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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Contents

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 [1] . 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. Two boreholes and rainwater supply on site cover the water demand.

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 groups of in total six 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, who's 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.

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.

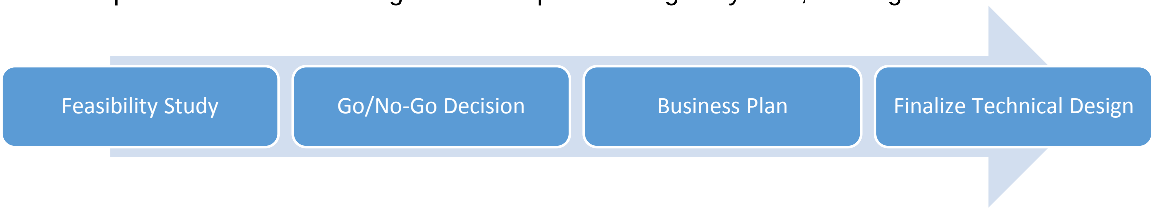

Figure 1: Project Flowchart.

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.

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 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 who student 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.

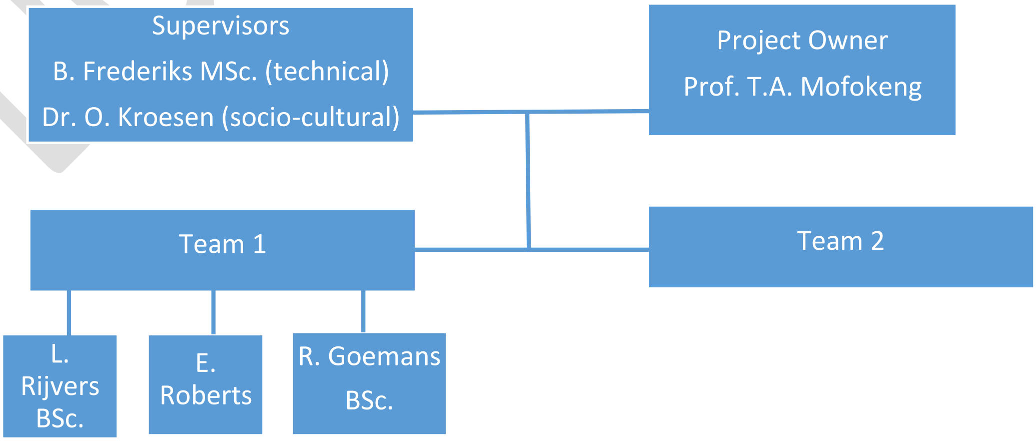

Figure 2: Organogram of the project team.

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.

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. On base of 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 bi-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.

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.

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.

Objective III

Objective III is broken down into four achievable sub-objectives and include 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.

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.

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 liveweight;
    - 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* [2].

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.

Planning

In order to determine the duration of to reach the Objectives and 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, who's 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 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.

References

[1] A. Ruffini, “SA not using its biogas potential,” ESI Africa, 2013. [Online]. Available: http://www.esi-africa.com/sa-not-using-its-biogas-potential/. [Accessed 23 9 2015].

[2] D. Deublein and A. Steinhauser, Biogas From Waste And Renewable Sources, Weinheim: Wiley, 2008.

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	