coordinates farm: 26°20’57” S , 28°44’37” E.
- 14 km; 15 minutes according to google maps.

General

- Solar cells near the chicken abattoir, approximately 5 m², were stolen on the same day they were installed.

Feedstock

- The chicken abattoir has 6 poultry runs. Two of the poultry runs are occupied with chickens while the remaining four poultry runs are currently empty.
- According to the employees the two occupied poultry runs contain around 2100 chickens. However, a quick calculation by the team results in a number of approximately 1600 chickens.
- In the coming weeks 3500 will arrive at the chicken abattoir and they will be placed in the remaining four poultry runs.
- The chicken dung from the two occupied poultry runs is used as fertilizer for the vegetables that are grown near the abattoir. The chicken dung from the other four poultry runs can be used as feedstock for the biogas system.
- A quick and rough calculation on the amount of chicken dung available as feedstock for the biogas system:
  - Per 800 chicken the area of dung, collected over a period of 5 days is equal to 2x0.6x16x0.6x2.25=2x9.6x1.35≈26m². Moreover, the “height” of the amount of dung is approximately 0.02m. Hence, in total this equals 0.52m³;
  - As the total amount of chicken will be equal to 3500 it follows that the total amount of dung, over a period of 5 days, is equal to $\frac{3500}{800} * 0.52 = 2{,}28$ m³;
  - This corresponds with 0,46 m³ chicken dung per day in total;

Phulosong Cooperative Atteridgeville

Attendees
Takatso Mofokeng (project owner)
Roxanne Goemans (team member)
Evan Roberts (team member)
Len Rijvers (team member)
(about) 11 participants in the project

Location & Time
Atteridgeville, 14:20-16:45 22-08-2015

Review History

Member	Action
Evan Roberts	
Len Rijvers	O
Roxanne Goemans	

Symbol	Definition
	Not notified about existence
R	Reviewed, no comments
C	Reviewed, commented
O	Original author

Report

<u>Chronology</u>

- Arrival of all the participants (14:10-14:20)
- Prayer (14:20-14:25)
- Substantive discussion (14:25-15:45)
- Braai – informal discussion between participants (15:45-16:45)
- Departure (16:45)

<u>Substantive discussion</u>

- Takatso introduces us as students from the Netherlands who are helping him with the realization of a commercial biodigester.
- Takatso introduces Tumelo, the consultant, and describes his view on the role of the consultant in the cooperative; resident consultant who guides the cooperative in the process. The be more specific, the consultant should advise the cooperative what steps to take, which hurdles are present (both technical and political), inform them on incentives and regulations.
- The consultant introduces himself. He has his own company. His current business is to help other businesses with applications, for e.g. grants, to the DTI. In his previous job he worked for the Department of Industry and Trade for fifteen years. At the DTI he was responsible for, among others, grants, financial incentives, and investments. In response to Takatso's view on his role in the cooperative, he needs more information to give advice.
- Takatso asks if more information means: biomass, waste, electricity
- According to Tumelo the level of detail is more like: I want to get a machine with the following dimensions…., that produces…., that I'll sell to…. By doing so, I am going to make…. Since the costs are…I'll earn…
- Tumelo: for a commercial generator you need a license from the National Energy Regulator South Africa.

- Tumelo: ESKOM operates in a similar was a Tender. A company has a certain break-even price for each unit of electricity. The company with the lowest costs gets a contract, e.g. for 20 years, from ESKOM. Once a company gets this contract, it can apply for funds.
- A second scenario is that a company sells its electricity to the municipality, who in turn sells electricity to their residents.
- For both scenarios the steps to take are more-or-less the same, namely:
  1. Write a proposal that complies with the requirements
  2. Take this proposal to the municipality or ESKOM; presentation
  3. GO: apply for grants, financial incentives, and/ or sort alike
     NO-GO:
  4. (continue) design of the system
  5. Construction of the system,
  6. …
- It is possible that there are grants for a feasibility study available.
- In the project of the cooperative: employees have to be trained. The same holds for our project.
- Might be necessary to lend some money from IDC.
- You'll have to protect yourself against people steeling the project plan.
- Evan will receive more information on ESKOM, energy market, commercial project from John via de mail.
- John: Look at the case study: Wind energy program, Case study, African team energy, Coast.

General

- Only one of the in total four women present at the meeting takes notes. The others do not (actively) participate in the meeting.
- Cooperative also participates in cleaning in the Zoo and sewing by the women.
- Overlap between our project and the cooperative project, there might be a possibility to cooperate/ exchange information.

Devon Meat Wholesalers – Mr. Gerrit

Attendees

Takatso Mofokeng (project owner)
Roxanne Goemans (team member)
Evan Roberts (team member)
Len Rijvers (team member)
Gerrit (manager of the abattoir)

Location & Time

Farm Palmietkuil, Devon, 2260, 09:15-10:45 21-08-2015

Review History

Member	Action
Evan Roberts	R
Len Rijvers	O
Roxanne Goemans	

Symbol	Definition
	Not notified about existence
R	Reviewed, no comments
C	Reviewed, commented
O	Original author

Report

<u>Feedstock</u>

- On average 6000 cattle and 2000 lambs are slaughtered each month, which corresponds to 200 respectively 67 each day. With other words, on average 267 animals are slaughtered each day.
- Naturally, these numbers vary throughout the year. In November and December up to 8000 cattle are slaughtered each month, which corresponds to 267 cattle each day[1]. In contrast, the minimal amount of animals being slaughtered each day lies around 150.
- The waste, suitable for use in the biogas digester, consists of blood, water and intestines.
- 50 cattle weigh around 15 tons, so 1 cattle weighs around 300 kilograms. The weight of the meat from 1 cattle ranges between 40-60 kilograms. This implies that the weight of the waste per cattle ranges between 240-260 kilograms. Note that this waste is only partially suitable for the biogas digester.
- On average between 240-300 animals are slaughtered each day.
- 8 to 10 animals provide around 60 kilograms waste [2]
- From these values it follows that the weight of the stomach content ranges between 600-750 kilograms, for the condemned matter it ranges between 300-680 kilograms, so the total weight ranges between 900-1430 kilograms [3].

<u>Logistics</u>

- The distance between the abattoir and Takatso's farm is equal to approximately 3,9 km.
- It might be possible to construct a road between Takatso's farm and the abattoir.
- It took the team 13 minutes to travel, by car, between Takatso's farm and the abattoir.
- Roads get flooded in the Summer.

General

- The abattoir has plans to start a biogas facility. Alternatively, they have plans to compost the waste. The main reason behind these two options is to get rid of the waste.
- The abattoir has two back-up generators, 320 kVA each.
- The territory covers 133 hectares.
- The manager, Gerrit, welcomes us to arrange a follow up meeting.
- The number of employees of the abattoir lies around 70.

Gesellschaft für International Zusammenarabeit (GIZ) - Mrs. S. Giljova

Attendees
Sofja Giljova (Coordinator of the National Biogas Platform)
Roxanne Goemans (team member)
Evan Roberts (team member)

Location & Time
Pretoria, 15:00-16:00, 14-09-2015

Review History

Member	Action
Evan Roberts	O
Len Rijvers	R
Roxanne Goemans	

Symbol	Definition
	Not notified about existence
R	Reviewed, no comments
C	Reviewed, commented
O	Original author

Report

About GIZ and the Platform

- GIZ started out in biogas market development specifically for waste-water treatment applications. These were mainly scoping studies. Afterwards GIZ was asked to facilitate the National Biogas Platform (NBP).
- Members of the Platform include many governmental departments, regulators, companies, and NGOs including the DoE, DoW, DoA, NERSA, UNEDO…
- ESKOM attends meetings, but doesn't play a significant role yet.
- As far as business support goes GIZ preferably supports farmers and not companies.
- GIZ has an "ad hoc" advisor based in Germany, who advises farmers in biogas
- DoE wants GIZ to create a national biogas framework including all licensing and regulation.
- It's easy to join the platform.

Projects

- Grabo (300kW) is currently searching for an off-season option, as feedstock fluctuates.
- Bronkhorstspruit was working on licensing for 7 years in total. The company had an (wheeling-) agreement to sell electricity to BMW. The negotiations with the Tshwane municipality took approximately 2 years.
- Jo'burg waterworks produces ~20% of its own energy demand with an installed capacity of 1MW. They would like to expand, but lack the necessary quantity of feedstock. They have a extraordinary contract with a contractor of 6-7 year in duration. This usually isn't possible as contracts between the municipality and free market are limited to 3 years as a corruption prevention mechanism.
- Durban municipality is currently trying to establish feasible energy solutions in waste-water treatment.
- Green Cape Project: SARETC is developing a curriculum in biogas.
- KwaZulu Natal Project??

REIPPPP – Tending process

- Power allocations for renewable energy sources.
- The process allocated 50MW to biogas, but as the range of eligible projects ranged between 1 and 5 MW in capacity this was not achieved.
- The tending process doesn't synchronize well with the life cycle of a biogas project. The tending process is typically open for approximately half a year whereas the licensing for biogas projects has shown to take up to 7 years.
- SABIA is currently negotiating with the tender program to support the biogas industry.
- REIPPP also takes social factors such as BEE level, local manufacturing, female employment, and allocation of revenue streams to the community into consideration
- The result is a preferred bidder. According to Ms. Giljova one landfill plant has made into the final round gaining status as a preferred bidder, as they had all necessary licenses lined up.
- So far GIZ does not consider the tending procedure a feasible option for biogas systems.

Regular Meetings – Platform Mpheetings

- Regular meetings (12 so far) last one including 44 people.
- Typically one from each department.
- Fist meetings were different – based on presentations by the Working groups listed below.
- Now different as WGs work independently.
- Next meeting is on the 28th of October. We are invited.

Studies

- ARC is conducting a study to analyze the potential for biogas on agro-waste.

Future Work

- Study on biogas potential then job creation potential for South Africa.
    - Biogas potential is ~800 MW.
    - The biogas potential study will focus on wastewater treatment plants for the Dept. of Water Affairs including sizes greater than 50 mega liters.

Working Groups (WGs)

Working Group 1 – Licensing

- Instructed by DoE. Licensing is bureaucratic chaos.
- So far the biggest barrier biogas start-ups face
- There's a report on licenses required for biogas production from landfill gas, waste-water, and agricultural waste.
- The regulations are on waste management regulations, electricity production regulations and water treatment regulations.
- The origin of the problem is a lack of communication and lack of agreement between the departments.
- The NBP is now in the process of streamlining the regulatory process.

Working Group 2 – Financing

- An analysis has found that no particular funding for biogas exists.
- Funding for feasibility studies is difficult to find as well. (MCEP does exist, but it's not streamlined to biogas feasibility studies)
- Funding can come from financial institutions such as the IDC or DBSA
- DTI part of the platform, but doesn't cooperate.

Working Group 3 – Information Gathering

- For example: Information on biogas yield with varying substrate yields
- The information is gathered on the Biogas Information Hub, which can be found on SABIA. The Department of Energy couldn't host it as it needs to remain neutral to the industry.
- Developing tool to help determine the gas yield depending on substrate input..

Working Group 4 – Rural biogas

- Templates for personal use

Working Group 5 – Vehicular

- Biogas for transportation.
- Group leader considers this a very promising solution.

Working Group 6 – Fertilizer

- WG looks into the content of the fertilizer depending on substrate input.

Mr. J. van Niekerk – Consultant Legislation

Attendees
Johann van Niekerk (environmental legislation consultant)
Roxanne Goemans (team member)
Evan Roberts (team member)
Len Rijvers (team member)

Location & Time
Cradlestone Mall Johannesburg, 10:00-11:00, 18-09-2015

Review History

Member	Action
Evan Roberts	C
Len Rijvers	O
Roxanne Goemans	

Symbol	Definition
	Not notified about existence
R	Reviewed, no comments
C	Reviewed, commented
O	Original author

Report
Johann van Niekerk

- Johann's daughter is an environmental lawyer.
- He has more than 17 years of experience in legislation in the field of feedlots, biogas, animal waste, and abattoirs.
- Johann has been involved in 8 biogas plants in South Africa (possibly grammar errors):
  - Morgan Beef
  - Karan Beef; main consultant
  - Rendering plant; processing dead meat
  - Belfor abattoir; beef
  - Poultry Glasdorp; Trigen; most successful in terms of construction, financial planning, and electricity output.
  - Poultry; near Bloemfontein
  - Kornhein Piggery

Biogas in South Africa

- The government's support for the biogas industry is not sufficient, according to Johann. In Devon it is even worse due to the fact that the township is located in the so-called coal belt. As the prospect is that coal can provide the region with energy for the coming 140 years, there is no direct need for the government to consider other energy sources.
- On the other hand, there is no too little resistance against biogas.

Licenses

- Licenses are required for a commercial biodigester. If the biodigester is for personal use, no licenses are required.
- The legislation varies throughout the country.
- Below an overview of the required licenses is given. The applications for the licenses, 1,2, and 4, can be run concurrently.

  1. Industrial Rezoning
    - The terrain on which the biodigester is built has to be rezoned to an industrial zone.
    - The license is requested at local and provincial authorities.
    - The costs are about 60.000 ZAR
    - It takes about 8 months before the license is granted.

  2. Environmental Impact Assessment (EIA)
    - The Environmental Impact Assessment (EIA) has to be applied for if the footprint of the biogas business is larger than 5 ha or larger than 1 ha if the biodigester is located at a farm. In practice this is seldom the case.
    - The license is requested at provincial authorities.
    - The costs are about 50.000 ZAR
    - It takes about 12 months before the license is granted.

  3. AEL
    - The AEL has to be applied for if the amount of solid waste processed exceeds 1 ton. Hereby, it should be noted that South Africa only distinguishes between solid and liquid waste. Moreover, 1500 kL is equivalent to 1 ton. In general plants are feasible when the input exceeds 2500 kL.
    - The license is requested at metropolitan authorities. Several municipalities belong to one metropole. Johan thinks that Devon belongs to the metropole of Springs.
    - The license can be requested while the biodigester is being build.
    - It takes about 4 months before the license is granted.

  ! One should immediately start with the application for the AEL. The reason to do so is that this results in significant costs reduction (40.000 ZAR instead of 240.000 ZAR; application 50k, determine gas species 100k; air dispersion 90k). Johann has connections in his network.
    - The yearly costs are about 6000 ZAR.

  4. Waste License
    - A Waste License is required at businesses where waste is managed. Hereby, a distinguish is made between hazardous waste and non-hazardous waste. In practice, one applies for both types.
    - The license is requested at the Department of Environmental Affairs (DEA).
    - The costs are about 30.000 ZAR
    - It takes about 12 months before the license is granted.
    - The waste license has be to renewed every two years. Only a small fee has to be paid.

  5. Major Hazardous Installation (MHI)
    - The license is requester at the metropolitan authorities. That is, at the same place and with the same people as the AEL.

  6. Water Use License (WUL)
    - A water use license is required when boreholes, or other natural sources, are used to supply the water.
    - The WUL consists of three parts:
      1. Extraction
      2. Lagoon
      3. Irrigation
    - It takes about 2 years before the license is granted. The license is not a prerequisite.

- The costs are about 50.000 ZAR

7. Geo-hydrological Studies (not a license)
   - Geo-hydrological study of the water capacity is required.
   - The costs are about 50.000 ZAR
8. NERSA license
   - A NERSA license is required if one wants to feed in electricity into the grid.
   - The costs are about 10.000 ZAR
   - Due to load shedding it is rather easy to get this license.

- For the licenses, except for the AEL license, a consultant is required to guide the process. That is, according to Johann by doing so doing so significantly reduces the costs. The same holds for the time required to get the licenses.
- First do the planning, then choose the site.

Leandra Abattoir – Mr. K. Louw

Attendees
Kobus Louw (owner)
Roxanne Goemans (team member)
Evan Roberts (team member)
Len Rijvers (team member)

Location & Time
Leandra, 10:40-11:20, 22-10-2015

Review History

Member	Action
Evan Roberts	R
Len Rijvers	O
Roxanne Goemans	

Symbol	Definition
	Not notified about existence
R	Reviewed, no comments
C	Reviewed, commented
O	Original author

Report
<u>Kobus Louw</u>

- Kobus Louw lives in Delmas together with his wife and children. During the week he commutes between Delmas, the abattoir in Leandra and his farm in Devon.
- He is the owner of Leandra's abattoir, started in 1993.
- He knows the basic principles of a biogas plant. That is, the basic working principle of a biogas digester, use of the biogas and the use of feedstock.
- Owns a biodiesel plant. At this plant 'dirty' fat is converted into biodiesel. The plants produces around 15000 liters of biodiesel per month. The diesel is used as fuel for the trucks of the abattoir. One liter of diesel is produced at a total cost of approximately 7 ZAR. The main problem that the he encounters is the conglomeration of the fat in the winter months, which makes it impossible to produce diesel in these months.
- 6 years Kobus Louw started to think about setting up his own biogas digester at the abattoir. After doing some research he came in contact with an intermediary who told him that he know somebody who could help him with this plan. The costs estimated were, according to Kobus, 'crazy and way too expensive for the abattoir/ him to afford'. Hence, he decided to do it himself.
- Wants to be self-sufficient in its energy supply:
  Water – boreholes
  Fuel – biodiesel plant
  Electricity – (future) biogas plant

<u>South Africa</u>

- According to Mr. Louw there are two kinds of people in South Africa. He illustrates this statements with a story: "two people spend a whole day at home affairs, waiting in line. The first guy will say that he wasted a whole day. The other one will tell that he was busy all day".
- Moreover, he states that these 'types' of people must find a way to come together.

Leandra Abattoir

- The Abattoir is located in Leandra.
- It has an license to slaughter 80 animals per day. In practice around 100 cattle, mostly cows, are slaughtered. The maximum, cooling, capacity lies around 120 cattle. The abattoir slaughters animals at full capacity in December.
- In the past the abattoir besides cows the abattoir also slaughtered pigs and sheep. Today, however, 99% of the animals slaughtered are cows. The remaining 1% are sheep.
- The waste is sprayed on a farm nearby.
- The condemned matter and blood are processed in a rendering plant.
- In the past the waste was put into a hole. During the night the hole was emptied by ‘poor’ people from the surrounding area.
- The abattoir has several boreholes.
- The abattoir has back-up generators.

Technical & Feedstock

- Kobus Louw will provide the team with information on the following topics in the coming days:
  - Type of biomass available at both the abattoir and his farm in Devon; blood, condemned matter, manure & stomach content.
  - Per type of biomass the quantity produced per head of cattle.
  - Monthly electricity demand, in kWh, of his farm in Devon.
- During the meeting he could provide the team with the following information:
  - 100 cattle slaughtered per day, mostly cows.
  - On his farm in Devon there are around 700 cows. A part of them are kept in crawls.
  - Average electricity demand of the abattoir is approximately 400 kW
  - Rough estimate: 30000 kg of waste per day of which 3% solids. Here waste includes water, blood, manure, stomach content, and condemned matter
  - Note that condemned matter is different per region. For instance, in South Africa people eat the lungs, liver, and stomach while in Europe this is seen as condemned matter. In general, condemned matter includes unborn calves and testiness (in SA).

Email received 2 days after the meeting

ABATTOIR

ITEM	KG	USABLE MATERIAL
CARCASS	250	
HEAD/FEET	19	
SKIN	32.5	
FAT	3	3
STOMACH/INTESTINES	22	
LUNG/LIVER/HART	10	
CONDEMNED	4	4
TONGUE/TAIL	2.5	
BLOOD	20	20
DUNG	30	30

AVERAGE OF 1 HEAD OF CATTLE 57 KG

NEED +- 400KW OF POWER

FARM

MIN IN KRAAL	350
MAX IN KRAAL	750

Mrs. L.M. van Zyl – Consultant on Legislation

Attendees
Louise van Zyl (Managing Director, Principal Consultant at Cape EAPrac - Environmental Assessment Practitioners)
Roxanne Goemans (team member)
Evan Roberts (team member)
Len Rijvers (team member)

Location & Time
Cape Town, CTICC,13:00-14:30, 07-10-2015

Review History

Member	Action
Evan Roberts	O
Len Rijvers	
Roxanne Goemans	

Symbol	Definition
	Not notified about existence
R	Reviewed, no comments
C	Reviewed, commented
O	Original author

Report
<u>General:</u>
Cost estimations for licensing are difficult to make as the legislative process entails costs, but the specialist costs conducting the assessments vary from province to province and from firm to firm.
Costs range from ZAR60k to ZAR1.5m.
The statutory time frames are guaranteed after application hand-in, however the assessment duration varies. (see GIZ licensing document)
Before any estimation can be made the exact situation must be clear (incl. location, province, surrounding area, etc.)
Basic Assessment: ZAR60-80k
Specialist costs: ZAR300-400k

Mrs. Mampe – Neighbouring Farmer

Attendees
Mampe (owner of the farm)
Takatso Mofokeng (project owner)
Evan Roberts (team member)
Len Rijvers (team member)

Location & Time
Devon, 09:15-11:15, 16-09-2015

Review History

Member	Action
Evan Roberts	O
Len Rijvers	
Roxanne Goemans	

Symbol	Definition
	Not notified about existence
R	Reviewed, no comments
C	Reviewed, commented
O	Original author

Report
Timeline

- The team arrived at the farm around 09:15. Takatso showed the team the dam in which the waste; manure is collected.
- The team is introduced to Mampe who gives the team and Takatso a guided tour on the farm. During this tour the team asks the questions which they prepared for the meeting.
- After the tour Mampe invites the team and Takatso into her house for coffee. Moreover, she gives the team an electricity bill and information on the gas use of the farm.

Location

- The farm is located in the municipality of Devon.
- It takes about 17 minutes to get from the Chicken Chain Farm to the farm (14 km – Google Maps – road distance) and about 5 minutes to get from Devon's abattoir to the farm (11 km – Google maps – road distance).

General Info on the Farm

- The farm is owned by Mampe. This woman lives and runs the farm since 2010 together with her daughter. Her husband left her a couple of months after they moved to the farm.
- The main business of the farm is breeding of pigs. Moreover, they have sheep, cows, dogs and chickens.
- Mampe is planning to build a biodigester with the aim to provide new-born pigs with heat. Moreover, this biodigester should provide the farm in its gas and electricity demand.
- The farm has an EIA certificate.
- Solar pump at the farm were stolen. Luckily the insurance refunded Mampe.
- It takes the newborn pigs about 70 days to weight about 30 kilograms. Subsequently it takes them another 80 days to weight 150 to 200 kilograms. When they have reached this weight they are sold.

- The farm cooks on gas. They empty a LGP 9kg AFROX tank in two months.
- The farm has 130 ha of planting and about 60 ha of grass, requiring 50-60 tons of fertilizer each year (estimation of Mampe). To date, no fertilizer or compost is used on the farm.
- The farm bought a transformer, about 17000 ZAR. Besides the investment costs, the farm has to pay 3000 ZAR per month to ESKOM to use this transformer.
- The farm uses a cleaning fluid named “jace fluid”.

Biomass Supply

- Today, the farm has around 60+24=84 pigs (by counting) and a number of so-called winners. Winners are pigs that are around 20 days old and have a weight in the range of 9-10 kilograms. Moreover, they have 130 sheep (according to Mampe) and 10 cows (count & Mampe)
- In the future, according to Mampe at the end of this year, this number will increase to:
  - 170 pigs
  - 1500 piglets (+ 600 piglets next year)
  - 130 sheep
  - 50 cows
- According to Mampe the total amount of waste, manure and water, is about 2 ton per day.

SABIA & BiogasSA – Mr. M. Tiepelt

Attendees

Mark Tiepelt (chairman South African Biogas Industry Association (SABIA) & owner of BiogasSA)
Roxanne Goemans (team member)
Evan Roberts (team member)
Len Rijvers (team member)

Location & Time

Cape Town, CTICC , Johannesburg,13:00-14:30, 05-10-2015

Review History

Member	**Action**
Evan Roberts	R
Len Rijvers	O
Roxanne Goemans	

Symbol	**Definition**
	Not notified about existence
R	Reviewed, no comments
C	Reviewed, commented
O	Original author

Report

General

- The team met Mark Tiepelt during the lunch break of the second day of the SAIREC Conference.
- As owner of BiogasSA and chairman of the South African Biogas Industry Association (SABIA) Mark Tiepelt is considered as an authority in the in the South African biogas industry. Next to that he was a speaker in several sessions at the conference. For more information see minutes of the REN21 SAIREC Conference.
- Despite the fact that there was only a limited amount of time (+- 1h) and the circumstances could have been better (lunch break) the team was able to obtain valuable information. An overview can be found below. Moreover, the team agreed with Mark Tiepelt that they will send follow-up questions by email.

Biogas

- There are only about 1300 biogas plants, ranging from small-scale to commercial size, in South Africa.
- Different types of seed- and feedstock can be combined. In contrast to Mr. Martin Myer, Mark Tiepelt claims that it is possible to use blood as seed stock. However, attention should be paid to the C:N ratio of the biomass supply.
- Typically payback period (PBP) is > 10 years. However, a PBP of 7 years is attractive to financial institutions.
- It is hard to predict the biogas output of a biogas plant, only very rough estimations can be made.
- Today, fertilizer is not used in the revenues stream of the financial analysis. The reason is that it is very hard to assign a 'value' (read composition) to the fertilizer. Nevertheless, the revenues of the fertilizer are often used to compensate for the waste management costs.
- The, by-far, most common technology is the CSTR technology (Continuous stirred tank reactor). The reason is that this technology has been proven in Europe.

Mr. Martin Myer

Attendees
Martin Myer (professor at the University of South Africa)
Roxanne Goemans (team member)
Evan Roberts (team member)
Len Rijvers (team member)

Location & Time
University of South Africa , Johannesburg,10:00-11:45, 17-09-2015

Review History

Member	Action
Evan Roberts	R
Len Rijvers	O
Roxanne Goemans	

Symbol	Definition
	Not notified about existence
R	Reviewed, no comments
C	Reviewed, commented
O	Original author

Report

- The Biogas Business in South Africa is small (<2000) compared to Europa and surrounding countries, like Ethiopia. This is explained by several reasons according to Martin Myer:
    - Water scarcity is one of the problems. Today, in most (rural) households women are responsible for the water supply. As the water sources are often located rather far from the households, the women are not likely to supply the biodigester with the required amounts of water.
    - The average project team responsible of the realization of a biodigester consists solely of engineers, economists and marketers. Microbiologists should also be involved since microbiology is the key to success or failure of these projects. Nevertheless, the gross of the companies in the business want turnkey solutions and don't want to spend no money on R&D activities.
    - Municipalities are not well managed. The budget is not spent effectively, the water management is dysfunctional and there is a lack of standards on biogas, feedstock, bacteria etc. Nevertheless, the South African Bureau of Standards (SABS) is currently working on such standards. Martin Myer supports the SABS by means of advice.
    - The field of legislation is vague, nobody understands the process.
- AGAMA and BiogasSA achieved promising results on compartmented biogas systems.
- Sofia (GIZ) and Mark (BiogasSA) "run" the biogas platform
- A Puxin gas meter, China, can be used to determine the composition of biogas and to determine the corresponding fractions of these components. AGAMA can be contacted to loan their gas meters.
- Martin Myer plans to establish a centre that gathers and generates knowledge on the effects of the use of different types of feedstock in a biodigester.
- Despite the potential of biogas and the increases awareness of this potential among the younger generations, this is not the case for the older generations. According to Martin Myer this is mainly due to the fact that the older generation does not listen to the younger generations.

- There are 7 ethnic groups in South Africa, their visions on biogas are not “aligned” which makes it different to organize effective cooperatives.
- Martin Myer was involved in education on biogas. The Department of Education is making it difficult to introduce this type of education into schools.
- Martin Myer is involved in SANCOOP.

Input Biodigester

- There is a difference between seed stock in feedstock. The seed stock, for instance cow dung, provides the biodigester with the necessary bacteria cultures for the production of methane. The feedstock, for instance kitchen waste or grass, can be seen as the “fuel” of the biodigester.
- The ratios of feedstock, seed stock and water are in the orders of: 20-%,20+%,and 60% respectively (volumetric ratios).
- Sheep dung needs to be crushed before you can use it as seed stock in a biodigester.
- Blood is a problematic to use as feedstock. This is caused by the high iron content of blood.
- Intestines are also problematic to use as feedstock.
- The seed stock has to be “fresh” in order to provide to biodigester with the required bacteria cultures.

Morgan Abattoir – Mr. D. Groenewald

Attendees
Dirk Groenewald (Managing Director)
Roxanne Goemans (team member)
Evan Roberts (team member)
Len Rijvers (team member)

Location & Time
Devon, 10:30-11:30, 09-09-2015

Review History

Member	Action
Evan Roberts	O
Len Rijvers	
Roxanne Goemans	

Symbol	Definition
	Not notified about existence
R	Reviewed, no comments
C	Reviewed, commented
O	Original author

Report
<u>Morgan Abattoir's Background</u>

- Looked into biogas as a resource in 2007/08. It wasn't feasible at the time. Due to policy change (energy shortage) and change in regulation (abattoir waste management) feasible solutions could be designed.
- Size of abattoir 500 cattle/day – expansion now enables 800 cattle/day.

<u>Legislation and Regulations</u>

- Waste management regulations prohibited burying and burning of condemned matter and blood and even composting was only partially possible.
- The red meat abattoir association looked in to possible solutions.
- Regulations (environmental impact assessment (EIA) by the Dept. of Environmental Affairs (DEA) made the use of condemned matter difficult as well, as the regulations didn't differentiate between condemned matter (not suitable for human consumption) and biologically hazardous substances, therefore limiting the use in digesters.
- The abattoir is located in the center of Springs. Therefore the social acceptance (due to fear of explosion etc.) required education of the local authorities.
- One of the main convincing aspects was smell prevention, which in this case was documented accordingly.
- The EIA took two years till it was approved.
- Morgan Abattoir also required proof of creating less air pollution towards the municipal, provincial and national DEAs.

Problems in Construction & Design

- Digester tank had problems. Contractor didn't use the correct concrete. The stress was too high.
- Second contractor build the tank incorrectly as well causing cracks which cause leakage. Sealing is possible however.
- The companies BiogasSA and IBert (subsidiary of German Bio4Gas) had conflicting opinions about the potential gas yield. Morgan Abattoir therefor consulted to Rhodes University (in Grahamstown) to clarify the issue.

Financial

- The company invested a fair amount of capital on a loan. Since biogas is a new technology a high amount of risk is involved.
- Generator cost R5m at the time of purchase. The fall of the ZAR would make it R8m now.
- The dti invests in projects such as this.
- BEE made the process difficult
- First and only receiver of the ESKOM rebate. Problems as the plant size increased. Currently, they lost a quarter of the rebate do to the fact that they are not operational.
- Payback time of initially 11 years went back to 15 years.
- Cost increased from R15m to R22m.
- No feed-in to grid. Used as base load electricity for abattoir
- Base fee for waste removal at other abattoirs and farms.

Technical & Feedstock

- The plant is operated and maintained by the company Wick a company, whose expertise lies in waste water treatment and owns a sewage treatment facility in Johannesburg. They also recently started producing electricity with the previously flared biogas in order to satisfy their base load shortage of 1 MW.
- Stirring mechanism based on gas circulation pumps
- Total volume of the larger tank 800.000 – 1.000.000 L
- Substrate output per day equals 40000L (42 day retention time)
- The fertilizer is sold in liquid form as drying it would be to costly.
- According to Groenewald the heat usage makes the biogas system economically viable. The heat is used sterilize, around 81 degrees Celsius, and warming water, 42 degrees Celsius.
- Other farmers and abattoirs have similar waste management problems and therefore send their waste to the bio digester.
- Due to an expansion of the abattoirs capacity the biogas system will only cover the plants base load (30-35%) in necessary electricity.
- 6-8 employees can operate the plant, as a lot is automated. Of these, 4 will be newly employed.
- Pressures in the system do not exceed 1 bar.

Future Plans

- Next plan is a water purification plant for personal usage (grey water).
- Assisting other abattoirs in the startup of a biodigester.

Nova Institute – Mr. A. van Niekerk

Attendees
Attie van Niekerk (Managing Director)
Roxanne Goemans (team member)
Evan Roberts (team member)
Len Rijvers (team member)

Location & Time
Garsfontein, 11:30-13:00, 10-09-2015

Review History

Member	Action
Evan Roberts	R
Len Rijvers	R
Roxanne Goemans	O

Symbol	Definition
	Not notified about existence
R	Reviewed, no comments
C	Reviewed, commented
O	Original author

Report

Background Attie van Niekerk

- Started as a minister in a black church
- Theology professor at University of Pretoria, teaches classes about community involvement
- Was involved in the Nova Biogas Project.

Nova Approach

1. Get an understanding of how both sides see the problem
2. Evaluate and adjust the suggested solution to the community
3. Implement

Development agencies often have a different perception of what the problem is. Attie tells a story of a promising stone mason in a community who was given modern technologies to expand his business. The mason didn't know how to use the technology and went bankrupt. The development agency was then accused of having the intention to bankrupt the community.

The purpose of the Nova Institute is to bring modern technologies closer to traditional communities, as modern and traditional culture are not well integrated. Instead of telling the community on how to use the technology, Nova lets the community tell them what is needed. The technology (or implementation of it) is then adjusted and redesigned for that. Education brings people closer to the technology, but the technology also needs to be adapted to bring it closer to the communities.

The structure of Nova is organic, the institute is not advertised and instead gets approached by people who want to join. They have about 20 full-time members, of which 5 are former students of Attie. The team is multi-disciplinary (engineers, theologists, marketing, etc). When they find a project to work on, a team is put together based on the knowledge that is needed.

The idea of getting involved with biogas projects came after Attie got in contact with the Dutch development organisation SNV, which undertook a biogas project in the East (e.g. Nepal) by bringing together government and banks in order to provide cheap digesters on a large scale. Eventually the project showed to not be sustainable without this support, it collapsed when the SNV withdrew.

Religion

- "Religion plays a very central role in how people use technology"
- When someone gets sick they look for a cause and instead of attributing it to an unhealthy lifestyle they often believe that someone bewitched them. African churches capitalize on this way of thinking.
- According to African culture you are not in control of nature.

Funerals

Funerals in South Africa are very important. The funerals still go the same as in the past: something gets slaughtered and eaten according to ancient traditions, but it is now bigger because families can fly in and the body can be preserved longer. So funerals can be 2-3 weeks after the person dies and more people can attend. Funerals can ruin a family. There are now groups where people put in a certain amount each month and whenever someone has a funeral, it is paid from the common fund. It is easy to join these groups and you don't get kicked out if you have a lot of funerals in a row for example.

Perception of time & trust

Thinking of the future is not in the nature of South Africans. Africans stand with their back to the future. What they see before them is everything that has happened (see book John Mbiti). People only look a few days ahead at most. They rarely save money, usually people spend what they have. This short-term vision is difficult in business and it is therefore essential to find the exception, a leader that does look ahead and which people are willing to follow. Traditionally there was a strong hierarchy in communities.

There is a lot of mistrust in communities and in order for a community to be willing to follow someone, there must be trust. Trust is gained based on past accomplishments. Politicians are usually least trusted. Teachers, nurses and priests usually do get trusted.

Control

South Africans feel like they are not in control. When something bad happens, someone must have bewitched them. This mentality prevails to this day, even in the younger generation. When a student fails, there are often strikes. Attie talks about a story where there were two wives, one got pregnant and the other didn't. One of the wives accused the other of jealousy, she must be bewitched. The woman denied, but in the end confessed. There was a ritual to take away the evil and after this there was a celebration. In another story, a man got drunk, something bad happened and there was a discussion in the community on who made this man get drunk. A couple got accused and they denied over and over again. In the end they confessed and got burnt alive.

The reason that people confess to these accusations is to make peace return to the community. If someone confesses, the evil will get dealt with and everything will go back to normal. South Africans are not individualistic like Europeans.

The lack of feeling in control makes South Africans reluctant to take risks, because they cannot assess the risk that they are taking.

It is believed that the government should solve problems. When the community pays for something, they pay a flat fee and expect that everything is then taken care of. If problems occur, the government should solve them.

<u>Biogas projects</u>

- Hendrina: a guy named Rianne/Ryan (?) worked there on a biogas project (see Nova website). The community was highly involved and he didn't take lead in pushing the project but let the community guide him, only supporting them. When he left, he told the people to turn it into a business, build digesters for other people,ut they were afraid and didn't do anything.
- Kwazulu-Natal: in a community a toilet was built on top of a biogas digester for the entire community to use. Saves transportation costs & efforts and increases available biomass since the biomass is being collected from an entire community and not just one household. Attie believes this could be a promising model.
- Maintenance is a big problem, people don't take good care of the digester.

<u>Biogas business potential</u>

- Reduce expenses
- Carbon credits from companies (1 credit = 1 tonne CO_2). Carbon credits were introduced by governments after the Kyoto protocol in order to provide companies with the opportunity to reduce their emissions and thereby comply with regulations by investing in green companies. That way they would not have to change their own business or install renewable energy technologies. Some companies or people buy carbon credits voluntary (e.g. to do good, improve their image). NedBank does this for example.
- Water credits for pollution prevention
- Potentially air credits (though they don't exist yet)

<u>Barriers</u>

- Believes biogas has an image problem. It does not make the people feel like they are going a step forward, it's not high-tech.
- The government doesn't support the industry enough.
- People think energy from coals is more reliable than renewable energy because it is not influenced by external factors such as the amount of sunlight.

People are not afraid of biogas, but they are afraid of LPG.

Mrs. N. Mofokeng – Consultant Funding

Attendees
Nqobile Mofokeng (Fundraiser project)
Roxanne Goemans
Evan Roberts (team member)
Len Rijvers (team member)

Location & Time
Johannesburg, 14:00-15:00 , 17-09-2015

Review History

Member	Action
Evan Roberts	
Len Rijvers	O
Roxanne Goemans	C

Symbol	Definition
	Not notified about existence
R	Reviewed, no comments
C	Reviewed, commented
O	Original author

Report

<u>Nqobile</u>

- Nqobile is not aware of the financial capacities of the company. She is only involved in the fundraising for the project. As far as she knows Takatso and his wife take care of the finances.
- Nqobile has a financial background:
  - KPMG
  - SAB
  - BP: costing, retail department, strategy implementation of BP in Africa

<u>Biogas in SA</u>

- Farmers understand fertilizer, but they have little knowledge on biogas. For this reason, they are reserved with respect to the installation of a biodigester on their farm.
- The main reason that biogas does not live up to its potential is a lack of marketing, solar beat them to it.
- Before 1994 only a “small” group of people had access to energy utilities. This changed with the abolition of the apartheids regime. As a result the demand for energy increased dramatically, resulting in an energy crisis. The government responded by increasing the installed capacity of coal driven generators etc. At that time, little attention was paid to renewable energy sources

Project

- The possibility exists that a new company, next to the Chicken Chain farm, is established for the biogas business.
- Regarding the fundraising, Nqobile contacted the following financial parties:
  - National Empowerment Fund (NEF)
  - InnovationHub
- In order to raise funds from the aforementioned, and other, financial parties a clear project proposal should be made answering the question: *What are we selling?*.
- At the start, the project should be funded entirely by third parties. That is, by investments. The intended investment, all fundraised by third parties, is 2 million rand.
- Renewable energy is a hot topic within the government. Hence, numerous grants and loans are available for projects like ours.

Prison Devon

Attendees
Mangaliso Mhlanga (employee of the Prison & electrician Mr. Mofokeng)
? (Second employee of the prison)
Roxanne Goemans (team member)
Evan Roberts (team member)
Len Rijvers (team member)

Location & Time
Devon, 11:10-11:50, 27-10-2015

Review History

Member	Action
Evan Roberts	
Len Rijvers	O
Roxanne Goemans	

Symbol	Definition
	Not notified about existence
R	Reviewed, no comments
C	Reviewed, commented
O	Original author

Report

<u>Location</u>

- The prison is located next to Kruger Feedlot at approximately 10 kilometer from the Chicken Chain Farm.

<u>General Info on the Prison</u>

- Around 260 prisoners are kept at the prison
- The prison is a part, together with two other prisons, of the so-called Mobadi Prison (not sure if the name of the prison is spelled correctly). In total this prison keeps around 6000 prisoners. The other two prisons are located in Nigel (+- 50 km) and Heidelburg (+- 70km)

<u>Biomass Supply</u>

- The food waste is currently used as fertilizer. A farmer collected the food waste at no cost. The reason that the farmer does not has to pay is because the prison saves money as they don't have to get rid of the waste themselves.
- The second waste stream is that of residential waste. This waste stream is treated and processed by the sewage treatment installation. The municipality also collects a part of this waste stream. Mr. Mhlanga will try to get more information, that is on the quality and quantity, on these waste streams (see *follow-up questions & comments*). As far as the team's understanding goes the human excreta are treated and processed by the sewage treatment installation. The other part of the residential waste is collected by the municipality. However this needs to be checked.
- The biomass supply differs in both quantity (the prisoners do not always like the food, seasonal influences, and so on) and quality (menu varies per day).

<u>Other</u>

- According to Mr. Mhlanga there are three different parties involved in the waste management of the prison: public works – sewage treatment installation, the prison, and the municipality.

REN21 SAIREC Conference

Attendees
Evan Robert (team member)
Roxanne Goemans (team member)
Len Rijvers (team member)

Location & Date
Cape Town, Cape Town International Convention Centre (CTICC),04-10-2015 until 07-10-2015

Review History

Member	Action
Evan Roberts	
Len Rijvers	O
Roxanne Goemans	

Symbol	Definition
	Not notified about existence
R	Reviewed, no comments
C	Reviewed, commented
O	Original author

Conference
The SAIREC conference runs for two and a half days, from 4 – 6 October. Site visits are scheduled for 7 October. During the conference the team collected a significant amount of literature on numerous topics varying from the agenda of conference to the status of the South African energy market to in-depth information on the biogas industry on the African continent. This literature is available on Mr. Mofokeng's farm. It is highly recommended that one uses the literature to get an in-depth insight in the outcomes of the conference. On top of that, documentation, e.g. the final declaration, can be found on SAIREC's website: http://www.sairec.org.za/. The presentations can be obtained via: http://www.sairec.org.za/presentations/ The goal of this document is merely to provide the team(s) with overview on the side events, meetings and session in which the team participated during the meeting, which makes it relatively easy for both the team and the follow up team to search for specific information. Moreover, the conclusions drawn from the conference, from the team's perspective, are listed.

Activities

Day 1 – Sunday 4th October 2015			
Time	Activity	Attendees	Comments
10:00	Registration	Len, Evan, Roxanne	
10:00-11:30	Side Event: BAPEPSA Development of a Biomass Action Plan for Electricity Generation in South Africa	Len, Roxanne	
10:00-11:30	Side Event: Promotheum/ zaRECs / Nano Energy South African Carbon Offset Trading	Evan	
11:30-13:00	Side Event: UNIDO/ GEF Developing Industrial Biogas in South Africa: Status of the waste to energy biogas project	Len, Evan, Roxanne	
14:30-16:00	Side Event: RIAB/ IRENA Coalition for Action / SAREC / REN21	Evan, Len	Left after 1,5 hours

	Renewable Energy Solution to Power Africa: Bridging the gap for off-grid renewable energy deployment		
14:30-17:30	Side Event: IEA Enabling Policy and Financial Frameworks for Renewable Energy Deployment in Southern and Eastern Africa.		
16:00-17:30	Side Event: BMZ Decentralized Renewable Energy Empowers the Global Energy Transition: Africa: a green continent of opportunities	Evan, Len	

Day 2 – Monday 5th October 2015			
Time	Activity	Attendees	Comments
09:00-10:30	Official Conference Opening	Evan, Roxanne, Len	
11:00-12:00	Sustainable Energy for All: Renewable Energy, a tool for economic development and poverty alleviation	Evan, Roxanne, Len	
12:00-13:00	Energy Transition with Renewables in Africa and Globally	Evan, Roxanne, Len	
13:00-14:30	Lunch	Evan, Roxanne, Len	Meeting with Mark Tiepelt, BiogasSA and Chairman of SABIA
14:30-16:00	Parallel Session: Regulatory Frameworks	Evan, Len	
14:30-16:00	Parallel Session: Socio-economic Development	Roxanne	
16:30-18:00	Parallel Session: Finance Mechanism	Evan, Len, Roxanne	

Day 3 – Tuesday 6th October 2015			
Time	Activity	Attendees	Comments
09:00-09:30	Opening Plenary	Evan, Len, Roxanne	
09:30-11:00	Parallel Session: Technology Innovations CSP	Evan, Len, Roxanne	Attended in our own interest
11:30-13:00	Parallel Session: Energy Storage	Evan, Len, Roxanne	
13:00-14:30	Lunch	Evan, Len, Roxanne	Meeting with Louise Marie van Zyl, consultant on legislation in the biogas industry
14:30-16:00	Parallel Session: Biomass	Evan, Len, Roxanne	The most important and interesting session according to the team
16:30-18:30	Closing Plenary: Key findings from SAIREC and adoption of the SAIREC declaration	Evan, Len, Roxanne	

Day 4 – Wednesday 7th October 2015			
Time	Activity	Attendees	Comments
10:00-13:00	Site Visit Elgin Fruit Juices	Evan, Roxanne, Len	

Conclusion

- The energy sector in Africa is mainly focused on wind- and solar energy. Relatively little attention is paid to biomass as source of renewable energy. The reasons are multifold. The most commonly mentioned reasons mentioned during the conference are:
  - there is no lobby behind the biomass industry, in contrast to the wind- and solar energy industry
  - there the governments lacks both awareness and knowledge on this topic
  - The REIPPP is not streamlined towards biomass
- Today, small scale (<1 MW) IPP are not allowed to feed electricity into the grid. Nevertheless, there are initiatives which aim to make this possible in the future.

Mr. R. Tsele – Neighbouring Farmer

Attendees
Mampe (owner of the farm)
Takatso Mofokeng (project owner)
Evan Roberts (team member)
Len Rijvers (team member)

Location & Time
Devon, 08:00-08:30, 26-10-2015

Review History

Member	**Action**
Evan Roberts	O
Len Rijvers	R
Roxanne Goemans	

Symbol	**Definition**
	Not notified about existence
R	Reviewed, no comments
C	Reviewed, commented
O	Original author

Report

<u>Location</u>

- GPS: 26° 20’50” S 28° 47’07” E

<u>General Info on the Farm</u>

- Cattle farmer
- Dirt road leading up to farm

<u>Biomass Supply</u>

- 70-150 cattle at farm
- Manure is sold at 150-200 R/ton.
- Cattle sleep in kraal (dirt kraal – not concrete)

<u>Other</u>

- No vegetables, fruit etc. farming in the surrounding area due to frostbite. No constant supply of organic waste.
- Vegetable farming when passing Delmas.
- Mr. Tsele has been to China to spectate biogas engines.

Rossgro – Mr. L. Smalle

Attendees

Roxanne Goemans (team member)
Evan Roberts (team member)
Len Rijvers (team member)
Luc Smalle (employee)
Dr. Rossgrow (temporarily)

Location & Time

Rossgro office, 11:30-12:30, 02-09-2015

Review History

Member	Action
Evan Robberts	O
Len Rijvers	C
Roxanne Goemans	

Symbol	Definition
	Not notified about existence
R	Reviewed, no comments
C	Reviewed, commented
O	Original author

Report

General

- Rossgro is a poultry farming company which has both broilers and layers

Logistics

- Location coordinates farm: -26.14784, 28.60938
- Drive 51 km, 37 minutes

Feedstock

- Chicken manure, which is sold at 150-200 ZAR/ton
- Total annual production is approximately 5000 tonnes. Raw material / raw chicken manure. Around 50% of the total production is used as compost/fertilizer, whereas the other 50% is (partially) used as high quality cattle feed 50%.
- Production is more-or-less constant throughout the year

Energy demand

- The company's demand is around 1MW (60% of which they back up with diesel generators)
- The company plans to install a 500 kVA photovoltaic system.
- 20 million rand
- ESKOM planned to build several power stations. To date, however, only one power station is being constructed/ started up. The rest of the power station will be operational around 2020. This is one of the reasons why Rossgro decided to invest in a 20 million photovoltaic system.

General

- Luc Smalle states that the highest density of poultry exists in a radius of 100km.
- Luc assumes that biogas as a technology is too expensive and therefore not viable. The grants available by DTI are energy source dependent and rank lower for biogas than solar. According to Luc most grants are given under employment prospects of the respective investments. According to Luc chicken farms in the area are not interested to cooperate as people are on themselves. Moreover, they don't feel the need to do so as "the costs outweigh the benefits".
- According to Luc the price for chicken manure is not high enough for transportation.
- In the past Danish and American companies planned on investing in biogas technology at Rossgro, who decided against it due to larger risk on their behalf.
- The company manager (Dr. Rossgrow) stopped by and exclaimed his enthusiasm on innovative energy technologies, stating that he intends to diversify his market by investing in energy technologies in order not to be a "looser".
- Other interesting parties (might not be the exact names)
    - Astral
    - Rainbow

Sewage Treatment Installation Devon

Attendees
Takatso Mofokeng (project owner)
Roxanne Goemans (team member)
Evan Roberts (team member)
Len Rijvers (team member)
2 employees
Security employee
Manager of operations

Location & Time
Sewage treatment installation, Devon, 09:30-10:30, 26-08-2015

Document
This document provides its reader with a pointwise report of the team's visit to the sewage treatment installation(henceforth denoted as STI) at the aforementioned location and time. Moreover, follow up questions and comments are listed. For inquiries please contact: l.p.m.rijvers@student.tue.nl.

Review History

Member	**Action**
Evan Robberts	
Len Rijvers	O
Roxanne Goemans	

Symbol	**Definition**
	Not notified about existence
R	Reviewed, no comments
C	Reviewed, commented
O	Original author

Report

General
- The STI collects the waste water from the city of Devon
- The manager of operations showed the team around the STI.

Logistics
- The STI is located next to the chicken abattoir in Devon.
- It takes the team around 17,5 minutes, by car, to get from the farm to the chicken abattoir.
- Location coordinates farm: 26°20'57" S , 28°44'37" E
- 14 km; 15 minutes according to google maps

Feedstock
- There is neither data available on the amount of the organic waste nor on the quality of the organic waste.
- Today, the organic waste is collected in four drying basins, subsequently dried and burned

Cova Advisory – Mr. T. Chipfupa

Attendees

Tumelo (consultant on financial support by the Department of Trade and Industry)
Roxanne Goemans (team member)
Evan Roberts (team member)
Len Rijvers (team member)

Location & Time

Café 41 Pretoria, 16:00-16:45 , 18-09-2015

Review History

Member	Action
Evan Roberts	R
Len Rijvers	O
Roxanne Goemans	

Symbol	Definition
	Not notified about existence
R	Reviewed, no comments
C	Reviewed, commented
O	Original author

Report

Tumelo - background

- Tumelo has an engineering degree. Moreover, he obtained his Master of Public Administration (MPA) and Master of Business Administration (MBA).
- The Department of Trade and Industry, henceforth denoted as DTI, was looking for employees with an background in the field of engineering and mathematics when Tumelo started working at the DTI.
- Left the DTI with specific knowledge, which he uses in his current business.
- Tumelo did research for GIZ on Energy Efficiency Tax Incentives. It turned out that this approach was not effective.
- Tumelo worked together with the two sons of Takatso. He knows Takatso since 1989.

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Biogas in SA

- Biogas is not prioritized in South Africa.
- However, if you have a project – business plan, it is definitely possible to get financial support from the DTI.

Financial support by the DTI

- The focus of the DTI is on manufacturing and engineering. Energy production belongs to the portfolio of the Department of Energy.
- Tumelo was involved in the financial support of the biogas plant in Bronkhorstspruit (Bio2Watt). He awarded the grant, the so-called Enterprise Investment Programme (EIP).
- Eskom, BMW, and the municipality signed a wheeling agreement for this biogas plant. The wheeling charges can be expensive, in the order of 50-60k. Hence, BMW pays more for the electricity than they were used to do as a result of "going green".
- The DTI supports projects in areas that do not get served well by the grid.
- As aforementioned, a biogas project can definitely get financial support from the DTI. In order to do so, there are two main requirements:
  1. It has to be an innovative project. The biogas plant of Sean Thomas is a typical example. The waste heat is used to heat tunnels on a dairy farm.
  2. There has to be a "financial gap" in the financing of the project. This means that it is required that the owner of the project also invests in the project. By doing so, the DTI assesses the viability of the project.
- There are several grant programs. A project should be shaped into a programme to increase the chance of getting a grant. Below some programmes are discussed in more detail.
- The government does cost-sharing, a part of the financing has to come from the private sector.
- In general, the process is as follows:
  Apply -> Approval -> Spent -> Claim -> get paid (in stages)
- In order to get paid some conditions have to be met. However, these conditions differ per, type of, project. Moreover, the money is paid in stages.
- Cost-sharing percentage might increase when the BEE-rating of the project is higher.

Critical Infrastructure Program (CIP)

- For projects that provide and/ or support the infrastructure, for instance a farm that is connected to the biogas infrastructure.
- Financial coverage up to 30% of the costs is possible (cost-sharing 30%-70%).
- Highest potential for the biogas business in Devon.

Job Fund

- For projects that create job opportunities.

Black Business Supplier Development Program (BBSDP)

- 51% of the business has to be black to be able to apply.
- Amounts up to 1 million rand:
  800.000 – 50%-50% - cost sharing
  200.000 – 80%-20% - feasibility study

Support for Industrial Innovation (SID)

- Focuses on research projects and product development
- Up to 50 mill ZAR – 50%-50%
- Low potential for the biogas business in Devon.

Small Grant Program

- Pays directly to contracted firms.
- Before paying the government, DTI, checks if the entrepreneur paid his part (cost-sharing).

MCEP

- A level 4, or higher, BEE rating is required to be able to apply for this fund.
- The money is paid overtime. Once a project is commissioned the money should be claimed within 6 months. The second payment is 18 months after commissioning.
- Not eligible according to Tumelo.
-

Capital Feasibility Programme

- For projects outside SA – export of services.
- Low potential for biogas business in SA.

- One can apply for the DTI grants throughout the year. The job funds has 13 windows.
- One need to apply before a project is started.
- It take some time before a grant is either approved or rejected:
  30-60 days: minimum
  6 months: average
  1 year: maximum (MCEP)

IDC – Tony Nkuna

Attendees
Tony Nkuna
Claren Chen
Roxanne Goemans (team member)
Eva ten Velden (follow-up team member)
Yonis Le Grand (follow-up team member)

Location & Time
IDC Office Sandton, 11.00-12.30, 09-11-2015

Review History

Member	Action
Eva ten Velden	
Yonis Le Grand	
Roxanne Goemans	O

Symbol	Definition
	Not notified about existence
R	Reviewed, no comments
C	Reviewed, commented
O	Original author

Report
Biogas is not recognized in the REIPPPP. It was SABIA who made the DoE take it seriously.

IDC played a big role in setting up the National Biogas Platform. The reason for them to get involved was that they wanted to communicate to the industry how to get funding for their projects. At that point they had a lot of "one-man shows", where someone would apply for funding without having the whole picture figured out (contracted suppliers, off-taker, etc). The Platform gave IDC a way of communicating the requirements from a funding point of view to the biogas industry

Advantages of biogas
The IDC likes biogas for the following reasons:

1. Baseload – electricity can be generated when it is needed (unlike for instance solar and wind power which have peak production periods).
2. Waste treatment – South Africa has an abundance of land but it is rapidly urbanising. Therefore there is less space available to dump sewage and agricultural waste, and legislation forces companies to dispose of their waste in environmentally friendly ways. Using it to produce biogas is the most convenient way of treating waste. Nonetheless, IDC hasn't really seen big projects yet aside from Bronkhorstspruit.

Requirements for funding applications for biogas projects

The most important thing to the IDC is that the project makes financial sense. When assessing applications for funding for biogas projects, the IDC pays particular attention to the following elements:

1. Feedstock
    a. Quantity – needs to match with the technology
    b. Quality – needs to match with the technology
    c. Costs – needs to be market related/competitive
    d. Contracting – contracts with biomass suppliers need to have a duration of at least the tenure of the loan with IDC + 2 years (e.g. 10 year loan -> 12 year contract with suppliers needed)
2. Technology

    Usually this part is quite straight forward in the sense that if a biogas plant is using technology that the IDC is familiar with, they will trust that it will be reliable. In the case of experimental technology it becomes trickier. Projects that use technology/equipment with a performance guarantee from the supplier have a higher chance of getting funding.
3. Market
    a. Market choice – which market is the project serving? What is the product (e.g. heat, electricity, gas)?
    b. Quantity – a minimum off-take needs to be agreed upon with the off-taker (in order to have a minimum guaranteed income)
    c. Pricing – at what price will the product be sold?
    d. Contracting – the contract with the off-taker needs to have a duration of at least the tenure of the loan with IDC +2 years.
4. Operation

    Who will operate the plant? How will the skills be transferred to the community? The project should make some development in the community and contribute to the biogas industry.

In general, if for example an application is handed in for a biogas project and one is handed in for a solar project and both of them make financial sense, they won't have to compete and can both get funding from IDC. If both projects are proposing a project for the same off-taker, the IDC will fund the project that is chosen by the off-taker.

It is not required to have all of the licenses already in place when applying for a loan at the IDC, but you should be able to show that there is a good chance that you will get all of the relevant licenses (e.g. good communication with authorities). In the financing agreement then the IDC might include a clause that the loan will be paid as soon as the licenses have been received.

The IDC does not provide loans to projects that have less than 1 million ZAR capital investment because the effort that they take do not outweigh the benefits (for the IDC).

IDC provides up to 49% loans for early stage development of projects.

Mistakes/problems in applications
In the beginning the IDC did not know very well how to assess applications for biogas projects and the first few projects they supported were sometimes a bit problematic, but they got better at judging the viability of the projects.

- Incorrect research methods – e.g. taking one sample of manure does not allow you to make reliable predictions with regard to biogas production.
- Project is not bankable yet – don't have supplier contracts and/or an off-taker. People come with the technology but haven't figured out the entire process from biomass supply to off-take.
- One of the abovementioned points missing
- Project not financially feasible – does not make financial sense.

IDC provides loans, not grants. Therefore the project developer needs to define their project in detail and show that they know their project in order to provide security that the project is viable and the loan will be repaid.

The IDC will help the project owner through the process, but you have to put in the work.

Having a biomass supplier that is also the off-taker is a good way to ensure security in the project.

Cooperation with Green Fund (DBSA)
The IDC has a cooperation agreement with the Green Fund. Sometimes the IDC would encounter promising projects that were not financially feasible and then Green Fund would give the project a grant, making it financially feasible and eligible for a loan from the IDC.

Unfortunately, Green Fund became fully committed around the same time as the special schemes (GEEF & AFD) of the IDC.

Funding opportunities for biogas projects
Most biogas projects still need concessionary funding (incentives).

GEEF and AFD are fully committed, but prospective biogas producers should still apply for a loan at the IDC. The terms (rates) that will be offered to them will be less favourable than the ones of the GEEF and AFD, but as soon as such a special scheme becomes available again, these projects will be the first to receive those favourable terms (e.g. the rates will be reduced).

NEDBANK & ABSA currently have schemes with terms similar to the AFD Fund.

With the National Biogas Platform, Tony Nkuna put together a list of funding opportunities for biogas projects.

Jan Kemp Dorp

The biogas plant in Jan Kemp Dorp was one of the first biogas projects that the IDC was involved in. It was financed through the GEEF scheme (Green Fund not involved). There were some hurdles, but one of the strong points in this project was that the off-taker had a stake in the project, adding security and making the project more attractive to the IDC.

Barriers for biogas projects

- Commercial banks are still not willing to support biogas projects because the technology is still very new in South Africa and they are not willing to take the risk. The IDC is a bit more bold in this sense "we are at the centre of the country's development".
- There is a big potential for biogas in landfill, but so far only big players seem to be able to break through the 3 year limitation of the MFMA.
- People don't know what a bankable/mature project is
- Lack of funding opportunities for the early stages of the project. In the early stages funding is needed e.g. to do an EIA.
- Finding a private off-taker is often difficult.
- Commercial banks are hesitant to lend money due to the lack of knowledge on the technology.

IDC special financing schemes

The IDC had two special funding schemes that are relevant for biogas projects:

- GEEF (Green Energy Efficiency Fund)
- AFD Fund (sponsored by the French Development Agency)

The IDC is currently fully committed on both schemes. The AFD will most likely be renewed for a second trench, possibly in February (though with potentially different terms), whereas the future of the GEEF is at the moment still unknown.

Nkuna sees this as a good sign, it shows that there is demand for this funding and that projects are being undertaken.

Development of the biogas industry in South Africa

Money is not the problem, the problem is the viability of the projects.

Bio2Watt – Sean Thomas

Attendees
Sean Thomas
Roxanne Goemans (team member)
Eva ten Velden (follow-up team member)

Location & Time
Cedar Square Sandton, 08.00-08.45, 09-11-2015

Review History

Member	Action
Eva ten Velden	R
Roxanne Goemans	O

Symbol	Definition
	Not notified about existence
R	Reviewed, no comments
C	Reviewed, commented
O	Original author

Report
Sean Thomas always had an interest in renewable energy. Biogas offers some distinct advantages compared to other types of renewable energy:

- Investment is small enough (~10 mil ZAR)
    - Feasible for a small start-up such as Sean Thomas'
    - Better possible to get support from financial institutions (because the number is lower)
- Biogas offers baseload energy
- Labour intensive sector (compared to e.g. solar)

He looked into different types of renewable energy, for example gasification is not ready yet he thinks. Sean Thomas wanted to create a company and be involved in the project for the long run, biogas was feasible financially and he saw many advantages.

Bronkhorstspruit
Sean Thomas had first done his research on the amount of biomass available and then shopped around a lot for an off-taker. He talked to BMW, Nissan and some other companies, but Nissan did not seem that interested. Sean Thomas was looking for a partner, someone to walk the road with and he found that in BMW, they liked the story. BMW then gave him credibility when talking to financial institutions, they also joined those meetings. "BMW carried weight".

<u>Convincing the municipality</u>
The plant covers about 30% of the energy demand of BMW, which means that the municipality would lose revenues. But according to Sean Thomas, the municipality of Tshwane looked at the whole picture. The plant would for example take care of part of the municipality's waste, create new jobs and produce green energy. On top of that, the backing of BMW was important, since it is a German company they would probably pay on time.

Convincing BMW

Sean Thomas says that such a project requires a project, someone who will fight for it and within BMW that was Christof Roth. He believes that BMW was interested in biomass (out of all renewable energy sources) for two reasons:

- Their experience with biogas in Germany: Sean wasn't reinventing the wheel
- Biogas offers baseload, which probably helped a lot with the convincing

The contracts with BMW were done by lawyers who knew the requirements of the financial institutions, so these did not need to be changed. In any case, it took many years before the contract with BMW was finalized.

Licensing

The licensing was not finished before going to BMW, but that was alright because Sean Thomas took on all of the financial risk - "It's a risk you have to take". At that point, BMW was not spending any money on the project, only time.

Sean Thomas estimated the cost of the licenses at 300k ZAR beforehand, but the costs turned out to be 3.5 million ZAR.

Funding

Sean Thomas says that there are two types of funding. The first one is seed funding, which you need to get the project off the ground. This mostly came from Sean Thomas. He then applied for a grant from the Dutch Ministry of Foreign Affairs, who agreed to provide funding but for every euro that the Ministry would provide, the company would have to put in a euro from local funding. This funding lasted from 2009-2014.

Initially the plant was designed to produce 2 MW, but that was not viable, so they needed to scale up to 4 MW.

Abattoir waste

Sean Thomas does not see using abattoir waste as such a problem. The only additional licensing you need is an AEL and the fertilizer can still be sold easily he believes, because abattoir waste these days is "clean". Abattoirs need a lot of licenses, so the waste is in good condition.

Fertilizer

The fertilizer is priced according to its nitrogen content.

Feedstock

One of the biomass sources is paper sludge. When asked if this does not contain chemicals that would disrupt the bacteria, Sean Thomas says that this is not the case because the sludge is the waste that remains when paper is close to the end of its life. Paper that is close to the end of its life can still be used to produce for example toilet paper, but when it is recycled too much it becomes paper sludge. There is then no more ink in it, but the fibres retain a lot of water, which improves the fertilizer quality.

Future

- Bronkhorstspruit
  The plant produces about 4 MW of heat. 1 MW is used to keep the digester at the right temperature and Bio2Watt is now looking into using the remaining heat for (potentially strawberry) greenhouses. The CO_2 produced by the plant can then also be used for the greenhouses.
- Cape Dairy Biogas Plant
  At the moment of the interview, Sean Thomas has just handed in a bid for the REIPPPP for the Cape Dairy project. The prices are now favourable for biogas so he decided to go for it.
- Other projects
  Sean Thomas' passion still lies in private off-take, but it is difficult because you need to find a company who is willing to pay the premium. BMW has given him credibility, he is now looking into Mercedes but in the meanwhile has gone for the REIPPPP with Cape Dairy in order to grow Bio2Watt and create mass. Another project that's in the pipeline is in Pretoria.

Lessons learned from Bronkhorstspruit

- Go straight to the waste managers (the ones who collect it, e.g. Veolia), not the waste producers. Have the waste companies bring the waste to you instead of the land-fill. They have to get rid of it anyway whereas waste producers might charge you for the waste, which in biogas projects results in a financially unfeasible business model.
- Make sure to first know the requirements that the financial institutions set for the contracts with suppliers/off-takers, before you make contracts with those parties. Otherwise you will for example make a contract with a supplier, find out it needs to be adjusted (e.g. more years) and then when you go back to them you are in an unfavourable position because they know you need something from them. If he would do it again he would prevent this "back-and-forth". For example, if you request financial support for a project with X amount of biomass (100%), then the banks might want you to have contracts for 125% so that if one of your suppliers drops out, you can still move forward with your project.

Sean Thomas says he has learned to assess biogas projects and if it is a viable process. From there he can go to investors.

Involvement in National Biomass Platform

Sean says he goes sometimes but he is not able to attend all of the meetings. They consult him sometimes and he gives input, for example for the meeting that Louise-Mari had/will have with the DEA.

Underdevelopment of the biogas industry

South Africans want everything to be done for them. They complain that the government should provide them with a list or map of where the biomass can be found, but they should put in the effort themselves and do the work.

Sean Thomas sees two main barriers in the South African biogas industry:

- The price of electricity is too low, it is not reflective of the costs to produce it and biogas cannot compete. Who would want to buy more expensive electricity (from biogas)?
  If the costs of producing electricity from biogas would decrease, it would become more interesting and the industry could grow. Sean expects that it will take another 3 years to get to that stage.
- Legislation: it is not impossible but it is definitely not easy.

He doesn't think the barriers have changed much since he set up the Bronkhorstspruit plant. The Platform is working on streamlining the licensing process but that will take a while, and the price of electricity is still too low.

Annex C – Soil & Climate Assessment

The performance of a biogas plant in operation is inherent to the governing environmental conditions. The microorganisms, for instance, that convert biomass into biogas are temperature sensitive. What's more, the conditions impose restrictions on the design and subsequent construction of the biogas plant. Think, for instance, on the conditions of the soil on which the biogas plant is constructed. For the aforementioned reasons a soil and climate assessment is carried out at the future location of the biogas installation. The outcomes of the soil & climate assessment serve several purposes in the course of the project. For instance, it can be used in determining the heat demand and optimal location of the installation. This section starts with a concise description of the location. Secondly, the assessment of the climate is elaborated upon. Thirdly, the assessment of the soil is discussed.

Location

The future biogas plant will be located in the township of Devon at the Chicken Chain Farm. In Table 34 geographical parameters related to the farm's location can be found.

TABLE 34: GEOGRAPHICAL PARAMETERS OF THE CHICKEN CHAIN FARM.

Geographical parameter	
Country	South Africa
Province	Gauteng
District	Sedibeng
Municipality	Lesedi
Location	Palmietkuil IR 322
Elevation	1647 [m]
Latitude	26°24'05.5"S
Longitude	28°44'48.8"E

Climate

Three of the climate's main features are assessed: the air temperature, the precipitation, and the irradiation. As aforementioned the microorganisms are temperature sensitive. Hence, the air temperature is assessed to determine the heat demand of the installation. The precipitation is assessed mainly for its influence on the water supply to the biogas plant. The irradiation is assessed for two main reasons. Firstly, it is a determining factor in estimating the energy supplied by the solar system. Secondly, irradiation is a source of thermal energy. In other words, it affects the temperature inside the biogas installation, which in turn determines the heat demand. In this section the methodology and results of the assessment of the temperature, the precipitation, and the irradiation are discussed. To start, the methodology, which is similar for the different parameters, is discussed. Next, the results are presented.

Methodology

To be able the assess the parameters relevant data is required. Hence, the team contacted several stakeholders identified in the stakeholder analysis requesting the following data:

- Hourly or daily air temperature
- Hourly or daily precipitation
- Hourly or daily global horizontal irradiation (GHI)

Preferably the dataset contains recent data from a period longer than 5 years.

The team obtained data from the following sources:

1. South African Weather Services
2. The South African Universities Radiometric Network (SAURAN)
3. Agro-Climatology department of the Agricultural Research Council

In Table 35 an overview of the data provided by the sources can be found.

TABLE 35: OVERVIEW ON THE (RELEVANT) DATA PROVIDED BY THE THREE CLIMATE SOURCES.

Location	Data	Format	Period
Springs	Monthly values: - Maximum temperature - Minimum temperature - Rainfall	Excel file	-
Delmas	Monthly values: - Maximum temperature - Minimum temperature - Rainfall	Excel file	1987-2010
Pretoria	Daily values: - Global horizontal irradiation - Diffuse normal irradiation - Diffuse horizontal irradiation - Rainfall - Air Temperature	Excel file	2014

At the time of writing only the data obtained from SAURAN is incorporated in the assessment. The data from the other two sources can be requested from the authors of the report.

Temperature
The average temperature in 2014 was equal to 18,7 degrees Celsius. In

Table 36 the average temperature for each month in 2014 can be found. In Figure 7 a boxplot of the air temperature can be found. Moreover, in Figure 8 the air temperature is plotted as a function of time.

TABLE 36: MONTHLY MEAN AIR TEMPERATURE IN DEGREES CELSIUS IN DELMAS, 2014.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Temp.	23,2	22,3	19,9	17,6	17,0	13,9	13,1	15,8	20,1	20,2	20,1	21,3

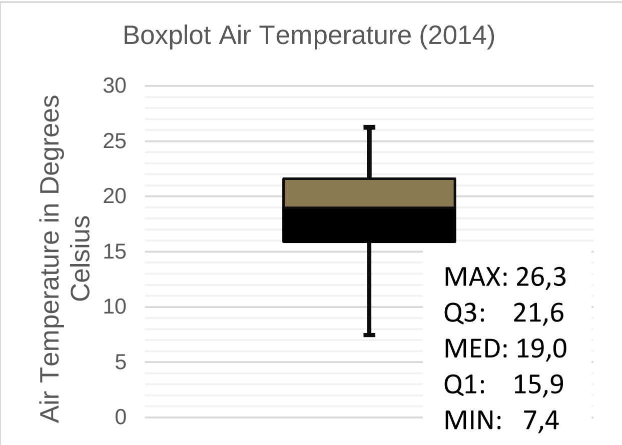

FIGURE 7: BOXPLOT OF THE AIR TEMPERATURE IN DEGREES CELSIUS IN DELMAS, 2014.

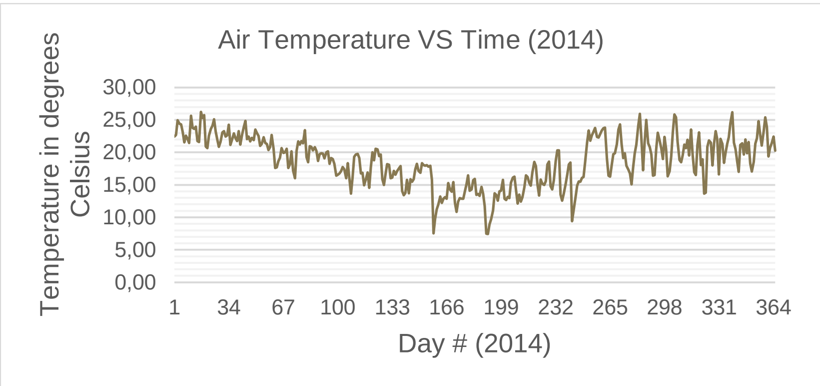

FIGURE 8: DAILY AIR TEMPERATURE VERSUS THE NUMBER OF THE DAY IN DELMAS, 2014.

Irradiation

The average global horizontal irradiation in 2014 was equal to 5,4 kWh/m²/day degrees Celsius [3]. In Table 37 the average global horizontal irradiation for each month in 2014 can be found. In Figure 9Figure 7 a boxplot of the global horizontal irradiation can be found. In Figure 9 the global horizontal irradiation is plotted as a function of time.

TABLE 37: MONTHLY AVERAGE GLOBAL HORIZONTAL IRRADIATION (GHI) IN KWH/M² IN DELMAS, 2014.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
GHI	6,6	6,0	4,3	4,9	4,5	4,2	4,4	5,0	6,2	6,9	5,7	6,4

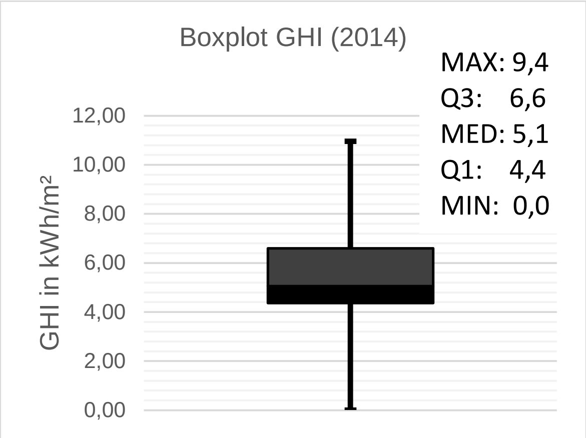

FIGURE 9: BOXPLOT OF THE GLOBAL HORIZONTAL IRRADIATION IN KWH/M² IN DELMAS, 2014.

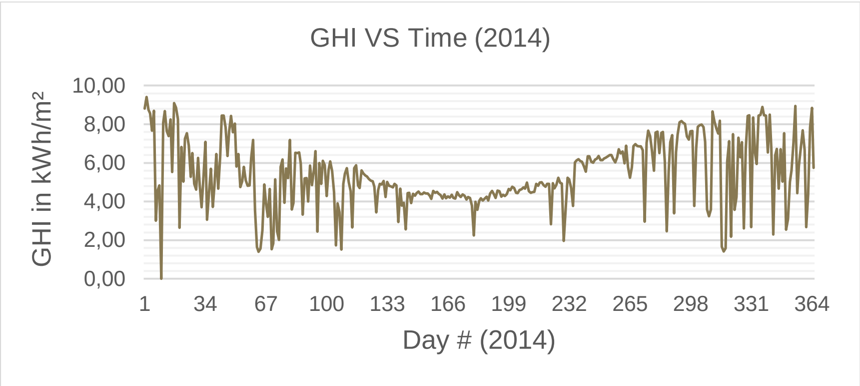

FIGURE 10: DAILY GLOBAL HORIZONTAL IRRADIATION IN KWH/M² IN DELMAS VERSUS THE NUMBER OF THE DAY, 2014.

Precipitation
The total amount of precipitation in 2014 equalled 877 millimetres. In

Table 38 the monthly mean amount of precipitation can be found. In Figure 11 the rainfall is plotted as a function of the time.

TABLE 38: MONTHLY MEAN PRECIPITATION – RAINFALL IN MILLIMETRES IN DELMAS, 2014.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Prec.	0,9	6,5	8,6	0,4	0,0	0,1	0,0	0,3	0,0	1,1	3,1	7,9

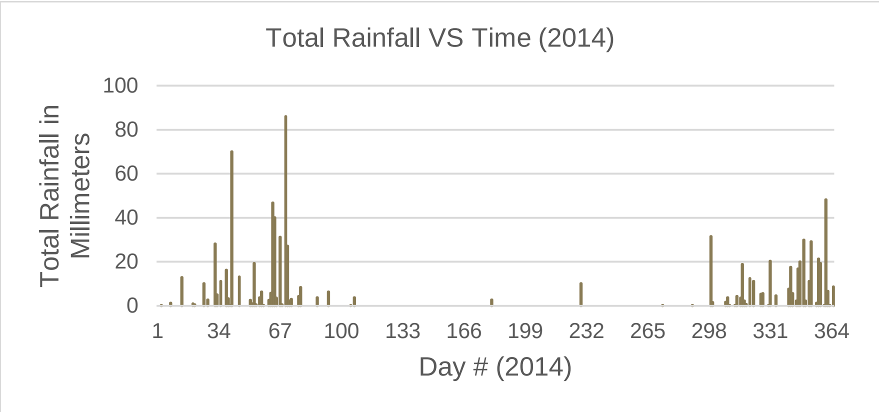

FIGURE 11: DAILY RAINFALL IN MILLIMETRES IN DELMAS VERSUS THE NUMBER OF THE DAY, 2014.

Soil
At the time of writing an assessment of the soil conditions has taken place. Data can be requested with the project owner.

Annex D – Energy Audit

An energy audit is executed by inspecting, surveying, and analyzing the energy flows on the Chicken Chain farm. Hereby, water, electricity and gas flows on the farm are considered. The maximum water supply to the future biogas installation is restricted by the water availability at the Chicken Chain Farm. According the project owner the gas and electricity infrastructure of the biogas installation and the Chicken Chain Farm will not be connected. Nevertheless, the gas and electricity flows are taken into account to keep a broad perspective regarding potential customers. This section is dedicated to describing the energy audit in its entirety. To start, the objectives of the energy audit are described. Hereafter, the methodology and findings of the electricity audit, the gas audit and the water audit are discussed.

Objectives

The project objectives, discussed in the Objectives & Methodology, serve as guideline in setting the objectives of the energy audit.

- Get an understanding of the energy infrastructure on the farm;
- Determine the daily average energy demand of the farm;
- Determine the daily average energy supply to the farm;
- Determine the storage capacity of energy on the farm.

Here, energy refers to the respective water, electricity, and gas flows.

Electricity Audit

The orders of the electrical energy storage capacity, daily average energy supply, and daily average energy demand are estimated by means of so-called back-of-the-envelope calculations. These calculations are rough calculations in which simplified assumptions are used, for instance the efficiency of the solar panels. The results are among others used to put the potential biogas yield in perspective, to identify an electricity surplus or shortage besides as verification of the accurate in-depth calculations.

Electricity Infrastructure

The electricity infrastructure of the farm is connected to two battery packages. The battery packages are connected to two invertors. In turn, the two inverters are connected to one and four solar panels respectively.

Electrical Energy Demand

The electrical energy demand is approximated using electricity bills from the year 2012, see Table 39.

TABLE 39: ELECTRICAL ENERGY DEMAND OF THE CHICKEN CHAIN FARM ACCORDING TO AN ELECTRICITY BILL, 2012.

Timeframe	Demand [kWh]	Days	Daily Demand [kWh/day]
10/04-11/05	366.00	32	12
09/07-10/04	317	27	12
09/11-10/09	340	28	12

As can be seen the electrical energy demand is in the order of 12 kWh/day.

Electrical Energy Supply

According to Annex C- Soil & Climate Assessment the daily average Global Horizontal Irradiation, or GHI, is equal to $GHI_{d,avg} = 5{,}4\ kWh/m^2$ On site measurements revealed that the surface area of the solar panels of $A_{pan} = 8{,}5\ m^2$. The daily amount of energy, E_{sol}, which can be harnessed equals:

$$E_{sol} = GHI_{d,avg} \cdot A_{pan}.$$

The daily electricity supply, $E_{sol,el}$, is equal to:

$$E_{sol,el} = E_{sol} \cdot \eta_{mono} \cdot \eta_{inv}.$$

Assuming an 20% efficiency for the mono-crystalline solar cells, η_{mono}, and a 100% efficiency for the invertor, η_{inv}, it follows that the daily electricity supply equals $E_{sol,el} = 9{,}2\ kWh$. Hereby efficiency losses in the system are neglected and assumed that the inclination angle of the solar panels equals zero. Hence, the GHI can be used.

Electrical Energy Storage Capacity

For a number of $n = 10$ batteries and their respective capacity of $Q_P = 102\ \mathrm{Ah}$ at a voltage of $U = 12\ \mathrm{V}$. The storage capacity per battery, E_{bat}, and the total storage capacity of electric energy $E_{el,tot}$ can be calculated as

$$E_{el,tot} = n \cdot E_{bat},$$

Where,

$$E_{bat} = Q_P \cdot \mathrm{t_d}.$$

Using that the number of seconds in a day is equal to $t_d = 86400$, it follows that the total storage capacity of electrical energy equals $E_{el,tot} = 12{,}2\ kWhe$. For this calculation the only assumption made is that it is assumed that no deterioration of the storage capacity of the batteries has taken place.

Electrical Energy Balance

The back-of-the-envelope-calculations show that electrical energy storage capacity, daily average electrical energy demand, and daily average electrical energy supply have the same order of magnitude, with respective values of 12 kWh, 12 kWh, and 9 kWh. It appears that there is an overall electricity shortage. The accurate in-depth calculations will provide an better insight in this matter.

Gas Audit

Gas Infrastructure

The current gas system in place is entirely based on LPG and biogas.

Gas Demand

The team consisting of three people has been cooking on LP-gas only. The average consumption of the team per month was $m_{LPG} = 20\ kg$. With the lower heating value of $h_l = 12{,}9\ \mathrm{kWh/kg}$ (engineering toolbox, 2015) this leads to a daily thermal energy demand of $E_{d,th} = 2{,}86\ \mathrm{kWh}$ per person. Note that this is very rough estimation of the energy demand, it can, however, be used as a reference point for thermal energy demand at this particular farm in its current state.

Gas Supply

Prototype

In this section the availability of biogas is described by means of a theoretical model of the gasholder. The variable volume ΔV_{GH} is the volume, at a stroke of Δh and a radius R, with which the gasholder can provide gas at a relatively constant pressure. It is a geometric value, which can be calculated with the following equation, see values in Table 40.

$$\Delta V_{GH} = \Delta h \cdot R^2 \cdot \pi.$$

The pressure can be determined by determining the force equilibrium:

$$p_e \cdot A_0 + F_G = p_i \cdot A_0 + F_b(x),$$

where p_e is the surrounding pressure, A_0 the projection area of the gasholder from above, F_{GH} the gasholder weight, p_i the pressure inside the gasholder, and $F_b(x)$ the buoyant force dependent on the level of the gasholder, see Figure 12. The equations can be broken down into:

$$p_e = p_0 \cdot e^{-\left(\frac{h_{altitude}}{h_O}\right)},$$

$$A_0 = \pi \cdot R^2,$$

$$F_G = (n \cdot m_{brick} + m_{GH}) \cdot g,$$

$$m_{GH} = \rho_{steel} \cdot t \cdot \left(2 \cdot h \cdot R \cdot \pi + \frac{R^2 \cdot \pi}{cos(\alpha)}\right) \cdot g,$$

$$F_b = 2 \cdot \rho_{water} \cdot t \cdot R \cdot (h - h_{top} - x) \cdot g \cdot \pi, 0 \le x \le \Delta h.$$

Solving the equation for p_i gives:

$$\Rightarrow p_i = p_0 \cdot e^{-\left(\frac{h}{h_O}\right)} + \left[\frac{n \cdot m_{brick}}{\pi \cdot R^2} + \rho_{steel} \cdot t \cdot \left(\frac{2 \cdot h}{R} + \frac{1}{\cos^2(\alpha)}\right) - \frac{2 \cdot \rho_{water} \cdot t}{R}(h - h_{top} - x)\right] \cdot g.$$

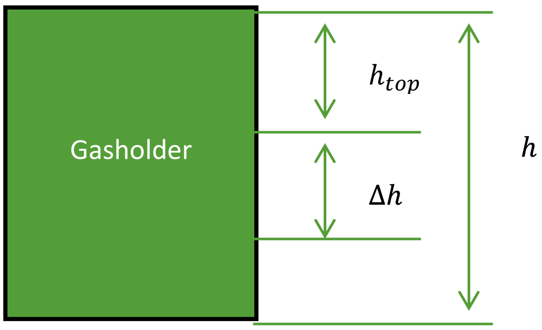

FIGURE 12: SKETCH GASHOLDER PROTOTYPE.

All newly introduced parameters and variables are given in Table 40 below (daftlogic, kein Datum) (regentsprep, kein Datum), (ngineeringtoolbox, kein Datum), Annex C– Soil & Climate Assessment.

TABLE 40: CONSTANTS AND PARAMETERS - BIOGAS PROTOTYPE CALCULATIONS.

Name	Symbol	Value	Unit
Standard atmospheric pressure	p_0	10^5	Pa
Number of bricks	n	17	
Weight of bricks	m_{brick}	3,18	Kg
Altitude	$h_{altitude}$	1,65	Km
Constant for Earth	h_0	7	Km
Radius of gasholder (GH)	R	0,62	m
Thickness of GH	t	0,005	m
Height of GH side	h	1,24	m
Angle at the top of the gasholder	α	9,18	°
Non-submersed length	h_{top}	0,43	m
Variable submersed length	x	$0 \leq x \leq \Delta h.$	m
Maximum variable stroke	Δh	0,55	m
Gravity	g	9,81	kg*m/s^2
Density of steel	ρ_{steel}	8000	kg/m^3
Density of water	ρ_{water}	1000	kg/m^3

It follows that the maximum pressure is $p_{i,max} = 0{,}814\, bar$ when the gasholder is at its highest position, and a minimum pressure $p_{i,min} = 0{,}813\, bar$ when the gasholder is at its lowest position.

The gasholder can provide a volume $\Delta V_{GH} = 0{,}664\, m^3$ of biogas at an average pressure of $\overline{p_i} = 0{,}8135\, bar$. The rate at which the gasholder empties can be calculated with the law of mass conservation and the law of ideal gases:

$$\frac{dm}{dt} = -\dot{m}_{out},$$

$$m = \frac{\overline{p_i} \cdot V \cdot M}{R \cdot T_0},$$

which give:

$$\dot{m}_{out} = -\frac{\overline{p_i} \cdot M}{R \cdot T_0} \cdot \frac{dV(t)}{dt}, 0 \leq V(t) \leq \Delta V.$$

Electricity Production

The generator power $P_{electricity}$ is dependant on the generator efficiency η_{gen}, the thermal energy of the biogas E_{th} and the load duration Δt.

$$P_{electricity} = \frac{\eta_{generator} \cdot E_{th}}{\Delta t},$$

$$E_{th} = h_l \cdot \Delta V_{GH},$$

As the load duration increases the power of the generator needs to be reduced or vice versa. The energy content of the biogas in the gasholder is relatively low. Therefore a relatively small-scale generator is chosen. It follows that $P_{el} = 1{,}5\ kW$. If we insert this into the equation it follows that:

$$\Delta t = \frac{\eta_{generator} \cdot E_{th}}{P_{electricity}} = 0{,}5\ h.$$

This means we could run a 1,5 kW generator for about 30 minutes, producing 0,75 kWhe on a daily basis.

NOTE: This is a theoretical calculation of the energy production possible, with many assumptions.

Water Audit

The water audit is conducted in order to make a forecast on the necessary water supply for the surrounding area. The demand forecast is based on a 1-person household and a 3-person household, the cattle's water demand and that of the commercial biogas digester. These are balanced to show the necessary installation of pumps in order to compensate for the water deficiency.

Water Infrastructure

The sources are based on both solar powered pumps in boreholes. Moreover, there are three unused boreholes according to the project owner. The storage capacity is provided by several storage tanks.

Water Demand

The water demand is based on a current demand and a forecast for a 1-person household, a 5-person household, the cattle, and that of the biogas digester. As the farm is not a representative household the average water demand is estimated based on the consumption of water using the toilet, washing hands, washing body, showering, drinking, cooking, cleaning and the water the cattle consume. The values are based estimations and measurements at the farm, and literature values. The scenarios are composed of

Current Minimum: 1-person household & prototype
Current Maximum: 3-person household & prototype
Future Minimum: 1-person household, commercial & prototype
Future Maximum: 3-person household, commercial & prototype

TABLE 41: WATER DEMAND ACCORDING TO FOUR DIFFERENT USER SCENARIOS AT THE CHICKEN CHAIN FARM.

Demand Scenario	Volume [L/day]
Current Minimum	1565
Current Maximum	1656
Future Minimum	1936
Future Maximum	2109

Water Supply

There are currently five boreholes located of which two are in use. One of the boreholes, which has a solar powered pump in it too is relatively far away from the farm - “borehole far”. The other is located underneath an decommissioned wind powered pump - “borehole wind”. Both pumps are of the same model, data of which can be found in Table 42.

TABLE 42: DATA SHEET SOLAR PUMPS.

Model:	SP-JS3-1.8-80
max. flow [m^3/h]	1,8
max. head [m]	80
Outlet [mm]	19
Power [W]	210
Voltage [V]	24
IP	68
ISO900:2000	

The maximum availability of water at the farm was based on empirical measurements, the results of which can be found in Table 43 .

TABLE 43: RESULTS OF FLOW RATE MEASUREMENTS

Borehole Far		Borehole Wind	
Volumetric flowrate [L/h]	14,399	Volumetric flowrate [L/h]	4,4
Volume per day [m^3/day]	0,345576	Volume per day [m^3/day]	0,11

Currently, approximately 0,45 m^3 (the sum of both borehole flow-rates) of water are available per day at the farm. The measurements were compared with the theoretical flow rate possible given the technical data of the pumps. The theoretical flow rate of the pumps is a function of the head, see also Figure 13.

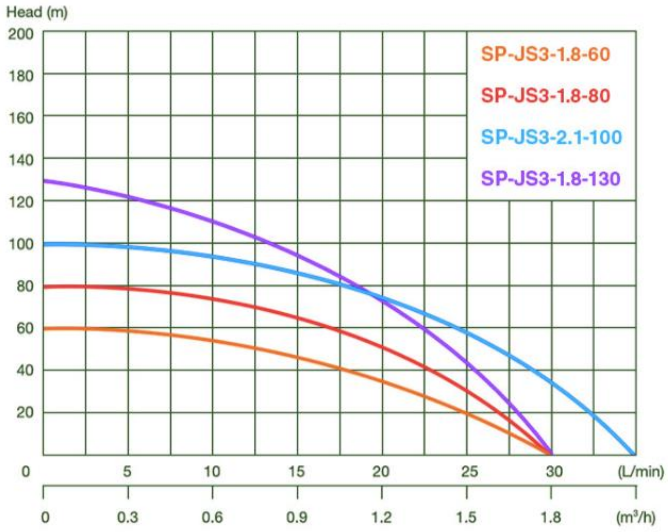

FIGURE 13: HEAD VERSUS FLOW RATE FOR DIFFERENT TYPES OF PUMPS.

For the given model SP-JS3-1.8-80 and a head of 54,1 m the flow rate per day is approximately 28,8 m^3. For a head of 35,2 m the flow rate per day is approximately 36 m^3 (as can be found in Table 44 and Table 45).

TABLE 44: FLOW RATE FOR BOREHOLE FAR BASED ON MANUFACTURER DATA.

Boundary Conditions		Conclusive Data	
Borehole Depth	31,9	max flow according to head (check table) [m^3/h]	1,2
Installation Depth	30,5		
Elevation difference to farm	10		
Height Top of Main Tank	12,2		
Head	54,1	Volumetric flow per day [m^3/day]	28,8

TABLE 45: FLOW RATE FOR BOREHOLE WIND BASED ON MANUFACTURER DATA.

Boundary Conditions		Conclusive Data	
Borehole Depth	23	max flow according to head (check table) [[m^3/h]	1,5
Elevation difference to farm	0		
Height Top of Main Tank	12,2		
Head	35,2	Volumetric flow per day [m^3/day]	36

The data shows a large discrepancy between the empirical data and pump manufacturer data. In this case the most probable case is water scarcity in the borehole and a too large installed pump for the given application.

Water Storage Capacity
The water storage system is based on an array of PVC tanks located at various locations around the farm. Currently, six tanks are installed, of which 5 are equal in size (1 m^3). The other one is 7 m^3 in size. The volume, the elevation, and the water level height was collected for each one of the tanks. Currently, the elevation and water level height are irrelevant for the feasibility study, however these figures pose important physically parameters if the water storage system were to be modelled hydro-dynamically. All relevant data can be found in Table 46.

TABLE 46: WATER STORAGE SYSTEM DATA.

Name	Volume [m^3]	Height [m]	Elevation compared to farm level [m]
Main Tank	7	3.5	8.7
Secondary Tank	1	1	2.5
Takatso Tank R	1	1	0.25
Takatso Tank L	1	1	0.35
Kabelo Tank	1	1	0.3

The total installed storage capacity currently equals 11 m^3approximately 100 L go to the cattle (based on borehole wind, which pumps to the cattle). This means that about 10,9 m^3 of installed storage capacity would be usable for the biogas system.

Water Balance
The Balance of the system is based on the simple difference between supply and demand as shown in:

$$Balance = Supply - Demand \; > 0,$$

$$Supply = f(number\ of\ boreholes),$$

$$Balance = f(household, cattle, digester).$$

A negative balance indicates a lack of water. In the case of the farm the deficiencies can be found in

Balance Scenario	Volume [L]
Current Minimum	-1114
Current Maximum	-1205
Future Minimum	-1484
Future Maximum	-1657

The team proposes to compensate for the lack of water by making use of the boreholes by installing more solar-powered pumps. The two pumps average a supply of $V_{pump,average} = 2255 \text{ L/day}$.

Thus the team proposes compensating for the water shortage by installing:

$Shortage = n \cdot V_{pump,average}$,
where,
$n = \frac{Shortage}{V_{pump,average}}, n \in \mathbb{R}$.

It will be necessary to install one more pump at the farm to compensate for the water shortage.

Tank Conditions

A specific temperature needs to be maintained in order to keep the microbiological process at an optimum. Mesophilic microbial organisms perform best at temperatures ranging from 32 to 42 degrees Celsius. The heat necessary for this process is composed of the heat losses through the digester walls ($Q_{digester}$) and the heat required to bring the biomass input up to tank conditions (Q_{input}).

$$\dot{Q}_{thermal} = \dot{Q}_{input} + \dot{Q}_{digester}$$

The required heat (recuperated from the engine) can be estimated, by assuming (rough assumption) one-dimensional heat transfer through the digester walls (conduction). With a heat transfer coefficient $k = 0{,}8 \text{ W}/(\text{m} \cdot \text{K})$, a minimum temperature inside the digester of $T_{i,min} = 37$ °C, a maximum temperatures outside the digester of $T_{o,max} = 22$ °C, and a thickness of $t = 15$ cm, the the heat losses of the digester $\dot{Q}_{digester}$ can be estimated by the following equation. Note that the maximum temperature is chosen to compensate additional heat sources, e.g. radiation.

$$\dot{Q}_{digester} = 2 \cdot \pi \cdot k \cdot \frac{T_{i,min} - T_{o,max}}{\ln\left(\frac{r_i + t}{r_i}\right)} + 2 \cdot k \cdot \pi \cdot r_i^2 \cdot \frac{(T_{i,min} - T_{o,min})}{t}$$

The heat necessary for the input can be approximated as:

$$Q_{input} = m_{input} \cdot c_{specific} \cdot (T_{i,min} - T_{o,max})$$

The most important specifications of the reactor can be found in Table 47.

The heat necessary to heat up the sludge is approximately 2,83 kW. The heat required to compensate for heat losses through the wall is approximately equal to 6,6 kW. If the efficiency of heat recovery is assumed the be 25% it follows that the heat required is approximately equal to 38 kW. Looking at the energy potential of the required heat has to be reduced with at least a factor 3. Note, however, that this is a rough estimation.

TABLE 47: KEY SPECIFICATIONS OF THE DIGESTER CONDITIONS.

Description	Value	Unit
Temperature (mesophilic)	37	°C
Heat Transfer Coefficient Concrete	0,8	W/mK
Required Heat to compensate for Heat Loss	6,6	kW
Required Heat to Heat the Sludge	2,9	kW
Required Thermal heat	38	kW

Annex E – Legislation & Licensing

This chapter on legislation intents to provide an overview on the project specific legislation, which will be required in any case, as well as a more general overview of the legislation, which might be relevant. First a general overview is given including an overview of assessment types, relevant to the understanding of the project specific overview.

E.1 General Overview of the Legislation

The following section includes a summary of the outcomes of the meeting with Mrs. S. Giljova (Sofja), a GIZ representative coordinating the national biogas platform, and Mr. J. van Niekerk (Johann), an environmental licensing specialist.

National Environmental Management Act 107 of 1998 (NEMA)

The National Environmental Management Act 107 of 1998 contains several sections relevant to biogas applications including:

- Construction;
- Geographical location;
- Capacity of electricity;
- And storage of "dangerous waste".

In Chapter 5 of NEMA, any activities identified in the Environmental Impact Assessment's (EIA) Regulations, the NEM: WA Waste Management Regulations or the NEM: AQA Regulations must undertake either a Basic Assessment or a Scoping and Environmental Impact Reporting.

Basic Assessment and Scoping & Environmental Impact Reporting

NEMA falls under the responsibility of the provincial authorities, however, the national authorities deal with renewable energy applications in which electricity is fed into the national grid. If one of the thresholds defined in NEMA is met the activity must undergo a:

- Basic Assessment (BA);
- Or Scoping & Environmental Impact Reporting (S&EIR).

This depends on the threshold.

The procedures and conditions are outlined below. Both are similar in the requirements needed to be met, with the key difference that the S&EIR is associated with larger projects that have an impact wider than the at the immediate site. NEMA also included Special Environmental Management Acts (SEMAs), which include:

- National Environmental Management: Waste Act (NEM:WA);
- National Environmental Management: Air Quality Act (NEM:AQA);
- National Environmental Management: Biodiversity Act (NEM:BA);
- National Environmental Management: Protected Areas Act(NEM:PAA).

These fall under the responsibility of the provincial authorities (Dept. of Environmental Affairs, DEA), unless hazardous waste is being handled, in which case the national authorities take charge. If hazardous of any amount is added as a co-digester substrate the total amount of waste is treated as a hazardous waste product.

Basic Assessment (BA)

The flowchart in Figure 14 depicts the process of a basic assessment under NEMA. In the particular case of a NEM:WA. According to GIZ the characteristic duration of this procedure is 182 days.

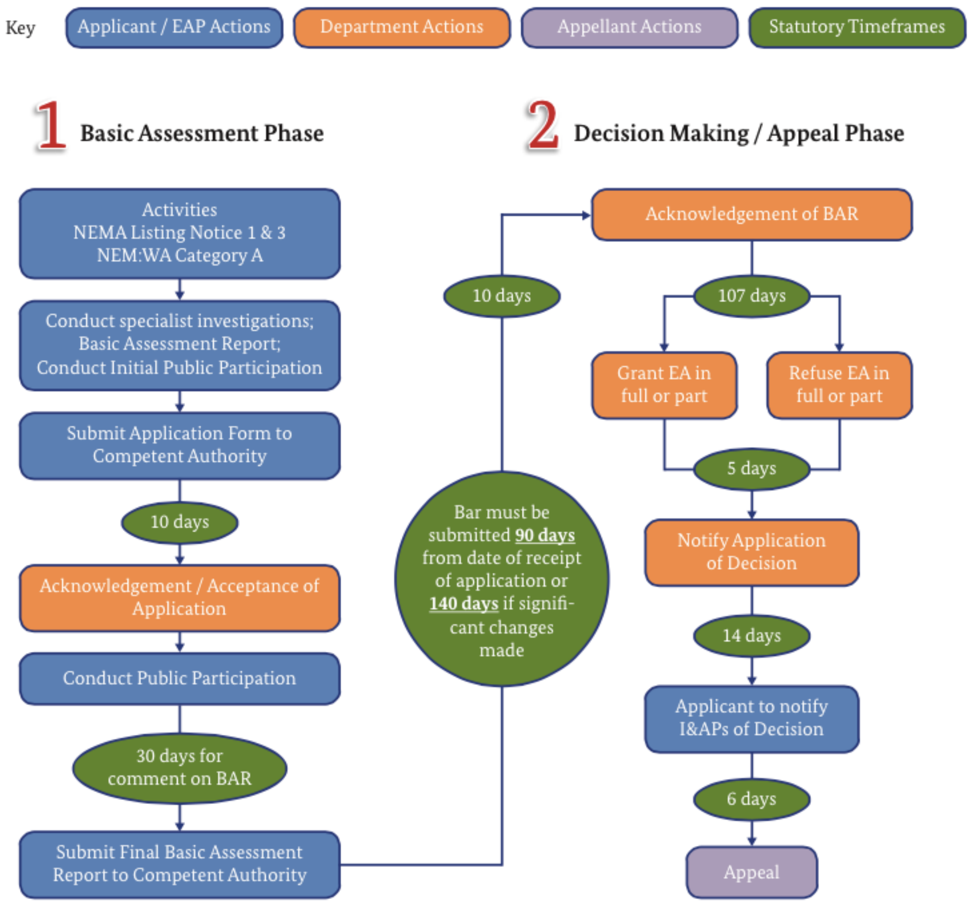

Figure 14:Basic Assessment process in terms of the 2014 EIA Regulations.

Scoping and Environmental Impact Reporting (S&EIR)

The flowchart in Figure 15 depicts the process of a basic assessment under NEMA. In the particular case of a NEM:WA. According to GIZ the characteristic duration of this procedure is 355 days.

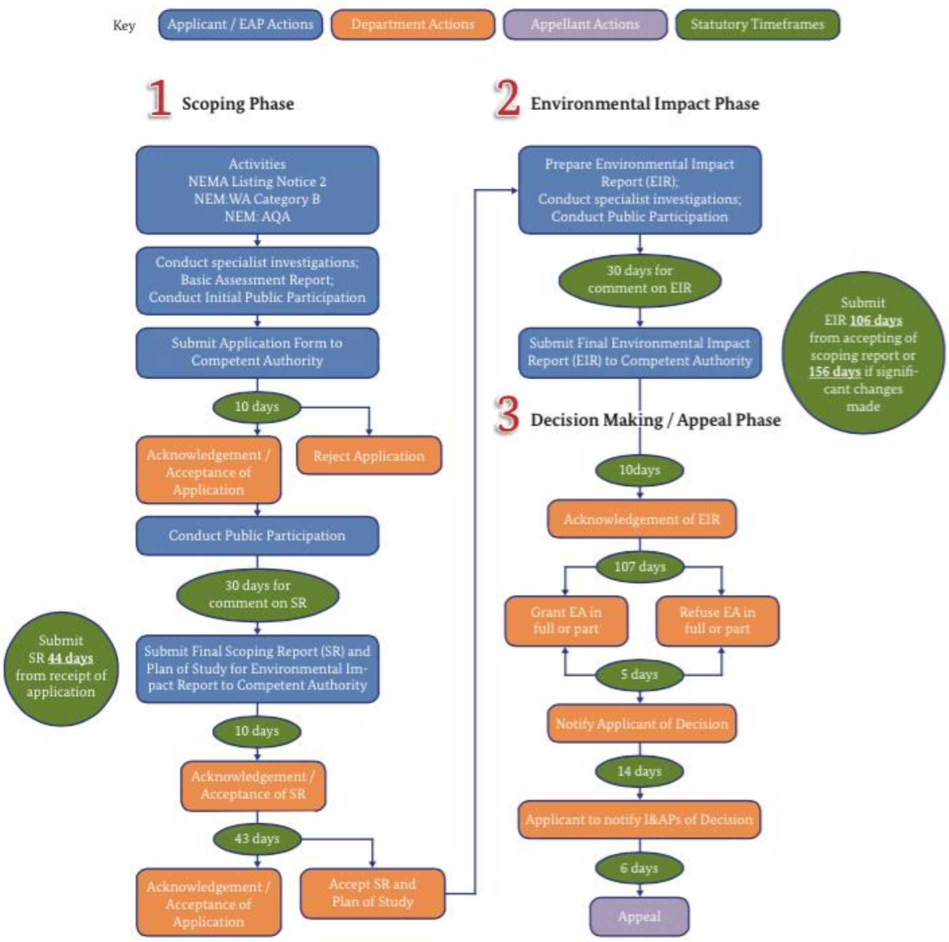

FIGURE 15: SCOPING & EIR PROCESS IN TERMS OF THE 2014 EIA REGULATIONS.

National Environmental Management: Waste Act (NEM:WA)

One of the SEMAs is the NEM:WA a regulation stating the requirements of licenses for the handling of waste — a waste license. The NEM:WA is conducted in different ways according to the amount of waste being dealt with. In the context of biogas this means that if more than 500kg of waste material are being handled an S&EIR is the chosen option. According to GIZ it either takes 182 or 355 days for the BA and S&EIR respectively.

According to Mr. van Niekerk, a private advisor in licensing, the EIA needs to be applied for if the footprint of the system is larger than 5ha or larger than 1ha if the biogas digester is located at a farm. He estimates the costs at 50.000 ZAR and duration of 12 months till its acquisition.

According to Mr. van Niekerk, the process takes about 12 months. He also estimates the cost of a waste license at approximately 30.000 ZAR. He also states that the license requires renewal every two years at a much lower cost.

National Environmental Management: Air Quality (NEM:AQA)
The responsible authority for this SEMA is municipal, however, the responsibility has been delegated to the provincial and national authority in some cases. If boiler heat output is greater than 50MW and the engine heat input greater than 10MW an Atmospheric Emissions License (AEL) is required. In the case of which an S&EIR is conducted. If changes to existing facilities are made which require amendments to the AEL then a BA is conducted.

According to Mr. van Niekerk a plant owner needs to apply for an AEL if the solid waste processed exceeds 1000 kg (This value contradicts the value given by GIZ and will be investigated). The authorities treat one 1.500.000 L of liquid waste as 1000kg of solid waste. It takes about 4 months until the license is granted. He recommends to start with the application for the AEL immediately as this can result in a cost reduction of 200.000 ZAR if the necessary knowledge can be acquired from other licenses. It is composed of application fees of 50.000 ZAR, determining gas composition of 100.000 ZAR, and air dispersion of testing of R90k. In the best case scenario it only costs 40.000 ZAR and annually 6000 ZAR.

National Environmental Management: Biodiversity Act (NEM:BA)
The competent authorities for the NEM:BA are the provincial or national authorities of the DEA. The Impact on biodiversity is included in the EIA, if the facility is located in specific geographically and specially defined areas especially if indigenous feedstock is used.

National Environmental Management: Protected Areas Act (NEM:PAA)
The competent authorities for the NEM:BA are the provincial or national authorities of the DEA. When considering site locations it is recommended the site is not located within or near protected areas. It also is included in the EIA.

According to birdlife.co.za there are several rare bird species whose protection they encourage — a future risk to be considered .

National Water Act 36 of 1998 (NWA)
The responsibilities of the National Water Act fall under the national Department of Water Affairs & Sanitation (DWS). It deals with the control of emergency incidents and a number of waste management uses, the discharge of water containing waste through pipes, and the discharge, which has an effect on a water resource. It also deals with the sustainable use of the resource.

Water Use License Applications (WUL)
A Water Use License is required in most cases, in which the municipality does not supply water. As depicted in Figure 16 the process takes approximately 498 days.

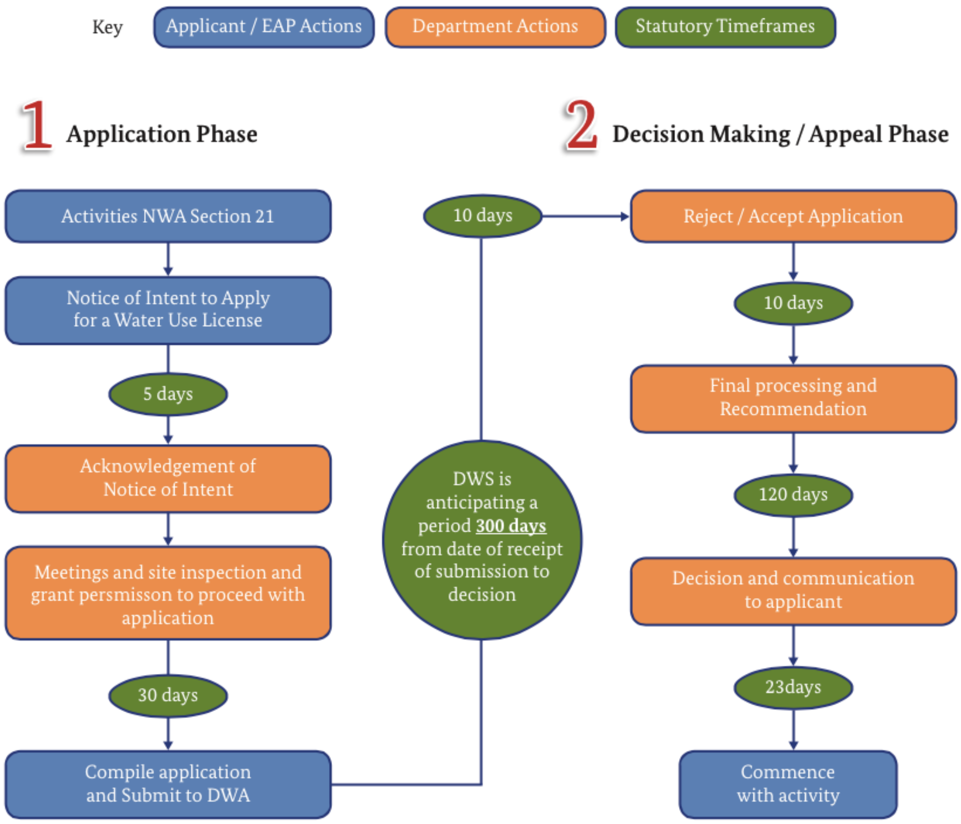

FIGURE 16: DRAFT PROCESS FLOW CHART IN TERMS OF THE NWA

According to Mr. van Niekerk the WUL is required in extraction, lagoon, and irrigation applications. It takes about 2 years and costs 50.000 ZAR until the license is granted.

Moreover he states that borehole applications require geo-hydrological studies to determine the water capacity, which costs 50.000 ZAR.

Hazardous Substances Act 15 of 1973 (HSA)
The competent authority for HSA related activities is the Department of Health. The act aims to provide control of any substance that could harm human's health. Certain types of abattoir waste are considered hazardous, which is why this is important in abattoir waste feedstock applications. A license for handling is required by the Dept. of Health and is usually handled as a part of the NEM:WA.

National Heritage Resources Act (Act 36 of 1998)
The competent authority for the National Heritage Resources Act (NHRA) is either the provincial or national Heritage Authorities. It promotes the good use of the national estate, which includes zoning of the country, roads etc. According to section 38 of the NHRA the construction of a road longer than 300m requires a license. The rezoning of an area larger than 10.000 m^2 requires a license as well.

Subdivision of Agricultural Land Act (SALA, Act 70 or 1970)
Subdivision of Agricultural Land is not permitted without the consent of the Minister of Agriculture. The act is implemented by the Department of Agriculture, Forestry & Fishery (DAFF). In the event that subdivision is necessary the planner needs to submit the necessary applications documents to receive permission. There are no statutory timeframes defined for the SALA.

According to Mr. van Niekerk the terrain of a commercial biogas application requires (industrial) rezoning. This process takes approximately 8 months and costs 60.000 ZAR.

Fertiliser, Farm Deeds, Agricultural Remedies And Stock Remedies Act (Act 36 of 1947)
The Act aims to control the sail and use of substances that may prove detrimental to livestock and the environment. The sale of fertilizer from the digester slurry will require licensing.

National Gas Act (NGA, Act 48 of 2001)
The competent authority for NGA related activities is the National Energy Regulator of South Africa (NERSA). Registration with the NERSA in terms of the NGA is required in the following applications:

- Production of gas
- Import of gas
- Transmission of gas for own exclusive use
- Small biogas projects not connected to the grid

A license is not necessary in the following applications—registration with NERSA, however, is mandatory:

- Any person engaged in the transmission of gas for that person's exclusive use.
- Small biogas projects in rural communities not connected to the national gas pipeline grid.
- Gas reticulation and any trading activity incidental thereto.
- Liquefied petroleum gas supplied from a bulk storage tank or cylinder, piped at less than 2 bar gauge and crossing no more than four erf lines between separate property boundaries.

In all cases a license is required.

Electricity Regulation Act (ERA, Act 4 of 2004)
The applicability of this Act to biogas facilities relates directly to the use of the generated electricity. Certain exemptions are identified in the Act with regard to the obligation of a generator to apply for and hold a license. These are:

- Any generation plant constructed and operated for demonstration purposes only and not connected to an interconnected power supply;
- Any generation plant constructed and operated for **own use**; and
- **Non-grid connected supply of electricity** except for commercial use.

According to Mr. van Niekerk this license for a grid-connection costs 10.000 ZAR.

E.2 Project Specific Overview of Necessary Licenses

This section provides an overview of four licenses in particular, as they will be required in any case of the realization of this project. It will include references to the respective legislation, the required licenses and a breakdown of the requirements they will entail. The description offered in this section is based on a break-down provided by an environmental consultant (Louise Mari van Zyl).

National Environmental Management: Waste Act (NEM:WA)

Abattoir waste is currently classified as hazardous waste in terms of the National Environmental Management Waste Act (NEM:WA). As soon as hazardous material is mixed with general waste, later is viewed as polluted or contaminated and thus considered hazardous as well. This means that the entire substrate will be regarded as hazardous. Activity 4, category B of NEM:WA is triffered for the treatment of hazardous waste exceeding 1 ton per day, which is the case in this situation.

The Legislation proscribes the necessity of a Waste Management License (WML), and will have to undergo what is called a Full Scoping & Environmental Impact Assessment in terms of NEMA.

National Environmental Management: Air Quality Act (NEM:AQA)

In this case manure is used as feedstock, which triggers category 10 of NEM:AQA for th treatment of animal matter exceeding 1 ton though digestion. An Air Emission License (AEL) will be required, and must undergo a full S&EIR.

National Environmental Management Act (Activity 28)

Activity 28 of NEMA (Regulation 984) is automatically also triggered because of category 10 of MEM:AQA. This activity (28) means that if any legislation is triggered, that requires a license or permit for air emissions, then you also have to apply into NEMA — an Environmental Authorization. This also has to undergo an S&EIR.

Procedure for the WML, the AEL, and the NEMA

In order to obtain all three licenses it is possible to follow an integrated process via the Department of Environmental Affairs (DEA), which evaluates and issues an integrated authorization to all legislation mentioned.

Water Use License Application (WULA)

If the slurry is used for irrigation (fertilizer), an application to the Dept. Water Affairs (DWA) is required, in order to obtain a WULA, in order to check the quality of the slurry and to ensure, that the application doesn’t result in any ground or surface water pollution. This will require, regular testing of the boreholes. The boreholes, will also have to be register with the DWA, as they are the main water supply for the plant.

Overview of Legislation, Licenses and Requirements

Listed blow in Table 48 is an overview of the required licenses and the required actions necessary to obtain them.

TABLE 48: REQUIRED LICENSES INCLUDING ABATTOIR WASTE

Legislation	License	Assessment Type	Required Actions
National Environmental Management: Waste Act NEM:WA	Waste Management License (WML)	S&EIR	• Provision of microbiological test data
National Environmental Management: Air Quality Act	Air Emissions License (AEL	S&EIR	• Either, verification of lack of air pollutants. • Or, performance of dispersion model determining the potential for emissions pollution. (expensive, but depends on municipality)
National Environmental Management Act (Activity 28)	Environmental Authorization (NEMA)	S&EIR	• Mostly, information from WML, AEL
National Water Act 36	Water Use License (WULA)	No information	• Ground water pump test • Sufficient borehole water for the surrounding environment

Unofficial Cost Estimate of S&EIA

The overview of the necessary costs in Table 49 is what the team utilizes in order to assess the costs necessary to obtain the required licenses for the biogas plant. It is not accurate, and merely based on rough "guessing-work" of an industry expert.

TABLE 49: UNOFFICIAL COST ESTIMATE OF S&EIA.

Category	Cost Estimate
Pre-Application & Start-up	ZAR 50.000
Stakeholder Engagement & Public Participation	ZAR 65.000
Impact Assessment	ZAR 80.000
Notification of Decision	ZAR 3.000
Total (excluding VAT and disbursements costs)	ZAR 198.000

Annex F – Alternative Business Models

Upon request of the company, the business model that has been presented in this study is based on a wheeling agreement. In this Annex, alternative business models will be presented as well as possible additions. As the company is striving to produce electricity, the scenario of biogas production and sales will be excluded from these options.

F.1 Business Model 1: 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 therefor 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.

The possible types of wheeling agreements are (Eskom, 2012):

- A generator sells the energy it produces directly to a buyer and not to a utility
- A municipality wheels energy from its own reticulation to ESKOM customers within close proximity to the municipal reticulation or vice versa (see Figure 17).

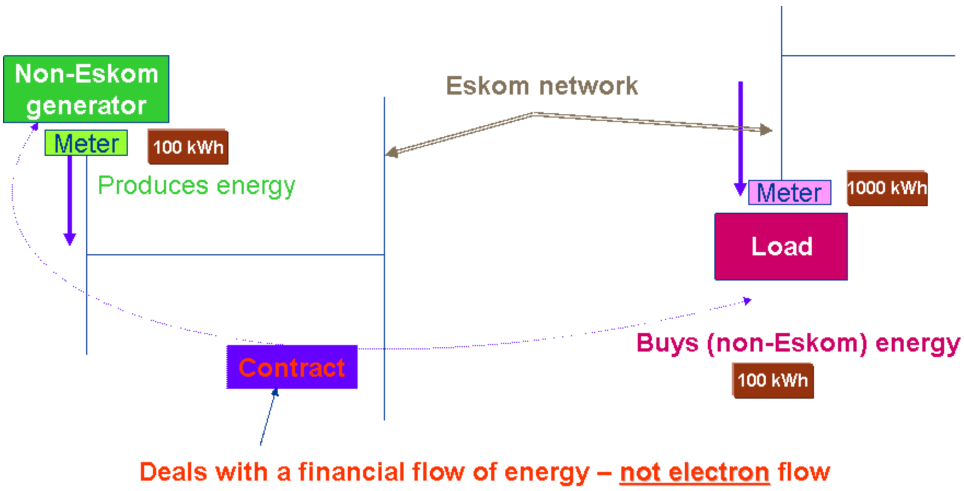

FIGURE 17 WHEELING AGREEMENT.

Connections to the grid must meet the following conditions:

- Generators cannot exceed 300MW
- Generator does not connect at low-voltage (<1 kV)

Charges payable by generator
All generators, whether selling wheeled energy or not, will be required to pay NERSA approves use-of system charges, as listed below.

- Network charges (transmission & distribution)
- Losses (transmission & distribution)
- Reliability services (system ops)
- Service and administration charges (transmission & distribution)

Charges payable by buyer
All loads connected to the network of ESKOM, whether selling wheeled energy or not, will be required to pay NERSA approves use-of system charges, as listed below.

- The costs of providing reliability services for the energy supplied by ESKOM and the generator based on the total energy consumed by the customer (ESKOM wheeled and the wheeled energy).
- Network charges on all energy delivered.
- The costs of losses for the energy supplied by ESKOM and by the generator, i.e. total energy delivered at the standard tariff loss factors.

F.2 Business Model 2: Renewable Energy Independent Power Producer Procurement Programme (REIPPPP)

South Africa has a high level of Renewable Energy potential and presently has in place a target of 10.000 GWh of Renewable Energy. The Minister has determined that 3 725 megawatts (MW) to be generated from Renewable Energy sources is required to ensure the continued uninterrupted supply of electricity. This 3.725 MW is broadly in accordance with the capacity allocated to Renewable Energy generation in IRP 2010-2030 (Department of Energy South Africa).

This IPP Procurement Programme has been designed so as to contribute towards the target of 3.725 megawatts and towards socio-economic and environmentally sustainable growth, and to start and stimulate the renewable industry in South Africa. The latest allocation for Biogas is 12,5 MW.

In terms of this IPP Procurement Programme, the Bidders will be required to bid on tariff and the identified socio-economic development objectives of the Department. The generation capacity allocated to each Technology is in accordance with the adjacent table and the maximum tariff that a Bidder may bid for purposes of the IPP Procurement Programme is as set out in the RFP. Prior to accessing the RFP, each prospective Bidder shall be required to pay a non-refundable fee of R15.000 (fifteen thousand Rand) per Bidder, and to complete the registration form.

Currently only bidders with an installed capacity of 1MW or larger are eligible to the bidding process.

F.3 Business Model 3: Electricity Generation for Personal Use

Another option would be to generate electricity for personal use. In this case, the company would provide electricity to a private off-taker through a direct connection (without using the Eskom grid) rather than via a wheeling agreement. This would significantly improve the value proposition, compared to using a wheeling agreement. In the case of a wheeling agreement, the private off-taker will still be affected by load-shedding at peak demand as this is caused by a system interruption related to the local network and energy constraints (Eskom, Process and pricing for the third party transportation of energy (wheeling) over Eskom networks due to a bilateral trade (Information Brochure), 2012). The off-taker is not excluded from these system interruptions. In the case of direct power purchasing without using the Eskom grid, the off-taker will be provided with stable baseload which is not affected by system interruptions. Furthermore, the company would be able to lower their price of electricity due to reduced expenses on for instance use-of-system charges. As such, the value proposition would not only include an improved image, but also increased energy security – at a lower price than can be offered by the current business model. In the case that the off-taker is an abattoir, there is another added value which is the provision of heat as a disinfectant.

If such a model were to be adopted, it could be a good idea to seek the off-taker among the biomass suppliers. The advantage of this is that such a partnership will lead to a greater commitment of the biomass supplier to the business, providing additional security to the project. In that case, it should be considered to locate the biogas plant in the near vicinity of the supplier instead of on the Chick 'n Chain farm. It should however be noted that most of the selected biomass suppliers are not wealthy and might not be able to afford the increased price of electricity from biogas. Furthermore, as the installed capacity of the biogas plant is expected to be relatively low, the biogas plant will most likely not be able to fully cover the baseload demand of the off-taker.

F.4 Business Model Expansions

The primary revue streams, whether it is a wheeling agreement with a private buyer, an IPP feeding into the grid, or a plant for personal are based mainly on the cost to produce electricity and the resulting revenue stream of this end product. The business model can be expanded to incorporate additional revenue streams, such as by means of carbon credits, renewable energy certificates, the utilization of fertilizer as a product, and the utilization of $C0_2$ emissions. The proposed expansion possibilities do not come without their challenges—of which we can only skim the surface—however we introduce the concept of these models and propose a possible action plan.

F.4.1 Voluntary Emission Reduction (VER)

Currently, no carbon tax or cap-and-trade mechanism to actively induce a CO_2 emissions reduction South Africa has been introduced. Therefore, all trading of carbon has happened on the voluntary market. The government is currently contemplating a carbon tax, which could be introduced as early as 2016—a measure which would affect the carbon credits market. Voluntary Emissions Reductions (VERs) also known as Verified Emissions Reductions (VERs) are a type of carbon offset exchanged in a voluntary market for carbon credits. One VER is equivalent to 1 ton of CO_2 emissions and can be traded on the voluntary market. In order to be traded, the certificates need to be verified in a certification process. There are many established standards organizations, that can be utilized, i.e. the CDM Gold Standard (CDM = "Clean Development Mechanism"), or the Verified Carbon Standard (VCS).

Challenges

Probably the biggest challenge a company faces in the attempt to incorporate VERs in their business model, is the certification process and the costs involved. In the case of biogas, the measure is the reduction of CO_2 emissions, if the energy produced had been produced by a fossil-fueled power plant. The process can be very expensive and bureaucratic, which is especially the case for the CDM Gold Standard.

Proposed Action Plan

The team proposes researching all potential certifications institutions and evaluating their respective pros and cons, which can include, cost involved or the bureaucracy involved. A selection can then be made, followed up by financial evaluation and an inclusion in the business model, if the revenue stream significantly enhances the overall value proposition. See the proposed action plan in the flow chart in Figure 18.

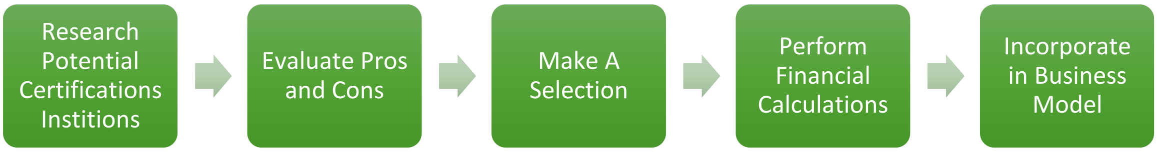

FIGURE 18: PROPOSED ACTION PLAN FOR THE INCORPORATION OF VERS IN THE BUSINESS MODEL.

F.4.2 Renewable Energy Certificates (RECs)

Renewable Energy Certificates are credits attainable per produced kWh of renewable energy and can be traded similar to the way VERs are traded today. The carbon tax and offset scheme proposed by the South African national government, will enable TRECs to kick-off in South Africa. Once this occurs, RECs can be incorporated into the business model. At this point in time, however, there too many uncertainties to pursue the incorporation of this business model.

Proposed Action Plan

The team recommends to closely monitor the development of RECs in South Africa. When the governing bodies have legally instated a system for tradable RECs the advantages and disadvantages can be evaluated and compared to the VER market and can be incorporated into the business model. See the proposed action plan in Figure 19.

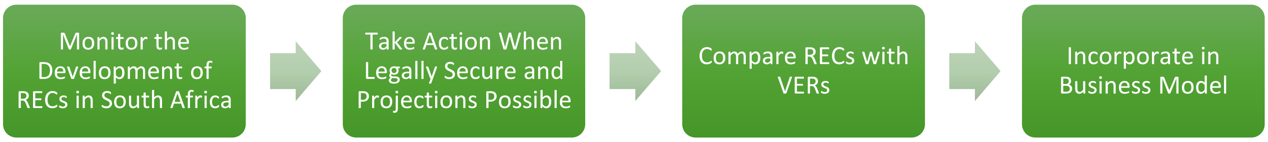

FIGURE 19: PROPOSED ACTION PLAN FOR THE INCORPORATION OF RECS IN THE BUSINESS MODEL.

F.4.3 Fertilizer

Post-digestion, the biogas digester’s output yields not only biogas, but also an organic slurry, which can be used for fertilizer. Animal manure, or abattoir waste already can be composted and utilized as fertilizer, and many farming companies do this already. The resulting slurry can be sold to farmers, who have a high demand for quality fertilizer in order to include an additional revenue stream in the biogas business’s business model.

Challenges

There are a number of challenges that this business model expansion faces. One example is the incorporation of the revenue stream prior to construction. It is quite difficult to predict the nutritional value of the resulting fertilizer, as the products haven't been researched thoroughly enough in South Africa. This makes it very difficult to assign a price to the fertilizer, and does not result in a reliable projection of the revenue streams. Furthermore, at the moment this market segment appears to be underdeveloped as the limited amount of knowledge on biogas and the quality of its fertilizer is believed to result in a low demand. Most companies in South Africa, have so far not incorporated this revenue stream into their business model prior to successful commissioning and operation of their biogas plants. As such, it is recommended to instead use the provision of fertilizer as a compensation for the biomass suppliers in order to convince them to support the business.

Proposed Action Plan

It is recommended to take a series of steps, which should be taken to acquire the necessary information to incorporate this revenue stream into the business model. A prerequisite is the commissioning and sustained operation of the plant, especially the digester. That being said at least one cycle of the retention time after full-loading of the digester needs to be completed. Samples must be taken to determine the nutritional value of the slurry—an expert needs to be consulted. All necessary licenses must be acquired to be able to sell the fertilizer lawfully. The product type must be defined, which is either a liquid or solid (dry) fertilizer. The pros and cons must be evaluated. After this a value per kg or m^3 can be assigned to the fertilizer in order to make financial calculations. If a buyer has not been found yet, this can be pursued, with a better foundation for price negotiation. See the proposed steps in Figure 20.

FIGURE 20: PROPOSED ACTION PLAN FOR THE INCORPORATION OF FERTILIZER IN THE BUSINESS MODEL.

F.4.4 CO2-Emissions Utilization

The benefits of carbon dioxide supplementation on plant growth and production within the greenhouse environment have been well understood for many years. Carbon dioxide (CO_2) is an essential component of photosynthesis (also called carbon assimilation). Photosynthesis is a chemical process that uses light energy to convert CO_2 and water into sugars in green plants. These sugars are then used for growth within the plant, through respiration. The difference between the rate of photosynthesis and the rate of respiration is the basis for dry-matter accumulation (growth) in the plant. In greenhouse production the aim of all growers is to increase dry-matter content and economically optimize crop yield. CO_2 increases productivity through improved plant growth and vigour. Some ways in which productivity is increased by CO_2 include earlier flowering, higher fruit yields, reduced bud abortion in roses, improved stem strength and flower size. Growers should regard CO_2 as a nutrient. (http://www.omafra.gov.on.ca/english/crops/facts/00-077.htm).

Challenges

In order to develop the business model by utilizing CO_2 emissions in greenhouses a buyer must be found, and thereby a greenhouse farm would have to be established in the surrounding area. If this can be encouraged in anyway possible the business model could take on two shapes. Either the CO_2 would be sold as a supplement to the owner of the greenhouses, or the “waste-product” CO_2 could be used to supplement greenhouses in the position of the biogas company and the resulting increased yield in crops could be viewed as a revenue stream.

Proposed Action Plan

The team proposes exploring the possibility of greenhouse farming in Devon and selecting one of the proposed revenue models. The scale of the farm would be dependent on the CO_2 emissions acquired from the combustion of the biogas. The concept could then be incorporated into the business model. See Figure 21 for a visualization of the proposed action plan.

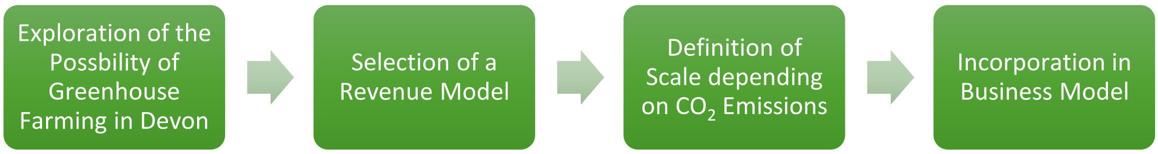

FIGURE 21: PROPOSED ACTION PLAN FOR THE INCORPORATION OF CO_2 EMISSIONS UTILIZATION IN THE BUSINESS MODEL.

F.4.5 Abattoirs

Though not necessarily a business model expansion, the company could also consider serving another customer segment in the future, namely the abattoirs in the area of Devon. In 2004, the government of South Africa placed significantly stricter requirements on waste management by abattoirs through their Meat Safety Act (Act 40) and processing waste has since become an issue of concern to many abattoirs. One of the ways to process abattoir waste is by using it as feedstock for biogas production and the company could thus consider including this in the biomass supply. It should be emphasized that by processing abattoir waste, the company would be providing a valuable service to the abattoirs and they should not be seen as only a biomass supplier but also as a customer. In such a scenario the company should consider either demanding free transportation of the abattoir waste to the biogas plant or potentially even charge a fee for reducing the abattoir’s waste quantity. However, due to the legislative difficulties and associated costs that arise when using abattoir waste as feedstock, it is advised to not include abattoir waste as feedstock at this moment.

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