Mid-Term Project Report

Biogas Business

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

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Project owner
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2 Introduction

To date, biogas has shown significant potential as a renewable energy source. 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 digesters installed in South Africa at present (Ruffini, 2013) . Especially, considering the substantial opportunity of biogas from agricultural activities in combination with the proven state of the technology.

The Chicken Chain Farm in Devon, a township located in the province of Gauteng, South Africa is one of the few who has seen and taken advantage of the potential of biogas. The farm has the ambition to become self-supporting in its energy supply. In its 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 Technical University of Delft in the Netherlands realized both a prototype biogas digester and a solar photovoltaics system, which provide the farm with its minimum gas and electricity demand respectively. The water demand is covered by the supply of two boreholes and collected rainwater.

At present, the farm plans to develop a biogas business. Hereto, a project is initiated by prof. T.A. Mofokeng, owner of the farm, and dr. O. Kroesen, assistant professor at the Technical University of Delft. By means of the project, the farm'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 the municipality of Devon, South Africa, by summer 2016.

In order to carry out the project in its entirety, 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 will continue the first team's work, whose timeframe has not been defined yet.

This report provides its reader with an in-depth understanding of the first two phases of the project, namely the exploration phase and the design phase. The outline of the report is as follows. To start, the scope of the project is discussed. Secondly, the project organization is explained. Thirdly, the objectives of the aforementioned phases are elaborated upon. Hereafter, the methodology to meet the objectives is discussed. The accompanying planning can be found in the fifth chapter. In the body of the report the findings of the exploration phase and the design phase can be found. The report concludes with a conclusion and recommendations for the follow-up team.

3 Scope

The first project team's tasks will 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.

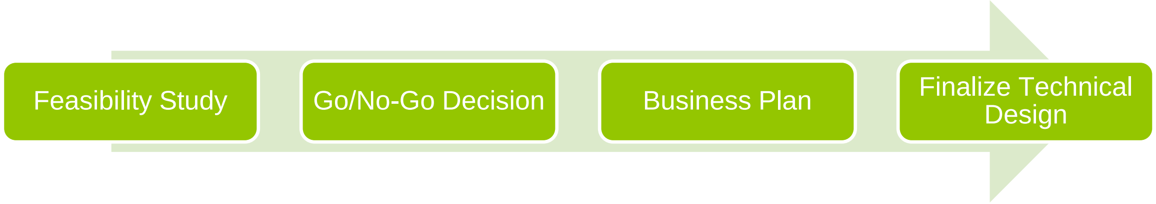


Figure 1: Project Flowchart.

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, and environmental framework from multiple angles and aims to demonstrate the feasibility by means of a cost-benefit analysis, thus leading up to a final "go- or no-go decision". In the case of a "no-go decision" the problem will be further analysed in order to determine an alternative possible feasible business scenario.

In the case of a go decision a business model will be developed by utilization of the Osterwalder Canvas for sustainable entrepreneurship. Most importantly the team pursues the objective to develop a business model, which balances the exploitation of business, technical social, and ecological opportunities in the environment of Devon. The team will formulate an internal and external business plan, which includes a risk-analysis, an actor analysis and an elaborate financial plan.

The biogas system can be designed in more detail once the business plan has been fully developed. It will be 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. These parameters set the foundation to model and simulate the technical system, determining its operation conditions.

4 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. A more detailed discussion on the cooperation and task division among the team members can be found in the section Project Planning.

Bart Frederiks MSc.
Bart Frederiks received his Master's degree in Development Studies from the Technical University of Eindhoven. Currently, he works as a freelance consultant with some 15 years of experience in the field of biomass and bioenergy. 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 Technical. He also teaches technology, innovation and development at the Technical University of Eindhoven. He has an affinity for the development of technology in developing countries. In the context of the project, he 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 currently 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
Len Rijvers is a student who received his Bachelor's degree Mechanical Engineering from the Technical University of Eindhoven. 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
Roxanne Goemans is a student who received her Bachelor's degree Molecular Science and Technology from the Technical University of Delft. 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.

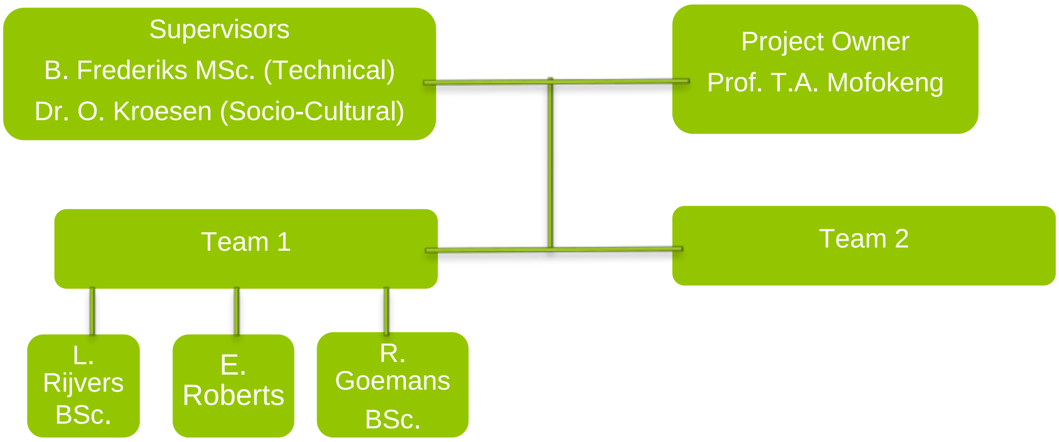


Figure 2: Organogram of the project team.

5 Objectives

As aforementioned the project's goal is to develop a commercially viable and sustainable biogas business in Devon, South Africa, by summer 2016. In order to accomplish this goal, it is broken down into three objectives, namely

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 clear tasks, they are in-turn broken down into sub-objectives. In this section the breakdown of the objectives into tasks is explained.

5.1 Objective I

Objective I is broken down into seen sub-objectives. To start, the stakeholders and the extent to which they can contribute to the execution of the project are identified. The appropriate stakeholders are subsequently addressed to determine the legislation (including licensing and regulation enforcement) around the electricity-producing biogas business. Moreover, the biogas production potential is determined by contacting the biomass suppliers in the surrounding area of Devon. Next, the location of the biogas system will be determined by means of a selection procedure. This selection procedure is mainly based on the local natural & climate conditions, water supply and available infrastructure. Based on the selected biomass suppliers and the selected location, the most suitable technology for the biogas system is identified. In parallel, the potential customers and their energy demand are determined. Finally, the feasibility and profitability of the electricity-producing biogas business is assessed by subjecting two scenarios to a cost-benefit analysis. For the first scenario, potential financial incentives are taken into account, while this is not done for the second scenario.

Table 1: The sub-objectives of Objective I.

Stakeholders

- Identify the stakeholders and the extent to which they can contribute to the exectution of the project.

Legislation

- Determine the legislation which affects independent power production in Devon.

Suppliers

- Determine the daily availability, type & composition, supporting transportation infrastructure and costs of biomass at each suppliers' location.
- Make a preliminary selection of biomass suppliers.
- Determine the maximum biogas production potential according to the biomass suppliers

Location

- Determine the nature & climate conditions and the extent to which they will influence the biogas production.
- Determine the daily availability and total storage capacity of water at each possible location.
- Determine the limitations that the current electricity distribution and transportation infrastructure. has on the production capacity of the biogas system and rank possible location.
- Determine the optimum location based on the ranking above.

Customers

- Identify potential customers and their electricity demands.
- Identify potential customers of biogas by-products.

Technologies

- Identify the most suitable technologies for the biogas system.

Cost-Benefit

- Identify possible financial incentives available to the biogas business.
- Perform Cost-Benefit Analysis with and without funding opportunities to showcase the feasibility and profitability of the project.

5.2 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 business, 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 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 until the delivery of the project. The financial plan will also contain an approximation of the operation and maintenance costs, which is why 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.

Table 2: The sub-objectives of objective II.

Sub-objective	Description
Business Model	Construct a business model, which balances the exploitation of business, technical, social and ecological opportunities.
Actors	Perform actor analysis.
Competition	Analyze competition, to which extent they pose a threat to the biogas business.
Finance	Develop a financial plan to demonstrate and predict current and future cash flows as well as investment conditions.
Risk-Management	Perform a risk-analysis until delivery of the project.
Operation & Management	Develop an operation and management plan.
External	Tailor business plan to an external business plan.

5.3 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. The process of completing the design will have to be completed by the follow-up team.

Table 3: The sub-objectives of objective III.

Specifications
• Determine the technical specification of the system components.
System Components
• Select possible system components based on previously determined criteria including: availibility & cost, risks involved and make-or-buy decisions.
Layout
• Construct the layout of the facility at the selected location.
Model & Simulation
• Create a model and simulate the system in operation in oder to determine the operational conditions.

6 Methodology

The sub-objectives are broken down into a selection of actions, including methods such as stakeholder interviews, measurements, estimations and calculations based on literature research. In order to ensure validity of the information and data required it is acquired by use a combination of these methods. The interviews are prepared and conducted in a semi-structured format in order to adapt to the local cultural norms. Measurements include gas flow measurements by use of a gas meter, electricity measurements using a multi-meter and weight measurements using scales provided at the farm. Estimations and calculations are made based on common literature values in order back the empirical data. Data retrieval in all cases is stored in standard documents and spreadsheets.

6.1 Methodology Objective I

1. Stakeholders
   1.1. Identify the stakeholders and the extent to which they can contribute to the execution of the project.
   - Identify all potential stakeholders by means of online research, and interviews with Prof. T.A. Mofokeng and other stakeholders.
   - Classify the stakeholders' position within the context of the biogas sector.
   - Analyze the relevant stakeholders by means of an interest/power quadrant diagram and separate them in primary, secondary and key stakeholders.
   - Determine key stakeholders for achieving the following sub-objectives.

2. Legislation
   2.1. Determine the Legislation, which affects independent power production in Devon.
   - The necessary information will be acquired by researching the available information provided online, as well as in personal meetings with stakeholders.

3. Suppliers
   3.1. Determine the daily availability, type & composition and costs of biomass at each suppliers' location.
   - Identify and list the potential suppliers by interviewing Prof. T.A. Mofokeng and using the stakeholder analysis.
   - Compile a supplier specific questionnaire containing information such as:
     - Number of animals [#] and their live weight;
     - Minimum, maximum, and average daily availability of biomass [kg/day];
     - Type & composition (dry matter – wet matter);
     - Forecast of the biomass supply;
     - The current and opportunity costs of the biomass [ZAR/kg];
     - Location and the estimated transportation costs.
   - Plan and perform an interview with the stakeholders using the questionnaire.
   - (Optional) Determine the availability of biomass [kg/day] on the basis of the stakeholder data, literature and measurements performed at the location of the farm.
   - Determine the composition of the biomass (dry matter – wet matter – inorganic matter) on the basis of literature research and measurements including:
     - Weighing a fresh sample;
     - Drying;
     - Weighing;
     - Burning;
     - Weighing ashes.

   3.2. Make a preliminary selection of biomass suppliers.
   - Define and rank the selection criteria on basis of the aforementioned parameters by means of a discussion among the team members.
   - Determine exclusion criteria based on energy potential and distance (ecological criterion, economical criterion).
   - Assess and select the suppliers on the basis of these criteria using the minutes and data sheet from the interviews with the suppliers.

3.3. Determine the maximum biogas production potential according to the biomass suppliers.

- Perform literature research on the biogas yield [l/kg] per type of biomass taking into account the prevailing operating conditions.
- The maximum biogas production can now be calculated.
- Use empirical data gained from prototype and surrounding biogas digesters:
  - Analyze the biogas digester;
  - Perform measurements (gas meter, calculation);
  - Perform interviews with stakeholders.

4. Location

4.1. Determine the nature & climate conditions and the extent to which they will influence the biogas production.

- The necessary information and data-set will be researched in literature and includes:
  - Annual precipitation;
  - Dry season (months);
  - Mean annual temperature and seasonal fluctuations;
  - Type of soil;
  - Climatic zone.
- The information and data will then be extracted by consulting nature & climate stakeholders.
- Moreover the extent, to which the biogas production is influenced by the variables, will be verified empirically by measurements performed on the prototype digester at the location of Chicken Chain Farm.

4.2. Determine the daily availability and total storage capacity of water at each possible location.

- The maximum daily water supply is determined by analyzing the specifications of the installed pump. The real supply of water is provided by test results, which are conducted and documented at the installation of the pumping system.
- Moreover the maximum daily, monthly and annual supply of rainwater can be acquired by analyzing weather & climate data provided by means of stakeholder interviews and analysis.
- Retrieve the volume, height, and elevation of the installed water storage tanks, by means of measurements and documentation for later modeling of the water system.

4.3. Determine the limitations that the current electricity distribution and transportation infrastructure has on the production capacity of the biogas system and rank possible locations.

- It might be necessary to determine the voltage of the available power lines at the location as well as the maximum power and availability of a nearby transformer, this can be achieved by contacting ESKOM, as well as site visits to determine the available infrastructure.

4.4. Determine optimum location based on the ranking above.

- The optimum location will be based on a ranking-system, based on weighting factors incl. the information of gained from the sections supplier and location.

5. Customers

5.1. Identify potential customers and their energy demands

- Explore possible business cases, i.e. wheeling agreements and personal use.
- Identify the potential customers by interviewing Prof. T.A. Mofokeng and using the stakeholder analysis.
- Compile a questionnaire containing:
  - Minimum, maximum and average daily energy demand;
  - Location of the customer;
  - Current energy tariffs;
  - Forecast on the energy demand;
  - Number of hours per year, frequency and average deviation of duration effected; by load-shedding;
- Perform an interview with the potential customers using the questionnaire.
- Besides interviews the following sources can be addressed:
  - Electricity bills;
  - Measurements;
  - Overview and the utilization rate of equipment.

5.2. Identify potential customers of biogas bi-products.

- Identify the potential customers by interviewing Prof. T.A. Mofokeng and using the stakeholder analysis.
- Compile a questionnaire containing:
  - Minimum, maximum and average daily fertilizer demand [kg];
  - Location of the customer;
  - Forecast on the fertilizer demand;
  - Current costs fertilizer [ZAR/kg].
- Perform an interview with the potential customers using the questionnaire.

6. Technologies

6.1. Identify the most suitable technologies for the biogas system

- Define the system scale which is based on the energy demand.
- Compare the performance of the pilot system with literature values. By doing so, the effectiveness of the technology is assessed.
- Identify the most common technologies applied in de biogas industry in South Africa.
- The digester and as holder technology will be chosen by evaluating the pros and cons of the respective technology similarly as in the Biogas Planning Guide found in *Biogas Digest - Volume II Application and Product Development* (Deublein & Steinhauser, 2008).

7. Cost-Benefit

7.1. Identify possible financial incentives available to the biogas business.

- Use the stakeholder analysis to identify possible financial incentives.
- Compile a questionnaire containing:
  - Type of incentive;
  - Terms and Conditions of the incentives;
  - Monetary value of the incentive.
- Perform an interview with the stakeholders.

7.2. Perform Cost-Benefit Analysis with and without funding opportunities to showcase the feasibility and profitability of the project.

- Estimate the total costs, including operational, maintenance and investment costs, by means of calculations and research.
- Estimate the total revenues, including revenues by selling energy and a monetary reduction in energy costs: by means of calculations and literature research.
- Calculate the economic indicators: Payback period (PBP), Internal Rate of Return (IRR) and the Net Present Value (NPV).
- Determine the total relative reduction of CO_2-emissions when compared to coal fired electricity generation as an factor to determine the environmental revenue.

7 Planning

In order to determine the time needed to reach the objectives an estimation for the duration to reach the respective sub-objectives must be found. This can be achieved by estimating the full-time equivalent (FTE) of the sub-objectives' actions. Estimating the total time and the respective manpower enables the calculation of FTE values based on an average 40-hour workweek.

$$FTE = \frac{Duration\ [h]}{FTE - Factor\ [h]}$$

Example:
The first sub-objective, related to stakeholders consists of four actions, whose durations in hours add up to 37 hours. This equates to:

$$FTE = \frac{37\ [h]}{40\ [h]} = 0{,}9\ [FTE]$$

In the case of this project the total duration to achieve its first objective accounts to 18,2 FTE. As three students are working on the project simultaneously, its duration can be approximated to

$$Duration\ [w] = \frac{18{,}2\ [FTE]}{3\ [Students]} \approx 6{,}1\ [weeks]$$

The planning for Objectives II and III will be conducted at a later point in time in order to improve time-efficiency, as the continuation of the project depends on the "go- or no-go decision" described in the scope of this report.

8 Status Quo

The content of the *Project Plan Biogas Business* is embodied in the previous chapters and lays a foundation for the realization of a biogas business in Devon, South Africa. It provides the internal stakeholders involved with a 'roadmap', in the form of objectives, a methodology, and a planning, towards the project's main aim, which is the exploration, design, construction, and start-up a commercially viable and sustainable biogas business in the municipality of Devon, South Africa, by summer 2016. Keeping this endeavour in the back of their mind, team 1 has kicked off the exploration phase and booked its first results. This chapter is dedicated to providing its reader with a brief overview of the team's activities in the period between the publication of the *Project Plan Biogas Business* and the *Mid-Term Project Report Biogas Business* (seeTable 1 Table 4). Hereby, the former is used as a framework. In the following chapters a detailed report of the activities, so-far, can be found.

Table 4: Status Quo of the project ranked according to objectives defined in the Project Plan Biogas Business.

Stakeholders

- About 75 stakeholders have been identified and categorized. Moreover, the extent to which they are relevant for the project is determined, see chapter *Stakeholder Analysis.*
- In total the team has met 20 stakeholders of varying background. For instance, biomass suppliers, financial institutions, consultants on legislation and cooperatives.

Legislation

- Regarding the legislation the team has met two stakekeholders, GIZ and J. van Niekerk, who are active in the legislation 'landscape' of the biogas industry in South Africa.They provided the team with a clear overview on the legislation, the costs involved and the corresponding timeframes. The findings are document in the chapter *Legislation.*

Suppliers

- The team visited about 8 potential biomass suppliers in the proximity of Devon. Using a questionnaire and a supplier selection tool, the economical biogas potential is determined. Note, however, that the bio-technical potential still needs to be determined. More information can be found in the chapter *Biogas Potential*.

Location

- In order the assess the energy management of the farm, inherent with multiple objectives, an energy audit is executed. At the time of writing, the outline of the energy audit is determined. Moreover a start is made with the energy audit. The progress made so-far is only partially documented in the chapter *Energy Audit.*

Technologies

- Multiple stakeholders, about 4, have been consulted on the biogas technologies which are commonly used in South Africa. The results still have to be documented.

General

- The team started with a literature study on business model generation.

9 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. Next, the stakeholders are categorized on base of their relevance in the course of project. Hereafter, the most important aspects of the relevant stakeholders and the nature of their interrelations are discussed in more detail. Finally, these understandings are used to set-up a plan of action to manage the stakeholders.

9.1 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.

9.2 Categorizing Stakeholders

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

- Core Business
- 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
    - Government & Regulators
    - Financial Institutions
    - Network and Consultancy Services
- Internal Stakeholders

In Table 5 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, a more in-depth description of the characteristic features of the identified stakeholders is given in Appendix B.

Table 5: Overview of the stakeholders, the category they belong to and their relevancy in the project.

#	Stakeholder [*Organization (abbreviation) – Representative / Individual – Role*]	Category	Relevant [R] / Possible [P] / Not Relevant [NR]
1	African Clean Energy Developments (ACED)	Networks & Consultancy Services	NR
2	Agricultural Research Council (ARC)	Networks & Consultancy Services	R
3	ARC Biomass Suppliers	Biomass Supplier	P
4	B. Frederiks MSc. - Supervisor (Technical)	Internal Stakeholders	R
5	Bertha Foundation	Financial Institution	P
6	Bio2Watt Pty Ltd	Networks & Consultancy Services	P
7	BiogasSA	Contractor	R
8	Brookfields Beef Pty Ltd	Biomass Supplier	NR
9	Chicken Layer Devon	Biomass Supplier	P
10	Clean Energy Africa	Financial Institution	P
11	Phulosong Cooperative Atteridgeville	Networks & Consultancy Services	P
12	Council for Scientific and Industrial Research (CSIR)	Network & Consultancy Services	P
13	Cova Advisory - Mr. T. Chipfupa	Networks & Consultancy Services	R
14	Department of Agriculture, Forestry and Fisheries (DAFF)	Government & Regulators	R
15	Department of Energy (DoE)	Government & Regulators	R
16	Department of Environmental Affairs (DEA)	Government & Regulators	R
17	Department of Trade and Industry (DTI)	Government & Regulators	R
18	Development Bank of Southern Africa (DBSA)	Financial Institution	P
19	Devon Meat Wholesalers - Mr. Gerrit	Biomass Supplier	P
20	Dr. O. Kroesen - Supervisor (Socio-Cultural)	Internal Stakeholders	R
21	Dresser-Rand	Contractor	P
22	E. Roberts – Team member 1	Internal Stakeholders	R
23	E² - Social Entrepreneurship	Financial Institution	P
24	Electricity Supply Commission (ESKOM)	Customer	P
25	ENER-G Systems	Contractor	P
26	Energy and Environment Partnership (EEP)	Financial Institution	P
27	ENSafrica	Contractore	P
28	EnviroServ	Contractor	P
29	Geselleschaft für International Zusammenarabeit (GIZ) - Mrs. S. Giljova	Networks & Consultancy Services	R
30	Industrial Development Corporation (IDC)	Financial Institution	P

#	Stakeholder [*Organization (abbreviation) – Representative / Individual – Role*]	Category	Relevant [R] / Possible [P] / Not Relevant [NR]
31	Innovation Hub	Networks & Consultancy Services	P
32	Innovative Development Solutions (IDS) Foundation	Financial Institution	P
33	Institute for Research in Waste and Resources Management (I-WARM)	Networks & Consultancy Services	NR
34	Institute for Soil, Climate and Water (ISCW)	Networks & Consultancy Services	P
35	International Energy Agency (IEA)	Networks & Consultancy Services	P
36	Johannesburg Water SOC Ltd (JW)	Networks & Consultancy Services	R
37	Karan Beef	Biomass Supplier	NR
38	L. Rijvers BSc. – Team member Team 1		R
39	Lesedi	Contractor	NR
40	Leslie Abattoir	Biomass Supplier	P
41	Michiel and Onno - Predecessors	Networks & Consultancy Services	R
42	Morgan Beef/ Abattoir	Networks & Consultancy Services	R
43	Mr. Abdul - Neighbouring Farmer	Biomass Supplier	P
44	Mr. J. van Niekerk - Consultant Legislation	Networks & Consultancy Services	R
45	Mr. Kabelo - Employee Chicken Chain Farm	Internal Stakeholders	R
46	Mr. Napol - Consultant	Network & Consultancy Service	P
47	Mr. Twala - Neighbouring Farmer	Biomass Supplier	P
48	Mr. X - Employee Chicken Chain Farm	Internal Stakeholders	R
49	Mrs. Mampe - Neighbouring Farmer	Biomass Supplier	P
50	Mrs. N. Mofokeng - Consultant Funding	Networks & Consultancy Services	R
51	Municipality of Devon	Government & Regulators	P
52	National Biogas Platform	Networks & Consultancy Services	P
53	National Energy Regulator of South Africa (NERSA)	Government & Regulators	R
54	National Research Foundation (NRF)	X	NR
55	Nova Institute	Networks & Consultancy Services	R
56	Prison Devon	Biomass Supplier	P
57	Prof. T.A. Mofokeng - Project Owner	Internal Stakeholders	R
58	R. Goemans – Team member Team 1		R
59	Re-energise Africa	Contractor	R
60	Renen Renewable Energy Solutions	Networks & Consultancy Services	P

#	Stakeholder [*Organization (abbreviation) – Representative / Individual – Role*]	Category	Relevant [R] / Possible [P] / Not Relevant [NR]
61	Rossgro - Mr. L. Smalle	Biomass Supplier	P
62	Sewage Treatment Installation Devon	Biomass Supplier	P
63	South African Bureau of Standards (SABS)	Contractor	P
64	Southern African Biogas Industry Association (SABIA)	Networks & Consultancy Services	P
65	South African Development Community (SADC)	Networks & Consultancy Services	NR
66	South African Local Government Association (SALGA)	Networks & Consultancy Services	P
67	South African National Energy Development Institute (SANEDI)	Networks & Consultancy Services	P
68	South African Waste Information System (SAWIC)	Government & Regulators	P
69	Sunshine Chicken Abattoir	Biomass Supplier	P
70	Team 2	Internal Stakeholders	R
71	University of South Africa – Prof. Dr. M. Myer	Networks & Consultancy Services	R
72	XERGI	Contractor	P

As can be seen in Table 5, per stakeholder an indication on its relevance in the project is given. The assessment whether a specific stakeholder is relevant or not depends on the category it is in and its specific criteria. For instance, a stakeholder in the category of *Biomass Suppliers* is relevant/TBD/not relevant if the supplier selection tool revealed that using biomass from this stakeholder is technically and/or economically -/TBD/not feasible. An explanation per stakeholder can be found in Appendix B.

9.3 Understanding Stakeholders and Interrelations

9.3.1 Actor Network

TBC (to be continued)

9.4 Managing Stakeholder

10 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.

10.1 National Environmental Management Acot 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.

10.1.1 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 **Error! Reference source not found.** 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.

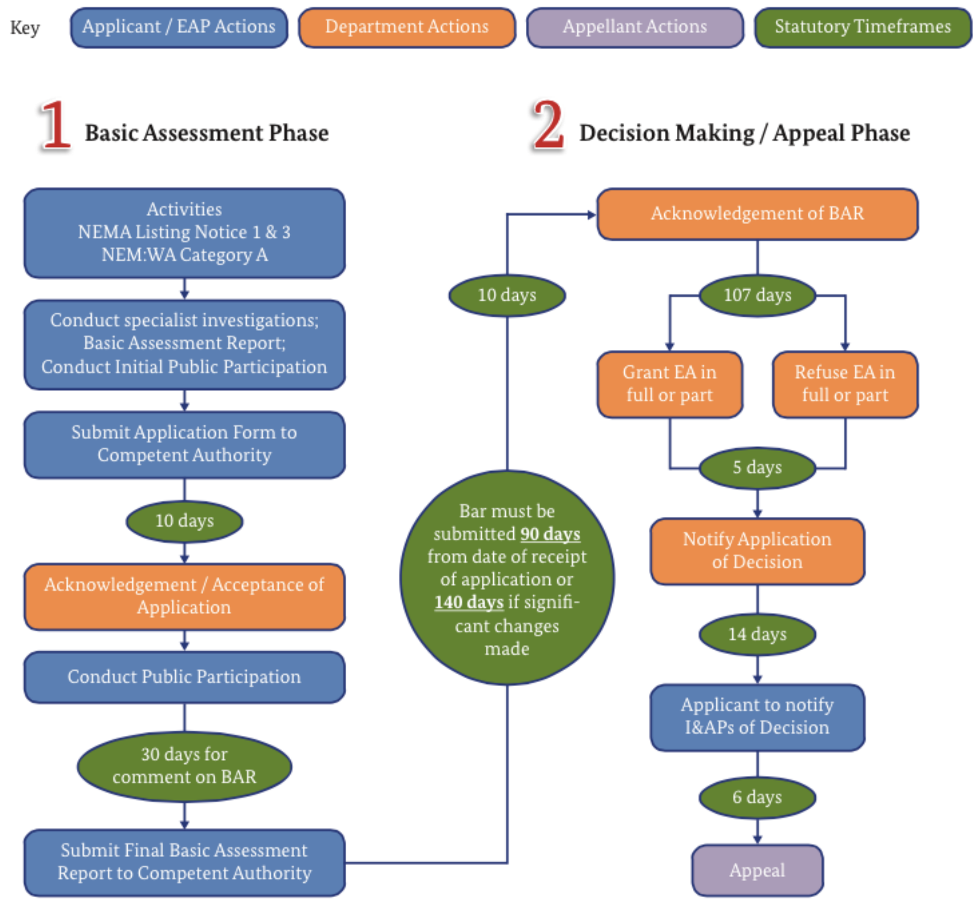


Figure 3:Basic Assessment process in terms of the 2014 EIA Regulations (Mackay, kein Datum).

Scoping and Environmental Impact Reporting (S&EIR)
The flowchart in **Error! Reference source not found.** 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.

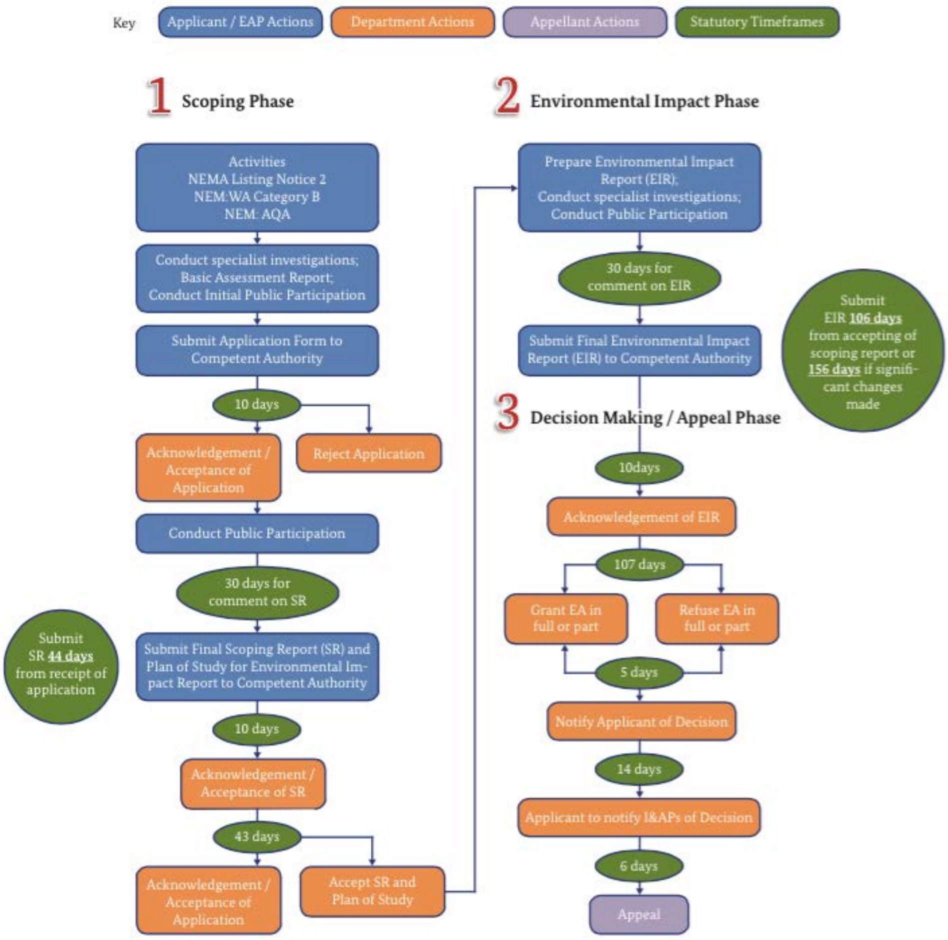


Figure 4: Scoping & EIR process in terms of the 2014 EIA Regulations (Mackay, kein Datum).

10.1.2 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.

10.1.3 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.

10.1.4 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.

10.1.5 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 (Birdlife, kein Datum)*.*

10.2 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.

10.2.1 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 **Error! Reference source not found.** the process takes approximately 498 days.

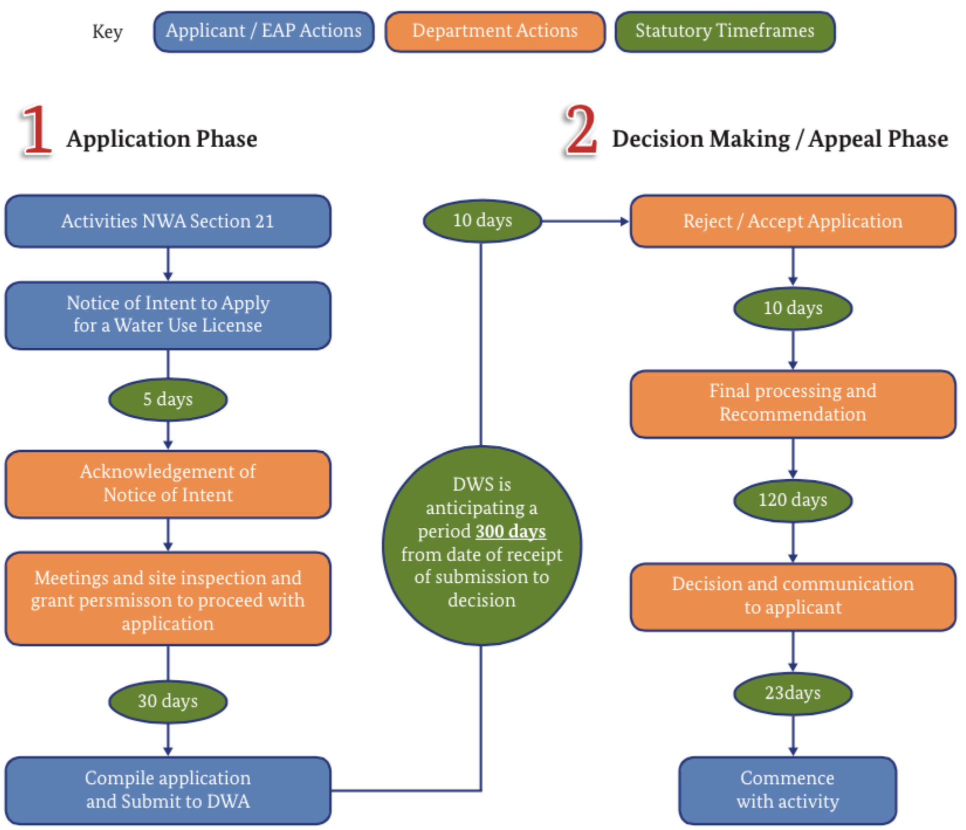


Figure 5: Draft process flow chart in terms of the NWA

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.

10.2.2 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.

10.2.3 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.

10.2.4 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.

10.2.5 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.

10.2.6 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.

10.2.7 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.

10.3 Process Overview

The minimum known processing time for all licenses is 2 years (based on statutory time frames determined by the authorities). There are still a number of licenses, which need to be taken into consideration, whose duration is unknown, Table 6.

Table 6:Statutory Timeframes for the Application of Licenses.

License Name	Condition	0	4	6	8	10	12	14	16	18	20	22	24
NEM:WA (EIA)	BA												
NEM:WA (EIA)	S&EIR												
NEM:WA (Waste lic.)	S&EIR												
NEM:AQA	S&EIR												
NEM:WA (HSA)	S&EIR												
WUL													
Geo-hydrological study		No statutory timeframe given.											
ERA		No statutory timeframe given.											
NHRA		No statutory timeframe given.											
SALA		No statutory timeframe given.											
Fertiliser		No statutory timeframe given.											
NGA		No statutory timeframe given.											
NEM:BA		No statutory timeframe given.											
NEM:PAA		No statutory timeframe given.											

10.4 Cost Overview

As not all license costs could be determined the exact costs are unknown but currently range from ZAR 230.000 in the best-case and ZAR 430.000 in the worst-case scenario.

Table 7: Cost overview.

License Name	Condition	Cost Estimations	
NEM:WA (EIA)	BA		
NEM:WA (EIA)	S&EIR	ZAR 50.000,00	
NEM:WA (Waste license)	S&EIR	ZAR 30.000,00	
NEM:AQA	S&EIR	ZAR 40.000,00	ZAR 240.000,00
NEM:WA (HSA)	S&EIR		
WUL		ZAR 50.000,00	
Geo-hydrological study		ZAR 50.000,00	
ERA		ZAR 10.000,00	
NHRA			
SALA			
Fertiliser			
NGA			
NEM:BA			
NEM:PAA			
Total Cost Estimate		ZAR 230.000,00	ZAR 430.000,00

11 Biogas Potential

11.1 Introduction

This chapter introduces the team's methodology and results for the calculation of the biogas potential at the farm.

11.2 Biogas Potential of Various Feedstock

11.2.1 Biology

The fermentation of methane 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 achieved in two stages (in practice in two tanks) — the process of degradation must be equal in size. In principle the methane formation follows an exponential curve of the form of:

$$\dot{V}_{BR} = C_1 \cdot (1 - e^{-C_2 \cdot t_{BR}}),$$

where $\dot{V}_{BR}$ is the volumetric flow rate of biogas, t_{BR} is the retention time of the substrate in the digester, and C_1 and C_2 are constants (Steinhauser, 2008).

11.2.2 Bio-chemical Processes

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 (2008), the following parameters must meet the conditions in the Table 8 below.

Table 8: Environmental Requirements.

Parameter	Hydrolysis/Acidogenesis	Methane formation
Temperature	25-35 °C	Mesophilic: 32-42 °C Thermophilic: 50-58 °C
pH value	5,2-6,3	6,7-7,5
Molar C:N ratio	10-45	20-30
DM content	<40 m% DM	<30 m% DM
Redox potential	+400 to -300mV	<-250mV
Required molar C:N:P:S ratio	500:15:5:3	600:15:5:3
Trace elements	No special requirements	Essential: Ni, Co, Mo, Se

11.2.3 Substrate Input and Composition

Introduction

As the processes require nutrients the C:N ratio of the substrate should be in the range of 16:1-25:1. This is only an indication as nitrogen can be bound in lignin structure (crucial part in the cell structure). In addition to this the C:N:P:S ratio is important as well and can be in the range of 500-1000:15-20:5:3 and or inorganic matter ratio of COD:N:P:S of 800:5:1:0,5 . 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 (Steinhauser, 2008).

Data on Sources

TBC

Water Ratio

TBC

Table 9:Volumetric Mixing Ratio of dry to wet matter from varying sources.

Application	Volumetric Mixing Ratio [dry/wet]
Pump applications	0,02-0,12%
Biogas Digest Vol. II	1/3 – 2
Martin Myer	2/3

11.2.4 Proposed Methodology to Determine the Substrate Input Composition

As the total C:N ratio R_{CN} for n-substrates must remain within a certain interval ($16 \leq R_{CN} \leq 25$), co-substrates can be added under the boundary condition of this ratio

$$R_{CN} = \sum_{i=1}^{n} x_i \cdot r_{CN},$$

where x_i represents the mass fraction of a substrate and r_{CN} represents the substrates C:N ratio.

11.3 Critical Data Acquisition

11.3.1 Introduction

This chapter introduces the relevant data the team takes into consideration to determine the biogas potential in the surrounding area of Mr. Mofokeng's farm.

11.3.2 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 and technical perspective.

11.3.3 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 including a minimum, an average, and a maximum value.

11.3.4 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 easy and reliable projection as to how much dung is available.

11.3.5 Weight of Biomass Supply

In the case of Mr. Mofokeng's farm and the Devon Abattoir, 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 farm the team will perform measurements to verify literature values giving more weight to their projections.

11.3.6 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 wet matter ratio of the substrate input. The relevant data includes determining the:

- Total Wet Matter;
- Total Dry Matter;
- Volatile Matter;
- Inorganic Matter.

11.3.7 Current Use of Biomass

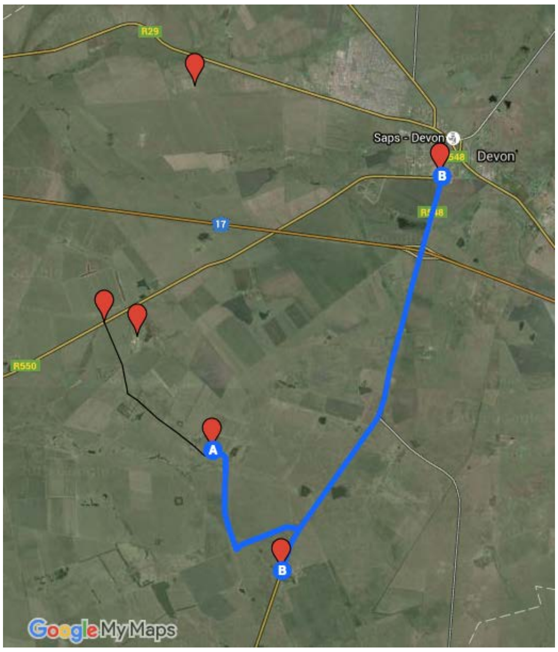
It is of great relevance to Mr. Mofokeng's biogas start-up to know what the suppliers currently do with the biomass they produce. The following possibilities exist:

- 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**).

11.3.8 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.



11.4 Supplier Selection Tool

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.

11.4.1 Ecological Criterion

The ecological quotient functions under the assumption that the potential biogas energy E_{BM} as a function of the daily biomass supply m_{BM} on the fuel energy E_{Fuel} as a function of the distance d is larger than 1 in order to make sense from an ecological perspective. This implies that the potential energy in the biomass is greater than the fuel energy converted. If this is not the case, the plant would never be ecologically sustainable, when supplied by the respective supplier. The approach states that

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

where,

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

and

$$E_{Fuel}(d) = 2 \cdot d \cdot \Psi_{consumption} \cdot c_{energy,Fuel}.$$

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 $K_{ecological}$.

$$\frac{m_{BM}}{d} > 2 \cdot \frac{\Psi_{consumption} \cdot c_{energy,Fuel}}{Y_{specific} \cdot c_{energy,BM}} \equiv K_{ecological}$$

The parameters for energy equations are given in Table 10.

Table 10:Relevant parameters for the calculation of the biogas and fuel energy content

Parameter	Description	Value
$\boldsymbol{Y_{specific}}$	Specific biogas production [m³/kg]	Slaughterhouse waste: 0,3-0,7 Cattle excreta: 0,6-0,8 Chicken excreta: 0,3-0,8 Pig excreta: 0,27-0,45 Sheep excreta: 0,3-0,4
$\boldsymbol{c_{energy,BM}}$	Specific energy [kWh/m³]	Biogas: 6-6,5
$\boldsymbol{\Psi_{consumption}}$	Specific fuel consumption [L/km]	40t-Truck: 0,3 3,5t-Truck: 0,15
$\boldsymbol{c_{energy,Fuel}}$	Specific energy [kWh/L]	Diesel: 10,72

Values for specific combinations $K_{ecological}$ using safe estimations can be found in Table 11 (goodyear, kein Datum) (IOR Energy – Engineering Conversion Factors, kein Datum).

Table 11: Possible values for $K_{ecological}$.

Specific case for $K_{ecological}$	Value
Slaughterhouse waste (40t-Truck)	21,4
Cattle excreta (40t-Truck)	10,72
Chicken excreta (40t-Truck)	21,4
Pig excreta (40t-Truck)	23,8
Sheep excreta (40t-Truck)	21,4

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 necessary.

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 easy calculation of the CO_2-emissions emitted during transport in order to calculate the plants carbon footprint.

11.4.2 Economical Criterion

The economical quotient gives a financial indication based on the quotient of all revenues R composed of electricity revenues $R_{electricity}$ and fertilizer revenues $R_{fertilizer}$ as well as all dominant costs C composed of fuel costs for transportation C_{fuel} and purchasing costs $C_{purchase}$. The inequality is formulated as:

$$\frac{R}{C} = \frac{R_{electricity} + R_{fertilizer}}{C_{fuel} + C_{purchase}} > 1$$

where

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

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

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

And

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

This implies that

$$\frac{m_{BM}}{d} > 2 \cdot \frac{\Psi_{consumption} \cdot c_{Diesel}}{Y_{specific} \cdot c_{energy,BM} \cdot \eta_{total} \cdot r_{feed-in} + (1 - \frac{m_{BG}}{m_{BM}}) \cdot r_{BM} - c_{BM}} \equiv K_{economical}$$

for

$$Y_{specific} \cdot c_{energy,BM} \cdot \eta_{total} \cdot r_{feed-in} + (1 - \frac{m_{BG}}{m_{BM}}) \cdot r_{BM} - c_{BM} > 0.$$

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 12.

Table 12: Relevant parameters for the calculation of the cost and revenue streams (Steinhauser, 2008) (goodyear, kein Datum).

Parameter	Description	Value
$\boldsymbol{Y_{specific}}$	Specific biogas production [m³/kg]	Slaughterhouse waste: 0,3-0,7 Cattle excreta: 0,6-0,8 Chicken excreta: 0,3-0,8 Pig excreta: 0,27-0,45 Sheep excreta: 0,3-0,4
$\boldsymbol{c_{energy,BM}}$	Specific energy [kWh/m³]	Biogas: 6-6,5
$\boldsymbol{\eta_{total}}$	Product of engine and generator efficiency	0,3 (approximation)
$\boldsymbol{r_{feed-in}}$	Feed-in tariff [ZAR/kWh]	0,96
$\boldsymbol{\frac{m_{BG}}{m_{BM}}}$	Ration of mass of biogas to total biomass input	$\rho^0 \cdot Y_{specific}$ = 0,36 ($\rho^0 = 1{,}2$)
$\boldsymbol{r_{BM}}$	Sales price of biomass [ZAR/kg]	0,15-0,20
$\boldsymbol{\Psi_{consumption}}$	Specific fuel consumption [L/km]	40t-Truck: 0,3 3,5t-Truck: 0,15
$\boldsymbol{c_{Diesel}}$	Diesel price [ZAR/L]	Diesel: 15
$\boldsymbol{c_{BM}}$	Specific cost of biomass [ZAR/kg]	Rossgro: 0,15-0,20

Values for specific combinations $K_{economical}$ using safe estimations can be found in Table 13.

Table 13: Possible values for $\boldsymbol{K_{economical}}$ no purchasing cost involved.

Specific case for $\boldsymbol{K_{economical}}$	Value
Slaughterhouse waste	14,6
Cattle excreta	7,9
Chicken excreta	14,6
Pig excreta	16
Sheep	14,6

The indicator K can be improved by a safety factor S, where S determines the minimum ration of revenue to costs. This means that if $S = 2$ the revenues will be at least twice as high as the costs involved. Naturally, this is only an estimation but a good indicator from a financial perspective.

11.5 Introduction and Selection of Suppliers

In this section the biomass suppliers are introduced including the type of biomass they supply, the biomass yield per day, their respective distance to Mr. Mofokeng's farm, resulting biomass-distance ratio (safe estimations), and ecological and economical criterion (no safety factor included).

11.5.1 Mr. Mofokeng's Farm

Mr. Mofokeng's farm is currently chosen as the reference point for all distance calculations. He runs a cattle feedlot with 100-130 cattle. The relevant data can be found in Table 14 below.

Table 14: Relevant Data for Mr. Mofokeng's farm

Category	Value
Type, Use	Cattle dung, none
Biomass yield per day	250-325 kg
Distance	0,1 km
Biomass-distance ratio	2500
$K_{ecological}$; $K_{economical}$	10,72; 7,9

11.5.2 Twala's Farm

Mr. Twala is a neighbouring cattle farmer who only has an average of 30 animals at his farm. The relevant data can be found in Table 15Table 15 below.

Table 15: Relevant Data for Mr. Twala's farm.

Category	Value
Type, Use	Cattle dung, none
Biomass yield per day	75 kg
Distance	0,5 km
Biomass-distance ratio	120
$K_{ecological}$, $K_{economical}$	10,72; 7,9

As the biomass-distance ratio is greater than both the ecological and economical criterion the supplier can be taken into consideration.

11.5.3 Abdul's Farm

Abdul is a neighbouring cattle and sheep farmer who has an average of 183 cattle and 350 sheep at his farm. The relevant data can be found in Table 16 and Table 17 below.

Table 16: Relevant Data for Abdul's farm (cattle)

Category	Value
Type, Use	Cattle dung, composting
Biomass yield per day	425 kg
Distance	4 km
Biomass-distance ratio	106
$K_{ecological}$, $K_{economical}$	10,72; 7,9

As the biomass-distance ratio is greater than both the ecological and economical criterion the supplier can be taken into consideration.

Table 17: Relevant Data for Abdul's farm (sheep)

Category	Value
Type, Use	Sheep dung, composting
Biomass yield per day	
Distance	4 km
Biomass-distance ratio	
$K_{ecological}$, $K_{economical}$	21,4; 14,6

11.5.4 Devon Abattoir

The Devon Abattoir slaughters 6000 cattle and 2000 lambs on average per month. The relevant data can be found in Table 18 and Table 19 below.

Table 18: Relevant Data for the Devon Abattoir (condemned matter)

Category	Value
Type, Use	Condemned matter, waste-product (hazardous)
Biomass yield per day	300-680 kg
Distance	3,9 km
Biomass-distance ratio	126
$K_{ecological}$, $K_{economical}$	21,4; 14,6

As the biomass-distance ratio is greater than both the ecological and economical criterion the supplier can be taken into consideration. Note that this is preliminary statement and so far the team has not distinguished between specific abattoir waste-products and their specific gas yield.

Table 19: Relevant Data for the Devon Abattoir (stomach content)

Category	Value
Type, Use	Stomach content, waste-product
Biomass yield per day	600-750 kg
Distance	3,9 km
Biomass-distance ratio	173
$K_{ecological}$, $K_{economical}$	21,4; 14,6

As the biomass-distance ratio is greater than both the ecological and economical criterion the supplier can be taken into consideration. Note that this is preliminary statement and so far the team has not distinguished between specific abattoir waste-products and their specific gas yield.

11.5.5 Mampe's Farm

Abdul is a neighbouring pig farmer who has 84 to 170 pigs at her farm. The relevant data can be found in Table 20 below.

Table 20: Relevant Data for Mampe's farm (pigs).

Category	Value
Type, Use	Pig dung, none
Biomass yield per day	112-214 kg
Distance	14 km
Biomass-distance ratio	8
$K_{ecological}$, $K_{economical}$	23,8; 16

As the biomass-distance ratio is smaller than both the ecological and economical criterion the supplier should not be taken into consideration.

11.5.6 Chicken Poultry

The Chicken poultry has a layer with approximately 1600 hens. The relevant data can be found in Table 21 below.

Table 21: Relevant Data for the chicken poultry.

Category	Value
Type, Use	Chicken droppings, composting
Biomass yield per day	198-510 kg
Distance	14 km
Biomass-distance ratio	14
$K_{ecological}$, $K_{economical}$	21,4; 14,6

As the biomass-distance ratio is smaller than both the ecological and economical criterion the supplier should not be taken into consideration.

11.5.7 Rossgro

Rossgro is a large poultry company, with several broilers and layers. The company reuses chicken droppings as fertilizer and sells them at a profit. If biomass up to 1091.4 kilograms is purchased per day the biomass-distance ratio reaches ecological equilibrium. Moreover in section 11.6.2 the C:N ration will be taking into consideration. Considering the fact that chicken dung is high in nitrogen, choosing Rossgro will be re-evaluated. The Go/No-Go decision must be based on this. The relevant data can be found in Table 22 below.

Table 22: Relevant Data for the Rossgro farming enterprise.

Category	Value
Type, Use	Chicken droppings, composting
Biomass yield per day	13.699 kg
Distance	51
Biomass-distance ratio	269
$K_{ecological}$, $K_{economical}$	21,4; 14,6

As the biomass-distance ratio is greater than both the ecological and economical criterion the supplier can be taken into consideration.

11.5.8 Summary and Preliminary Go/No-Go Decision Overview

This summarizes the supplier selection based on the supplier selection tools. The go/no-go decisions are summarized in Table 23**Error! Reference source not found.** below. As can be seen, Mampe's farm and the chicken poultry farm will not be taken into consideration as potential suppliers of biomass. Rossgro is to be treated with care as a supplier due to the significantly larger transportation distance. The condition is described in section 11.5.7 and should be taken into consideration while developing the business plan.

Table 23:Go/no-go decision overview.

Supplier	Go/No-Go Decision
Mr. Mofokeng's farm	Go
Twala's farm	Go
Abdul's farm (cattle)	Go
Abdul's farm (sheep)	TBD
Abattoir (condemned matter)	TBD
Abattoir (stomach content)	TBD
Mampe's farm	No-Go
Chicken Poultry	No-Go
Rossgro	Go (see condition)

11.6 Biogas Potential

This section is divided into two sections highlighting the economic-theoretical and bio-technical potential. All are different perspectives the as to how large the biogas potential is. The economic-theoretical potential takes into consideration what is economically feasible. In this case we take suppliers into consideration, which make sense from a business perspective. Section 11.5.8 highlights this to some extent. The bio-economical potential puts all of the above into one context by comparing what is technically possible under economic conditions taking the biological processes into consideration.

11.6.1 Economical-theoretical Potential

The economic-theoretical potential highlights the biogas potential in the simplest manner after supplier selection. The potential biogas yield per day V_{BG} equals a simple sum of the product of biomass per source $m_{BM,i}$, and the specific gas-yield per source $Y_{specific,i}$ where i is the respective source. For n sources this gives:

$$V_{BG} = \sum_{i=1}^{n} m_{BM,i} \cdot Y_{specific,i}$$

The data can be retrieved from **Error! Reference source not found.** found below. All values based on data ranges are safe approximations.

Table 24: Overview of the total gas yield per source.

Source	Type	Yield [kg/day]	Specific Gas Yield [m^3/day]	Gas Yield [m^3/day]
Mr. Mofokeng	Cattle dung	250,00	0,6	150,00
Twala	Cattle dung	60,00	0,6	36,00
Devon Abattoir	Condemned matter	300,00	0,3	90,00
	Stomach matter	600,00	0,3	180,00
Abdul	Cattle dung	425,00	0,6	255,00
	Sheep dung	0,00	0,3	0,00
Rossgro	Chicken droppings	13698,63	0,3	4109,59
Total				4820,59

11.6.2 Bio-Economical Potential

TBC

12 Energy Audit

The energy management of the Chicken Chain Farm has impact on both the future demand of energy from the biogas plant as on the future supply of energy from the biogas plant. To assess the energy management of the farm an energy audit is executed by inspecting, surveying, and analyzing the energy flows on the farm. Hereby, water, electricity and gas flows on the farm are considered. This chapter is dedicated to describing the energy audit in its entirety. To start, the objectives of the energy audit are described. After setting the objectives, the methodology is determined. Next, the findings of the energy audit are elaborated upon. The chapter concludes with a conclusion and recommendations.

12.1 Objectives of the Energy Audit

The project objectives, discussed in Chapter 4, serve as guideline in setting the objectives of the energy audit. Where applicable, a reference is made to the related project objective(s). Moreover, the Chicken Chain Farm is supported in its endeavor to reduce its energy demand.

- Get an understanding of the energy infrastructure on the farm – Objectives: 1.4.2 and 1.4.3;
- Determine the current and forecasted daily, monthly and yearly energy demand of the farm – Objective: 1.5.1 (indirectly);
- Determine the current and forecasted daily, monthly and yearly energy supply to the farm. – Objectives: 1.3.3, 1.5.1 (indirectly);
- Determine the storage capacity of energy on the farm – Objective: 1.4.2;
- Determine the current and forecasted energy costs – Objective: 1.5.1;
- Identify the daily, monthly and yearly energy surplus and energy shortage – Objective: 1.5.1;
- Define a strategy to reduce the farm's energy demand.

,

12.2 Methodology of the Energy Audit

For practical reasons *energy* is distinguished in water, electricity and gas in pursuing the aforementioned objectives. The actions that are required per objective, are described below.

12.2.1 Electricity

- Get an understanding of the electricity infrastructure on the farm.
  - Interview Mr. Mofokeng
  - Inspect the electricity infrastructure
- Determine the current and forecasted daily, monthly and yearly electricity demand of the farm.
  - Make an inventory of appliances and the corresponding user patterns
  - Execute measurements on the appliances
- Determine the current and forecasted daily, monthly and yearly electricity supply to the farm.
  - Execute measurements on the electricity sources
  - Model the supply of energy from the solar panels
- Determine the storage capacity of energy on the farm.
  - Make an inventory of the storage capacity
- Determine the current and forecasted energy costs.
  - Analyze the energy bill(s) of the farm
  - Interview Mr. Mofokeng
- Determine the daily and forecasted, monthly and yearly electricity surplus and electricity shortage.
  - Combine the findings on the electricity demand from and the electricity supply to the farm
- Define a strategy to reduce the farm's energy demand.

12.2.2 Gas

- Get an understanding of the gas infrastructure on the farm.
  - Interview Mr. Mofokeng
  - Inspect the gas infrastructure
- Determine the current and forecasted daily, monthly and yearly water demand of the farm.
  - Make an inventory of appliances and the corresponding user patterns
  - Execute measurements on the appliances
- Determine the current and forecasted daily, monthly and yearly gas supply to the farm.
  - Execute measurements on the gas sources
  - Model the supply of energy from the biogas digester and LPG bottles
- Determine the storage capacity of energy on the farm.
  - Make an inventory of the storage capacity
- Determine the current and forecasted energy costs.
- Determine the daily and forecasted, monthly and yearly gas surplus and gas shortage.
  - Combine the findings on the gas demand from and the electricity supply to the farm
- Define a strategy to reduce the farm's energy demand.

12.2.3 Water

- Get an understanding of the water infrastructure on the farm.
  - Interview Mr. Mofokeng
  - Inspect the water infrastructure
- Determine the current and forecasted daily, monthly and yearly water demand of the farm.
  - Make an inventory of appliances and the corresponding user patterns
  - Execute measurements on the appliances
- Determine the current and forecasted daily, monthly and yearly water supply to the farm.
  - Execute measurements on the water sources
  - Model the supply of energy from the biogas digester and LPG bottles
- Determine the storage capacity of energy on the farm.
  - Make an inventory of the storage capacity
- Determine the current and forecasted energy costs.
- Determine the daily and forecasted, monthly and yearly gas surplus and water shortage.
  - Combine the findings on the water demand from and the electricity supply to the farm
- Define a strategy to reduce the farm's energy demand.

12.3 Findings

12.3.1 Electricity

TBC

12.3.2 Gas

The Gas-system
The current gas system in place is mainly based on LPG and biogas.

Current Demand and Forecast
TBC

Current Supply and Forecast
TBC

Gas Storage System
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, 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 25.

$$\Delta V_{GH} = \Delta h \cdot R^2 \cdot \pi = \ 0{,}664\ m^3.$$

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_G the gasholder weight, p_i the pressure inside the gasholder, and $F_b(x)$ the buoyant force dependant on the level of the gasholder. The equations can be broken down into

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

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

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

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

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

Solving the equation for p_i gives

$$\Rightarrow p_i = p_0 \cdot e^{-\left(\frac{h}{h_0}\right)} + \left[\frac{n \cdot m_{brick}}{\pi \cdot R^2} + \rho_{steel} \cdot t \cdot \left(\frac{2 \cdot h}{R} + \frac{1}{\cos^2(\alpha)}\right) - \frac{2 \cdot \rho_{water} \cdot t}{R}\left(h - h_{top} - x\right)\right] \cdot g$$

All newly introduced parameters and variables are given in Table 25 below (daftlogic, kein Datum) (regentsprep, kein Datum) (ngineeringtoolbox, kein Datum).

Table 25: Constants and Parameters.

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	$h_{altitude}$	1,64652	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 length	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

The equation results in a maximum pressure $p_{i,max} = 0{,}814\ bar$ 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 first law of thermodynamics 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

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

Cost of the System
TBC

The Supply-Demand Balance
TBC

Proposed Strategy
TBC

12.3.3 Water

The Water system
The sources are based on both solar powered pumps in boreholes and precipitation. In the following section the sources of water will be highlighted and described.

Current Demand and Forecast
TBC

Current Supply and Forecast
TBC

There are currently six 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, which is why we call it "borehole far". The other is located underneath an old wind powered pump, which is why we call it "borehole wind". Both pumps are of the same model, data of which can be found in Table 26.

Table 26 Data sheet for both pumps

Pump	
Model:	SP-JS3-1.8-80
max. flow [m^3/h]	1,8
max. head [m]	80
Outlet [mm]	19,05
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 27

Table 27: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]	0,1056

Currently, approximately 0,45 m^3 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 6.

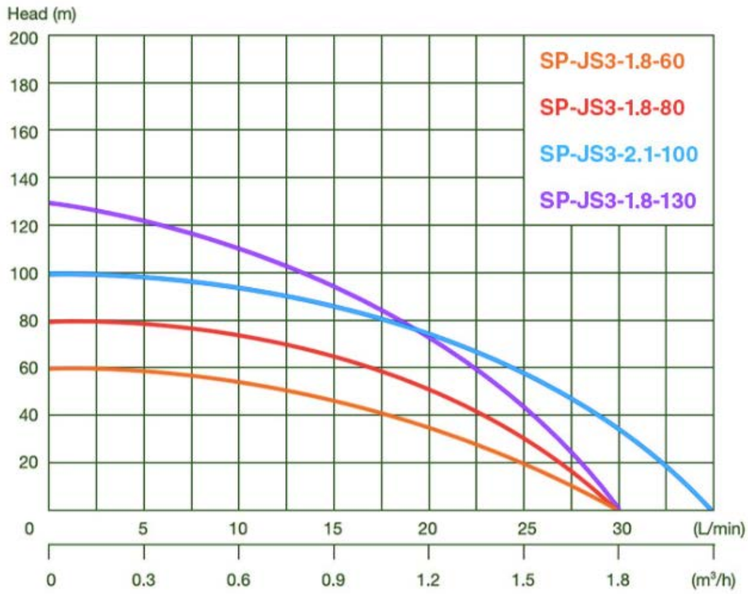


Figure 6: Head versus flow rate for different types of pumps.

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 28 and Table 29).

Table 28: 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 29 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.

A fraction of the farms water supply is based on precipitation. Currently the farm relies on a single rain gutter connected to Kabelo's (the worker at the farm) house. The team estimated the annual total water supply based on weather data from Johannesburg, as there is currently no weather station, that can provide the up to date weather data (Johannesburg Climatemps, kein Datum). The team estimates the water supply as the product of precipitation (in mm, which is an equivalent of L/m^2) and the projection roofing area available to the rain gutter. In the case of the available rain gutter this is $A_{Kabelo} = 12{,}25\ m^2$. This does not take the rain gutter cross section into consideration, which is another limiting factor to the maximum flow rate it can handle. Thus the annual volume of water V_{actual} based on the following equation

$$V_{actual} = \sum_{i=1}^{n=12} p_i \cdot A_{total}$$

is 6,65 m^3, where p_i is the monthly precipitation. Find all relevant data in Table 30

Table 30: Precipitation and actual volumetric yield at the farm per month and annually.

Month	Average Precipitation Johannesburg (L/m^3)	Actual Volumetric Yield at Farm (m^3)
Jul	4	0,05
Aug	6	0,07
Sep	27	0,33
Oct	7	0,09
Nov	11	0,13
Dec	103	1,26
Jan	125	1,53
Feb	94	1,15
Mar	90	1,10
Apr	54	0,66
May	13	0,16
Jun	9	0,11
Annually	**543**	**6,65**

The farm is currently only using about 6,25% of the farm's roofing area ($A_{total} = 496\ m^2$) for water supply. This means that the total annual potential is actually 269,33 m^3 of water if the farm invests in the necessary rain gutters. The assumption is simplified and ignores the dry season during the months of May through November, hence monthly fluctuation would have to be taken into consideration in terms of water storage.

Water Storage System

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 31.

Table 31: Water Storage System Data

Name	Volume [m^3]	Height [m]	Elevation [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^2 approximately 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.

Cost of the System
TBC

The Supply-Demand Balance
TBC

Proposed Strategy
TBC

12.4 Conclusion and Recommendations

TBC

13 Outlook

This chapter gives an overview of the planned actions till the completion of the feasibility study, which is scheduled for the end of week 43 of 2015. It runs the reader through the information the team currently lacks.

Table 32: Overview of the outlook on the period in-between the mid-term report and the final report.

Legislation

- There are still some open questions as to which licenses will be necessary and their respective costs and characteristic application period. The team plans to investigate the lacking information.
- Mainly, the team relies on meeting with a leading industry expert and consultant, and the conference SAIREC in Cape Town.

Suppliers

- The team still lacks some of the contact details of relevant possible suppliers and intends to investigate these as soon as it is possible.
- The supplier selection will be revised as soon as the supplier list is complete and the composition of the digester substrate input is complete.

Location

- The energy audit is yet to be completed. The team will continue conducting the necessary research, making the relevant measurements, creating the relevant models, and making the necessary calculations to formulate strategies as to how the locations infrastructure can be streamlined and adapted to the planned biogas system.
- The team will continue evaluate the locations' suibility after the energy audit is complete and the digester substrate input has been determined.

Customers

- The team will contact, or meet with the relevant stakeholders to determine possible customers. These include:
- Municipal Authorities
- ESKOM
- Abattoirs
- Production clusters

Technologies

- The technology choice is yet to be evaluated and to some extent depends on the business model choice.
- The team will continue researching possible technologies, in both literature, meetings, and the upcoming conference.

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15 Appendix A

FTE Factor	**40,0**				
What	**Time [h]**	**Persons [#]**	**Time per person [h]**	**FTE**	**Comment**
TOTAL				**18,2**	
1. Stakeholders					
1.1. Identify the stakeholders and the extent to which they can contribute to the execution of the project.				0,9	
· Identify all potential Stakeholders by means of online research, and interviews with Takatso and other stakeholders.	4,0	3,0	1,3	0,1	
· Classify the Stakeholders position within the context of the biogas sector.	24,0	3,0	8,0	0,6	
· Analyze the relevant stakeholders by means of an interest/power quadrant diagram and separate them in primary, secondary and key stakeholders.	6,0	3,0	2,0	0,2	
· Determine key stakeholders for achieving the following sub-objectives.	3,0	3,0	1,0	0,1	
2. Legislation					
2.1. Determine the Legislation, which affects independent power production in Devon.				4,5	
· The necessary information will be acquired by researching the available information provided online, as well as in personal meetings with stakeholders.	180,0	3,0	60,0	4,5	Estimation of 10 meetings
3. Suppliers				5,5	
3.1. Determine the daily availability, type & composition and costs of biomass at each suppliers' location.				2,8	
· Identify and list the potential suppliers by interviewing Takatso Mofokeng and using the stakeholder analysis.	3,0	3,0	1,0	0,1	
· Compile a supplier specific questionnaire containing information such as:	1,0	1,0	1,0	0,0	
· Plan and perform an interview with the stakeholders using the questionnaire.	90,0	3,0	30,0	2,3	Estimation of 5 meetings
· (Optional) Determine the availability of biomass [kg/day] on the basis of the stakeholder data, literature and measurements performed at the location of the farm.	4,0	2,0	2,0	0,1	
· Determine the composition of the biomass (dry matter – wet matter – inorganic matter) on the basis of literature research and measurements including:	12,0	2,0	6,0	0,3	
3.2. Make a preliminary selection of biogas suppliers.				0,4	
· Define and rank the selection criteria on basis of the aforementioned parameters by means of a discussion among the team members.	8,0	2,0	4,0	0,2	
· Determine exclusion criteria based on energy potential and distance (ecological criterion, economical criterion).	4,0	2,0	2,0	0,1	
· Assess and select the suppliers on the basis of these criteria using the minutes and data sheet from the interviews with the suppliers.	4,0	2,0	2,0	0,1	
3.3. Determine the maximum biogas production potential according to the biogas suppliers				0,9	
· Perform literature research on the biogas yield per type of biomass	4,0	2,0	2,0	0,1	
· The maximum biogas production can now be calculated	6,0	2,0	3,0	0,2	
· Use empirical data gained from prototype and surrounding biogas digesters	24,0	2,0	12,0	0,6	2 measurement days + 3 company meetings

FTE Factor	40,0				
What	**Time [h]**	**Man-power**	**Time per person [h]**	**FTE**	**Comment**
4. Location					
4.1. Determine the nature & climate conditions and the extent to which they will influence the biogas production.				0,3	
· The necessary information and data-set will be researched in literature and includes	2,0	2,0	1,0	0,1	
· The information and data will then be extracted by consulting nature & climate stakeholders, which will be identified in the stakeholder analysis.	4,0	2,0	2,0	0,1	
· Moreover the extent, to which the biogas production is influenced by the variables, will be verified empirically by measurements performed on the prototype digester at the location of Takatso's farm.	4,0	2,0	2,0	0,1	
4.2. Determine the daily availability and total storage capacity of water at each possible location.				0,3	
· The maximum daily water supply is determined by analyzing the specifications of the installed pump. The real supply of water is provided by test results, which are conducted and documented at the installation of the pumping system.	8,0	2,0	4,0	0,2	
· Moreover the maximum daily, monthly and annual supply of rainwater can be acquired by analyzing weather & climate data provided by means of stakeholder interviews and analysis.	2,0	2,0	1,0	0,1	
· Retrieve the volume, height, and elevation of the installed water storage tanks, by means of measurements and documentation for later modeling of the water system.	2,0	2,0	1,0	0,1	
4.3. Determine the limitations that the current electricity distribution and transportation infrastructure has on the production capacity of the biogas system and rank possible locations.				0,4	
· It is necessary to determine the voltage of the available power lines at the location as well as the maximum power and availability of a nearby transformer, this can be achieved by contacting ESKOM, as well as site visits to determine the available infrastructure.	16,0	2,0	8,0	0,4	
4.4. Determine optimum location based on the ranking above.				0,4	
· The optimum location will be based on a ranking-system, based on weighting factors incl. the information of gained from the sections supplier and location.	16,0	2,0	8,0	0,4	
5. Technologies					
5.1. Identify the most suitable technologies for the biogas system and the nfluence of temperature on the production of biogas				0,4	
· The digester and as holder technology will be chosen by evaluating the pros and cons of the respective technology similarly as in the Biogas Planning Guide found in "Biogas Digest - Volume II Application and Product Development" (p.32).	16,0	2,0	8,0	0,4	

FTE Factor	40,0				
What	**Time [h]**	**Man-power**	**Time per person [h]**	**FTE**	**Comment**
6. Customers					
6.1. Identify potential customers and their electricity demands				2,4	
· Identify the potential customers by interviewing Takatso Mofokeng and using the stakeholder analysis.	4,0	3,0	1,3	0,1	
· Compile a questionnaire containing:	3,0	2,0	1,5	0,1	
· Perform an interview with the potential customers using the questionnaire.	90,0	3,0	30,0	2,3	Estimation of 5 potential customers
6.2. Identify potential customers of biogas bi-products.				1,0	
· Identify the potential customers by interviewing Takatso Mofokeng and using the stakeholder analysis	4,0	3,0	1,3	0,1	
· Compile a questionnaire containing	1,0	1,0	1,0	0,0	
· Perform an interview with the potential customers using the questionnaire.	36,0	3,0	12,0	0,9	Ask Taktso --- estimation of 2 meetings
7. Cost-Benefit					
7.1. Identify possible financial incentives available to the biogas business.				2,1	
· Use the stakeholder analysis to identify possible financial incentives.	9,0	3,0	3,0	0,2	
· Compile a questionnaire containing:	4,0	2,0	2,0	0,1	
· Perform an interview with the stakeholders.	72,0	3,0	24,0	1,8	
7.2. Perform Cost-Benefit Analysis with and without funding opportunities to showcase the feasibility and profitability of the project.				1,4	
· Estimate the total costs by means of calculations and research.	16,0	2,0	8,0	0,4	
· Estimate the total revenues: by means of calculations and literature research.	16,0	2,0	8,0	0,4	
· Calculate the economic indicators: Payback period (PBP), Internal Rate of Return (IRR) and the Net Present Value (NPV).	16,0	2,0	8,0	0,4	
· Determine the total relative reduction of CO_2-emissions when compared to coal fired electricity generation as an factor to determine the environmental revenue.	8,0	2,0	4,0	0,2	

16 Appendix B

16.1 Internal Stakeholders (9)

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.

16.2 External Stakeholders

16.2.1 Biomass Suppliers (13)

ARC Biomass Suppliers
TBC

Brookfields Beef Pty Ltd
Biomass Supplier. 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.*

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.*

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 kilometres from Devon. Moreover, the company has advanced plans for a biogas plant. Hence, they have no significant role in the project.

Leslie Abattoir
TBC

Mr. Twala - Neighbouring farmer
Twala is a neighboring 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.*

Mr. Abdul - Neighbouring farmer
Abdul is a neighboring farmer of the Chicken Chain Farm. The cattle dung, on average 183, can be used for the production of biogas. Moreover, he keeps 350 sheep, on average. Hence, Abdul is a potential *Biomass Supplier.*

Mrs. Mampe - Neighbouring farmer
Mampe is a neighbouring farmer. 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.

Prison Devon
TBC

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 animal 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.*

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.

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

16.2.2 Customers (1)

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 Customer. Due to their dominant position, they are involved, in one way or another, in almost every transaction on the electricity market. 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.*

16.2.3 Contractors (9)

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.* ***Invalid source specified.***.

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. **Invalid source specified.**.

ENER-G Systems
ENER-G systems provides businesses 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.).

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.

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. There are no other biogas projects known in which the company is involved. 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.

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.

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 Beef. Its activities are limited in relevancy but can function as a good external source if information.

16.2.4 Financial Institutions (7)

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 could possibly be interested in investing 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.*

E^2 - Social Entrepreneurship
E^2 is a philanthropy that provides venture capital financing to businesses and social entrepreneurial ventures that are likely to have a high impact in alleviating poverty and/or joblessness in South Africa. As a funder E^2 can be a valuable stakeholder for the success of the business model.

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 endeavor 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.*

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. **Invalid source specified.**.

16.2.5 Governments & Regulators (6)

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.

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.* **Invalid source specified.**.

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.

Department of Trade and Industry (DTI)
The Department of Trade and Industry, or DTI, is the part of the South African government which is responsible 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.

Municipality of Devon
TBC

National Energy Regulator of South Africa (NERSA)
The National Energy Regulator of South Africa, also known as the NERSA, is a regulatory authority whose 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. Naturally NERSA is involved in numerous partnerships.

16.2.6 Networks & Consultancy Services (27)

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 startup 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. **Invalid source specified.**.

Bio2Watt Pty Ltd
The company Bio2Watt Pty Ltd 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. ***Invalid source specified.****.*

Council for Scientific and Industrial Research (CSIR)
TBC

Cova Advisory – Mr. T. Chipfupa
Tumelo is director of Cova Advisory. His current business is to help other businesses with grant 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.

Gesselleschaft 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).*

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).*

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 organisation 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 Water 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.).

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 Beef and Karan Beef in the role of main consultant.

Mr. Napol – Consultant
TBC

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.

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 a non-profit institution 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).*

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.

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).*

Morgen Abattoir/ Beef
TBC

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). **Invalid source specified.**.

Michiel and Onno – Predecessors
Michiel and Onno designed and constructed the present prototype at Mr. Mofokeng'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.*

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 programme 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 whose 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.