Assessing the economic viability of biogas plants at abattoirs in South Africa

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Mini-dissertation submitted in partial fulfillment of the requirements for the degree Magister in Business Administration at the Potchefstroom Campus of the North-West University

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November 2013

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ABSTRACT

With electricity tariffs in South Africa escalating at a rapid pace the demand for alternative power sources has increased. One of these renewable energy sources includes the use of biogas. Biogas is not only one of the most efficient and effective renewable energy possibilities available but also requires less capital investment as compared to other renewable sources like hydro, solar and wind and are also more economical as it involves less per unit production cost. Biogas plants have been used around the globe for numerous years, but are a relative new technology in South Africa, predominantly in the red meat industry with the use of slaughter waste as a form of biomass. Slaughter waste offers a vital possible source of renewable energy. A variation of factors makes the production of renewable energy from slaughter waste particularly appealing. The continuous rise of energy prices, waste disposal prices, and incentives for renewable energy production have increased the value of outputs from slaughter waste-to-energy systems.

The primary objective of the research is assessing the economic viability of biogas plants at abattoirs in South Africa and if such a biogas plant would be beneficial to an abattoir. The research aimed to determine the viability through various capital budgeting techniques and define what the most significant calculated variables are that should be addressed in such an economic viability model. For the purposes of this study a Class A abattoir with a slaughtering capacity of 400 cattle per day was used as a case study. Biogas will be generated through anaerobic digestion and the utilising of the gas for the generation of electricity and heat by means of a CHP generator.

The economic viability study contains of a base case scenario and two other possible scenarios and provides recommendations and a concluding report, based on the scenario that is the most viable. The succeeding techniques which were recognised were used to analyse the economic viability of the biogas plant: Payback Period, Discounted payback period, Net present value, profitability index, and internal rate of return. Furthermore a sensitivity analysis was done in the study with a pessimistic and optimistic outcome on key variables. The study establish that in the base case scenario a positive net present value was realised, the internal rate of return was more than the required rate of return and the payback periods was shorter than required.

In this study the concept of biogas plants in the red meat industry were researched with the purpose of determining the economic viability of these plants. In determining the viability of the biogas plant the key variables that will impact the viability was also identified and discussed. Based on the data gathered and assumptions that was made it was concluded that a biogas plant will be beneficial to an abattoir and was considered economically viable.

Key terms: biogas, renewable energy, red meat, abattoir, economic viability.

ACKNOWLEDGEMENTS

My sincere appreciation and gratitude are due to the following individuals, who by their attendance and assistance contributed to this study:

- The Lord for giving me determination and strength to complete this dissertation.
- My wife, Priscilla, for all her patience, support, assistance and motivation in her own way, helping me to stay focused.
- To Professor R.A. Lotriet, my study leader, for his guidance and invaluable assistance.
- Wasserfal, my syndicate group members, for their hard work and assistance during this study. It would not have been the same without all your encouragement, help and entertaining times. I am sure we are going to miss all the group gatherings.
- My employer for the support, encouragement and patience the past three years.
- Christo Beyers, without your encouragement I would never have attempted this MBA. Thanks for that and the motivating words over the past years.
- Antoinette Bischoff, my language editor, for the extremely professional work.
- A special thanks to my parents, for the education they provided me with, in order to get to where I am today, and the constant love and support.
- My family, friends and colleagues for their support and interest throughout my studies.

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AD	Anaerobic Digestion
CAPEX	Capital Expenditure
CF	Cash Flow
CH4	Methane
CHP	Combined Heat and Power generation
CO2	Carbon Dioxide
CDM	Clean Development Mechanism
DCF	Discounted Cash Flow
Digestate	Anaerobically Digested Material
DPBP	Discounted Payback Period
DR	Discount Rate
FS	Feedstock Cost
GHG	Green House Gases
IRR	Internal rate of return
kW	Kilowatt, unit of power
kWe	Kilowatt, unit of electrical power
Kwh	Kilowatt-hour
kWh	Kilowatt hour, unit of energy
kWhe	Kilowatt hour, unit of electrical energy
MC	Maintenance Cost
MWh	Megawatt hour, unit of energy

MWhe	Megawatt hour, unit of electrical energy
NPV	Net present value
O&M	Operation and maintenance
O2	Oxygen
OC	Operating Cost
OPEX	Operating Expenditure
PI	Profitability Index
PU	Production unit
REFSO	Renewable Energy Finance & Subsidy Office
WACC	Weighted Average Cost of Capital
WWTP	Waste water treatment plant

CHAPTER 1: SCOPE AND NATURE OF STUDY

1.1 BACKGROUND

Demand for meat is increasing globally. One reason is the rapid growing global population, which is forecasted to reach 9.3 billion in 2050 (Kajiwara & Tsuru, 2012:1). An additional factor is that as the per capita income increases in line with economic development, lifestyles and eating habits also change. The production of livestock in South Africa, as part of agriculture activities, continued to dominate its total contribution of total gross value in the agricultural sector. Statistics as indicates that livestock production contributed to 48% of the total gross value of agricultural production during the 2010/2011 season. A breakdown revealed that the red meat sector contributed 15% of the total livestock production (DAFF, 2012:79).

These animal slaughtering to meet consumption demand generate a vast amount of waste. The traditional methods worldwide for disposal of blood by abattoirs and meat processors are rendering, land application, composting and transfer to a waste water treatment plant (Mittal, 2006:1119).

In South Africa the most common methods for disposal of slaughter waste include rendering, land application, composting and transfer of blood to waste water treatment plants. As most slaughter waste are disposed by rendering plants, rendering plants have started charging a disposal fee for blood and other slaughter waste due to the user demand. Due to this fee, rendering is now less attractive and less economical method for an abattoir to dispose of their slaughter waste (Mittal, 2006:1119).

An alternative to this problem is the installation of a biogas plant at abattoirs. All the slaughter waste is transferred to a digester where the slaughter waste will, through an anaerobic digestion process, produce biogas. This biogas can then be used to generate electricity through a converted generator set.

1.2 PROBLEM STATEMENT

With electricity tariffs in South Africa escalating at a rapid pace the demand for alternative power sources has increased. One of these renewable energy sources includes the use of biogas. Biogas is not only one of the most efficient and effective renewable energy possibilities available but also requires less capital investment as compared to other renewable sources like hydro, solar and wind and are also more economical as it involves less per unit production cost (Rao et al., 2010:2087).

Biogas plants have been used around the globe for numerous years, but are a relative new technology in South Africa, predominantly in the red meat industry with the use of slaughter waste as a form of biomass. The problem abattoirs are currently encountering is to determine if this technology is economically viable considering the high amount of capital expenditure required. Biogas plants economics is characterised by large investment costs, operation and maintenance costs, mostly free materials and income from the sale of biogas or electricity and heat generated (Amigan & Von Blottnits, 2007:3091). These variables that symbolise the economics of a biogas plant will determine if such a plant will be a viable option or not.

This research will address the question of whether a biogas plant powered by slaughter waste is economically viable for an abattoir, what drives the viability of such a plant and how this will influence the environmental sustainable strategy of an abattoir.

1.3 RESEARCH OBJECTIVES

1.3.1 Primary objective

The primary objective of this research is assessing the economic viability of biogas plants at abattoirs in South Africa and if such a biogas plant would be beneficial to an abattoir.

The researcher aimed to determine the viability through various capital budgeting techniques and define what the most significant calculated variables are that should be addressed in such an economic viability model.

1.3.2 Secondary objectives

The secondary objectives included in this research were as follow:

- Establish what are the dominant variables that will impact the project as viable or not viable
- To analyse and identify other essential advantages biogas plants may offer at abattoirs in South Africa
- Evaluate the green impact a biogas plant may have on the abattoir

1.4 SCOPE OF THE STUDY

This study focuses on biogas plants principally at abattoirs in the red meat industry and the impact of such plants in relation to financial implications it will have.

An abattoir in Gauteng was selected in a case study research to determine the economic viability of a biogas plant. This abattoir was selected as it is an A-class abattoir (in section 2.3 the classification of abattoirs are discussed) that represents an acceptable spread of large abattoirs across South Africa where most of the animal slaughtering takes place.

1.5 RESEARCH METHODOLOGY

Welman, Kruger and Mitchell (2005:2) describe research as a method that encloses the gaining of scientific knowledge by means of numerous objective methods and procedures and outlines that research methodology considers and explains the logic behind the research methods and techniques.

This research comprises a broad literature overview and a case study methodology to reach the identified objectives.

1.5.1 Literature review

In this study an inductive approach will be followed by using a literature review as a research method.

Welman *et al*. (2005:39) note there are several important reasons why a literature search is important. One of these reasons is the fact that a review of related literature can provide the researcher with background information and other important facts about the subject being researched.

A broad literature review will be presented to identify critical issues in current literature available regarding the red meat industry and variable factors influencing the industry. The literature review will help develop various parts of the study and also help with gaining awareness concerning weaknesses and problems of previous studies.

The literature review will further focus on the following important aspects within the red meat industry:

- Environmental concerns about the industry;
- Waste disposal methods;
- Energy situation in South Africa;
- Renewable energy sources; and
- Biogas as an alternative energy source.

1.5.2 Empirical study

The research can be classified as qualitative and non-experimental quantitative research. Qualitative research will be embraced using exploratory semi-structured interviews and field work in obtaining relevant information needed.

Analysis of financial data and costs will be reviewed. These costs and benefits regarding savings of a biogas plant will be analysed using a case study in order to calculate the financial viability of a biogas plant. Central to this is the problematical issue of defining which variables significantly impact the economic viability of such a plant and to what magnitude these variables can be managed. To this end a detailed model has been compiled to determine the economic viability and with the use of a sensitivity analysis being able to identify the main factors that can have a negative influence on the results obtained.

The succeeding methods and techniques will be applied to calculate the economic viability:

- Payback Period;
- Discounted Payback Period (DPBP);
- Net Present Value (NPV);
- Internal Rate of Return (IRR); and
- Profitability Index (PI).

1.6 LIMITATIONS OF STUDY

There are various factors that may influence the results and findings in this research. The limitations should be taken into account when the results and conclusions of this research are considered. The limitations identified during this study include:

- As this study was based on a case study done, the findings made are particular to this study and other studies may yield other results.

- The aim of this study was to determine the economic viability and was based on data collected and certain assumptions made. The scientific nature of the amount of biogas that could be generated per slaughter unit was not conducted for the purposes of this study. Determining the precise yield on biogas produced from slaughter waste would require a distinct scientific research and it would be recommended that further research needs to be done on this.

- The results obtained cannot be accepted as an overall reflection of biogas plants at abattoirs in South Africa. Therefore, care should be exercised in the interpretation and utilisation of the results and findings cannot be generalised to all biogas plants' viability. But this research can be used as a guideline in determining the viability of biogas plants and can be used as a foundation for future research.

1.7 LAYOUT OF THE STUDY

This study is divided into four chapters:

Chapter 1 - Nature and scope of the study:

This chapter embraces the nature and scope of this research. This chapter includes an introduction, problem statement and stating the primary and secondary objectives of this research. This is followed by the research methodology, layout of the research and is concluded with the contribution of the research.

Chapter 2 - Overview of the red meat industry:

This chapter consists of a comprehensive literature review on the global red meat industry and also a breakdown of the South African industry and the value chain within the industry. The literature review further emphasises on current waste disposal methods used by abattoirs, the energy situation in South Africa and current renewable energy sources available. It further focuses on the use of biogas as a renewable energy source and the impact on the company's environmental sustainability.

Chapter 3 - Economic viability model: a case study:

This chapter entails a discussion on the various capital budgeting techniques that will be used with a brief description of each. It further consists of the different assumptions and calculations made to be used in the scenarios entailed.

This chapter further contains the results obtained in the research using the assumptions and scenario's as listed in chapter 3. It further discusses the results obtained, and possible recommendations in regard to the different scenarios are also provided.

Chapter 4 - Conclusion and recommendations:

This is the final chapter and provides the conclusions and recommendations in relation to the results obtained in the previous chapter.

1.8 CONTRIBUTION OF THE STUDY

With rapid electricity price escalations and the risk of persistent power shortages, various businesses across South Africa are considering alternative energy sources to help minimise these business risks. Biogas as a renewable energy source is an alternative option for abattoirs in the red meat industry but unlike some other possibilities is a relatively unaccustomed technology in South Africa. The question is whether biogas plants constitute a viable option for the red meat industry.

This research will provide abattoirs in the red meat industry with valuable information which can be used to encourage the use of biogas plants across South Africa.

1.9 SUMMARY

This chapter defined the background of the research, the problem statement, the scope of the study, the framework of the study, methodology, limitations and layout of the study. In the next chapter a comprehensive literature review will be performed on the red meat industry, factors influencing the industry and current practices in the industry.

CHAPTER 2: THE RED MEAT INDUSTRY

2.1 INTRODUCTION

A world increase in energy demand has resulted in rising energy prices and scarcity of energy resources. This has resulted in a crucial concern over energy security for states and the private sector alike (Van Hatzfeldt, 2013:199). Sukhatme (2012:1153) states that fossil fuels, essentially coal and natural gas, are non-renewable and may at best supply the needs for world energy consumptions for another 100-150 years. Additionally, fossil fuels contribute significantly to the escalation in greenhouse gases as stated in Rao *et al.* (2010:2086) where the world consumption of energy in 2010 was about 13 terawatt (TW). Approximately 80% of this consumption came from the burning of fossil fuels. This over-dependency on fossil fuels implicates definite risks such as the exhaustion of fossil fuel resources and increased atmospheric CO2 levels that cause global climatic changes. Because of this global concern about climate change and environmental pollution as well as the depletion of fossil fuel reserves, the increased use of renewable resources, reduction of energy usage together with efficient energy productions are priorities and key to a sustainable future (Amiri *et al.*, 2013:242)

The general pollution evading targets, objectives of the Kyoto arrangement (an international environmental arrangement with the objective of realising the stabilisation of greenhouse gas concentrations in the atmosphere) as well as the important issues relating to human and animal health, and food safety calls for gradually more sustainable solutions for handling and recycling of organic wastes. Biogas from anaerobic digestion plays an increasing important role with these requirements (Holm-Nielsen *et al.*, 2009:5478).

Climate change concerns have prompted massive attention on available methods to reduce the emission of greenhouse gases (Baylis & Paulson, 2011:446). Livestock production is achieved at a substantial environmental cost and contributes 18% of total global greenhouse gas emissions. The global livestock sector is one of the largest contributors of land and water degradation and current animal waste management practices are potentially hazardous to human, animal and wildlife health (Massé *et al.*, 2011:437).

According to Steinfeld (cited in Massé *et al.*, 2011:437) social expectations persist for more environmentally responsible livestock production practices and require additional environmentally sustainable production practices to be adopted for the industry to be further productive.

A variety of factors make the production from slaughter waste predominantly appealing for abattoirs. Escalating energy charges (refer to figure 1.1), environmental fears, costs of slaughter waste disposal, rising fertiliser prices, and incentives for renewable energy production have increased the value of outputs from slaughter waste-to-energy systems (Gloy, 2008:2). Yiridoe *et al.* (cited in Massé *et al.*, 2011:437) state that anaerobic digestion technologies were mainly developed to provide renewable sources of energy but with growing concerns over environmental issues more consideration for environmental, hygienic, agronomic and social benefits are taken into perspective. Akbulut (2012:381) describes biogas being produced by anaerobic digestion from organic feedstock. This organic feedstock includes crop residues, dedicated energy crops, animal waste, domestic food waste and municipal solid waste.

Anaerobic digestion systems generating biogas provides an opportunity for abattoirs to produce renewable energy from slaughter waste. These anaerobic digestion systems typically entail high capital expenditure and require comprehensive economic analyses to assess the economic feasibility.

The following section will give an overview on the red meat industry and what factors will influence the viability of a biogas plant.

2.2 INDUSTRY OVERVIEW

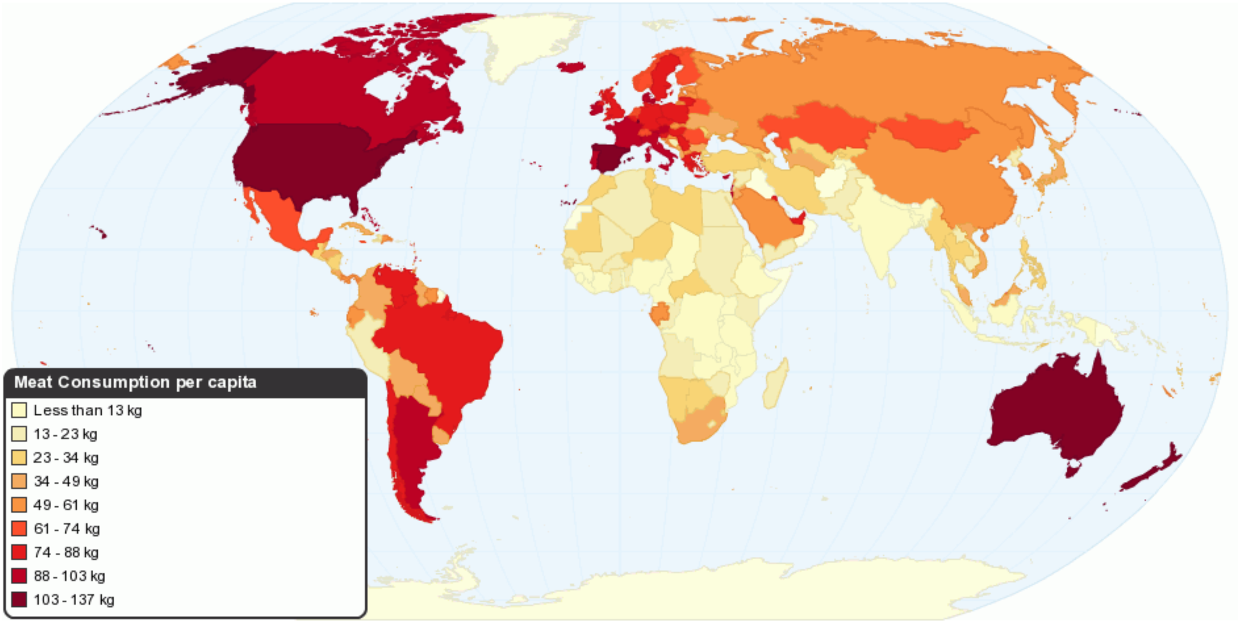
This section of the study will focus on the red meat industry from a global perspective followed by a South African overview of the industry. It will conclude with an overview of the value chain in the red meat industry and cost drivers within the industry.

2.2.1 Global Industry

Demand for meat is increasing globally. One reason is the rapid growing global population, which is forecasted to reach 9.3 billion in 2050 (Kajiwara & Tsuru, 2012:1). An additional factor is that as the per capita income increases in line with economic development, lifestyles and eating habits also change. There are more people living in cities, and the spread of the food service industry, including fast food chains, has led to more regular consumption of meat.

Looking back on the period from 1961 to today, the world's population has more than doubled from around 3 billion to 7 billion, while the volume of meat consumed annually has quadrupled from 70 million tons to just under 300 million tons. Kajiwara and Tsuru (2012:1) report that the U.N. Food and Agriculture Organization asserts that the production of food, including meat, must be increased by 60% by 2050 in order to meet the dietary needs of the planet's human population. The global meat consumption per capita is illustrated by Figure 2.1.

Figure 2.1: Global meat consumption per capita per annum



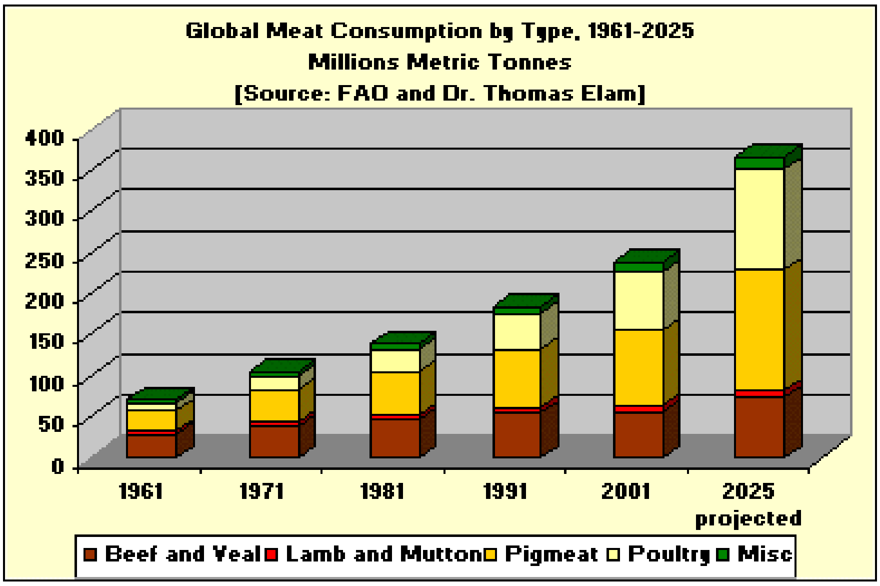
(Source: Pereltsvaig, 2013)

From Figure 2.1, it is evident that the meat consumption is the highest in developed nations such as the U.S., Australia and parts of Europe with an average of between 103-137kg meat consumption per capita.

Raising livestock requires vast amounts of grains for food. For example, it is estimated to take 11 kilograms of grain feed to produce 1 kilogram of beef, compared to 7 kilograms for pork and 4 kilograms for poultry. In the future, the degree to which meat production can be increased will be directly linked to the degree to which the production of corn and other basic ingredients used to make livestock feed can be increased (Kajiwara & Tsuru, 2012:1). The global consumption history per meat type from 1961 and forecasted up to 2025 is illustrated by Figure 2.2 below.

As can be seen from the Figure 2.2, pork has been the most widely consumed kind of meat globally. Beef used to be a close second, but its relative prominence on the global plate has diminished greatly over the last half-century. Poultry, however, is consumed in growing quantities, both in absolute and relative terms; whereas the consumption of lamb, mutton, and other miscellaneous types of meat remains marginal yet stable (Pereltsvaig, 2013:1).

Figure 2.1: Global meat consumption from 1961 to 2025



(Source: Pereltsvaig, 2013)

According to figures from the U.S. Department of Agriculture, with regard to poultry, the volume of chicken consumed globally have risen 37% in the 10 years from 2002. In the same period, pork consumption only increased by 15% and beef by 3%, making the growing popularity of chicken all the more remarkable.

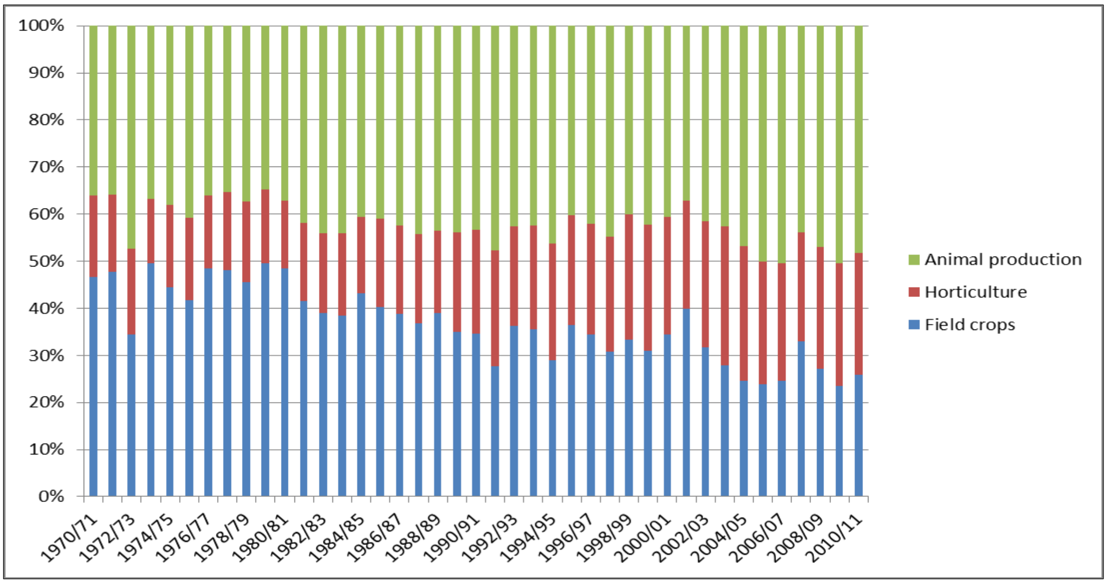
The global consumption of beef peaked in 2007, but has continued to trend downward in recent years. This is particularly pronounced in developed nations such as the United States, France and Australia. In Russia, the most popular meat shifted from beef to poultry over a 10-year period through to 2009. The same applies to China, where beef consumption peaked in 2008, and has continued to decline in the past few years. Worsening economic conditions have fostered a practical economical approach, and consumers are starting to turn to the cheaper meat. Coupled with greater health consciousness, there is a progressive shift towards poultry because of its low fat content. Although the global demand for beef is declining, Kajiwara and Tsuru (2012:1) report that the Food and Agricultural Organisation (FAO) sees this as a temporary decline only.

Beef consumption is expanding in developing countries at a greater pace than it is declining in developed nations, and the FAO predicts that it will rise to around 73 million tons in the year 2020, a 15% increase compared to the 2009 figure. Based on this assessment of the global meat market it is evident that there is a lot of growth expected within the developing countries of Africa of which beef specifically will contribute to a massive extent.

2.2.2 South African Industry

The production of livestock in South Africa, as part of agriculture activities, continued to dominate its total contribution of total gross value in the agricultural sector. Statistics as indicated in Figure 2.3 below indicated that livestock production contributed to 48% of the total gross value of agricultural production during the 2010/2011 season. A breakdown revealed that the red meat sector contributed 15% of the total livestock production (DAFF, 2012:79).

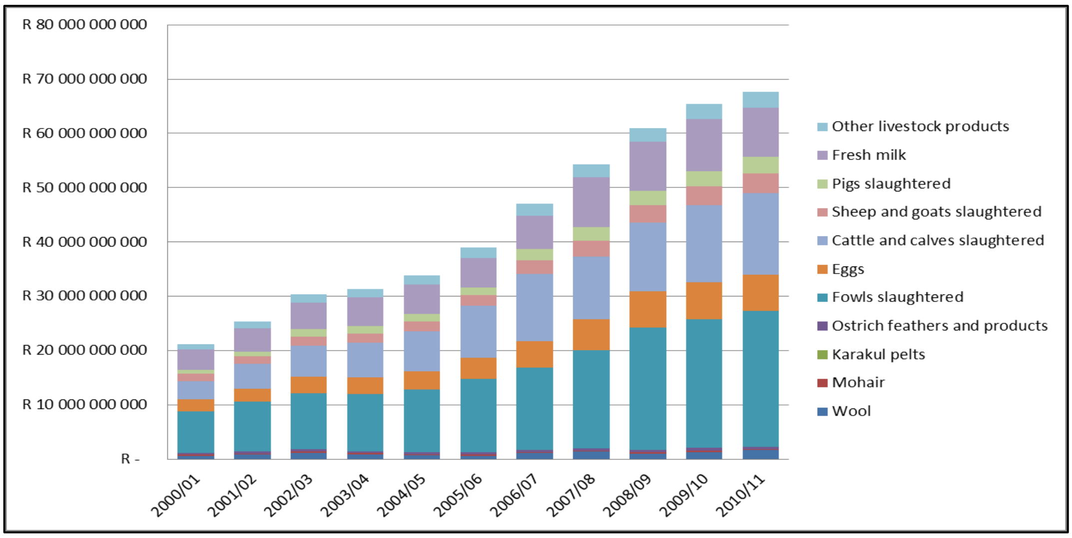
Figure 2.2: Gross value contribution breakdown of agricultural activities



(Source: DAFF 2012:78)

Figure 2.4 below, illustrates beef as the main contributor of the total value of animal production, at 22% during the 2010/2011. Furthermore, sheep and pork contributed 5% and 4% respectively, during the same period. This is however still trailing the white meat contributor (fowls/poultry), with an overwhelming contribution of 37% (DAFF, 2012: 79).

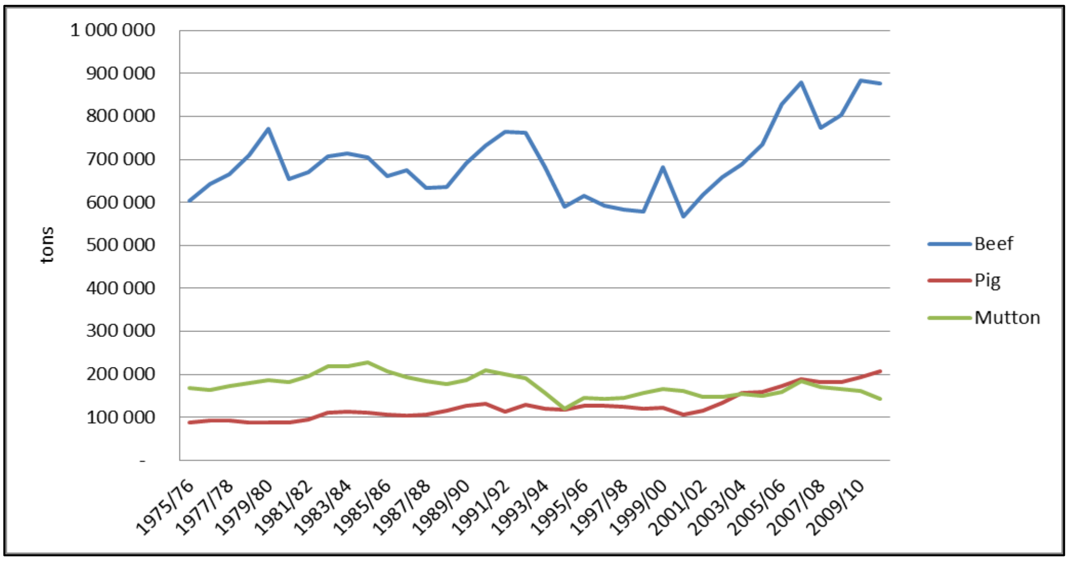
Figure 2.3: Gross value breakdown of animal production



(Source: DAFF 2012:79)

Statistics, as revealed in Figure 2.5 below, confirmed that beef is by far the main contributor to the total red meat production, which experienced a substantial increase in production since 2000.

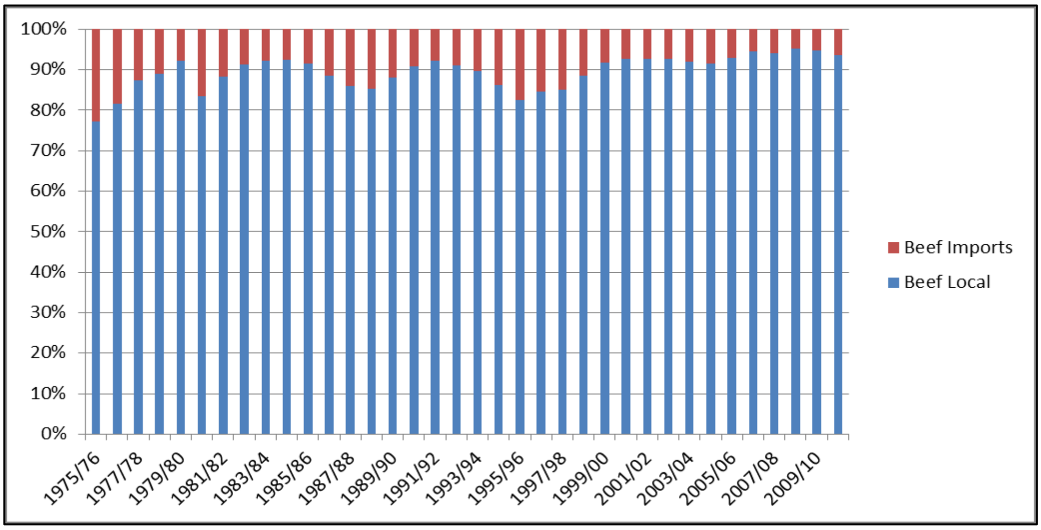
Figure 2.4: Red meat production breakdown (tons)



(Source: DAFF 2012:60)

During the same time from 2000 to 2010 imports of beef have continued to decline and remain less than 10% of total production in South Africa (Refer to Figure 2.6).

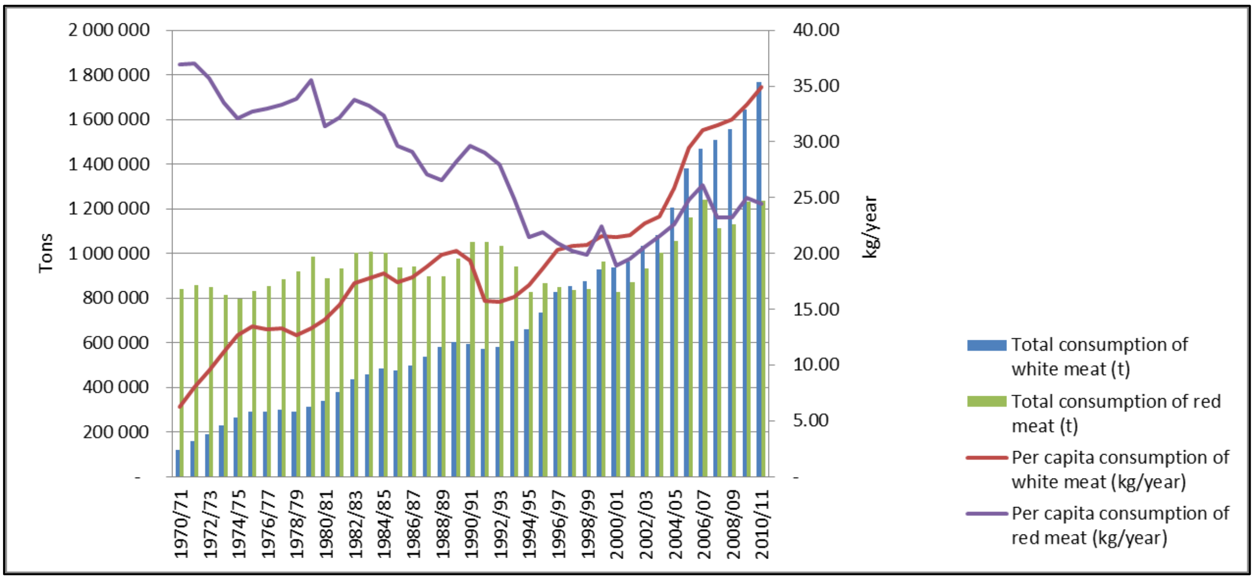
Figure 2.5: Beef production: Local vs. Imports



(Source: DAFF 2012:60)

Substitute products such as white meat (chicken) are becoming a major competitor to red meat and subsequently beef.

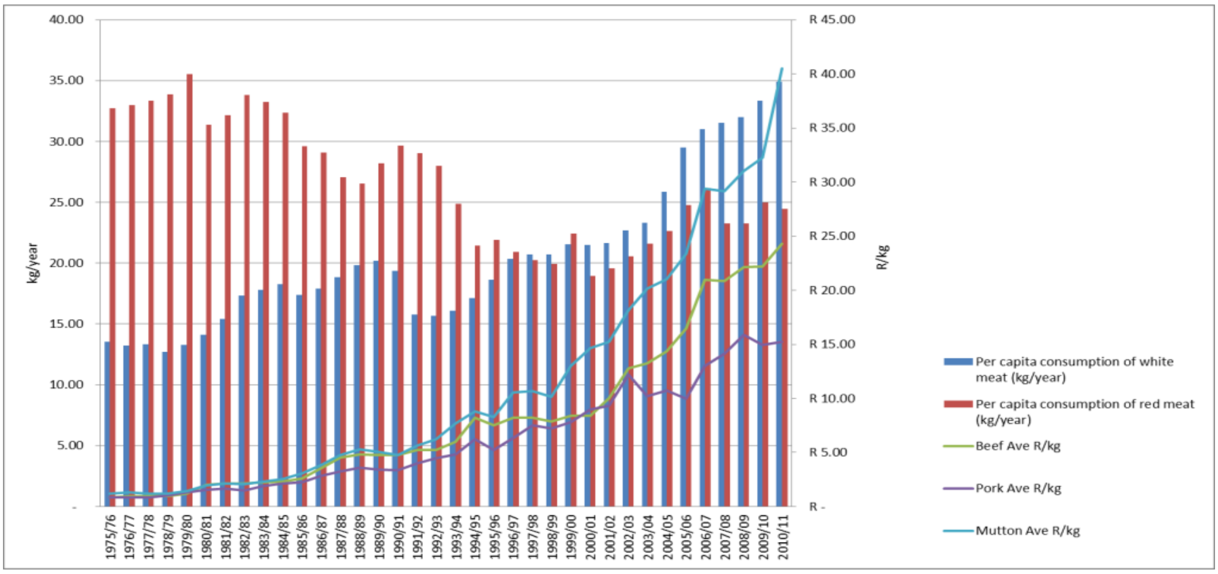
Figure 2.6: Change in consumption between red and white meat



(Source: DAFF 2012:69)

Figure 2.7 highlights an approximately 35% decrease in per capita consumption of red meat since 1970. Conversely, per capita consumption of white meat recorded an impressive growth of approximately 460% over the same period. This is in line with the global practical economical approach of consumers turning to cheaper meat.

Figure 2.7: Change in price of Beef, Pork & Mutton

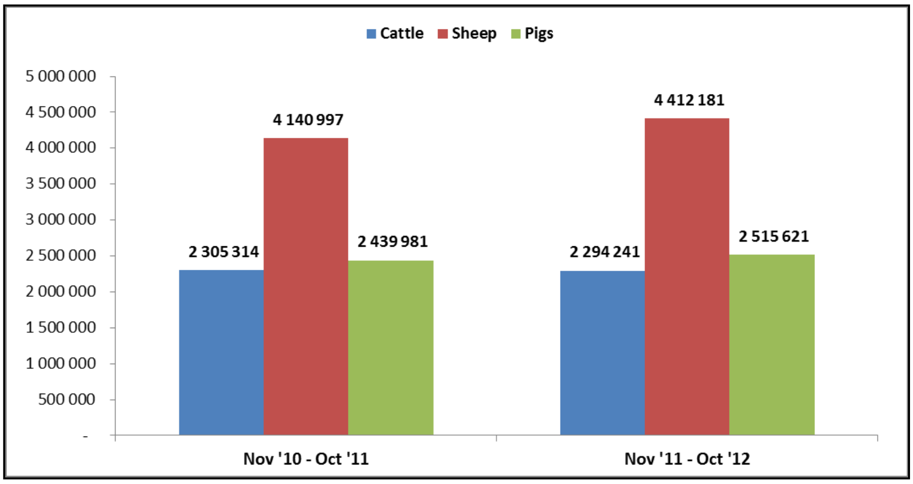


(Source: DAFF 2012:62)

Figure 2.8 above indicates the different increase in pricing between beef, pork and mutton. Beef's price grew moderately compared to mutton and pork. The price of beef has increase with around 200% from 1998/99 to 2010/11 while pork increased with about 100% and lamb with about 272% during the same period.

The total animals slaughtered in the red meat industry for the past two years are summarised in Figure 2.9 with an overview of the number of abattoirs per province. From this it can been seen that the most abattoirs are in the Eastern Cape, Free State, Western Cape and Northern Cape provinces. There can also be seen in Figure 2.9 that the number of cattle and pigs slaughtered have slightly decreased from 2011 to 2012 while there were an increase in the number of sheep slaughtered.

Figure 2.8: Slaughtering Figures and Number of Abattoirs in South Africa



Province	Number of Abattoirs
Gauteng	38
Limpopo	29
North West	29
Free State	84
KwaZulu Natal	50
Eastern Cape	91
Western Cape	63
Mpumalanga	41
Northern Cape	63
Total	**488**

(Source: Own Compilation)

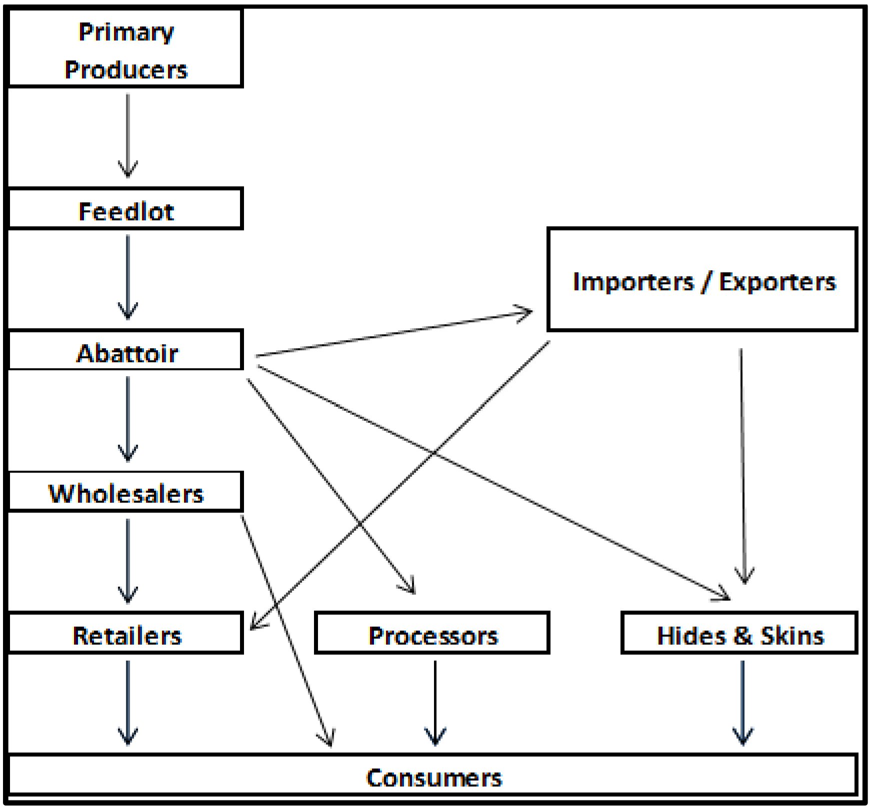
The decline in red meat consumption as discussed above can be a concern regarding the economic viability of biogas plants as less consumption will result in lower slaughter volumes and subsequently less biomass to generate the biogas needed. The next section discusses an overview of the value chain within the industry and the deregulation history of the industry.

2.3 SOUTH AFRICAN RED MEAT INDUSTRY VALUE CHAIN

Livestock farming is the only viable agricultural activity in a large part of South Africa. In South Africa 68.61% of the 122.3 million hectares of land surface are suitable for raising livestock, especially cattle, sheep and goats. (Olivier, 2004:172)

The red meat industry in South Africa evolved from a highly regulated environment to a current totally deregulated environment today. Various government policies, such as restrictions and establishment of abattoirs, supply control via permits and quotas, setting of floor prices and the compulsory auctioning of carcasses according to grade and mass in controlled areas were all characteristics of the red meat industry before deregulation commenced in the early 1990s. The prices in the red meat industry are since the deregulation of the agricultural marketing exemption been determined by market forces (RMMA, 2002:176).

Figure 2.9: The red meat industry structure (supply chain)



As illustrated in Figure 2.10 shows the red meat supply chain. Some important developments in the beef industry since the deregulation of the industry include:

- The supply chain has become increasingly vertically integrated. The integration is fuelled by the feedlot industry where most large feedlots own their own abattoirs and, in addition, have also integrated further down the value chain towards consumers through their own retail outlets due to low industry profit margins.
- The abattoir industry expanded immensely in numbers and capacity. Official numbers of registered abattoirs at the Red Meat Abattoir Association (RMMA) are shown in Table 2.1. According to this classification of abattoirs, the A and B class abattoirs; mostly comply with all statutory measures, whilst it is questionable whether the majority of C, D and E class abattoirs act in accordance with these statutory measures. This noticeably has a cost implication for compiling abattoirs which affect profit taking at different abattoir levels (RMMA, 2002:177).

Table 2.1: The different classes in the abattoir industry

Class	**Slaughter Units***	**Number of abattoirs**	**Estimated slaughtering per class (%)**
A	100+	33	40%
B	50-100	38	20%
C	15-50	38	15%
D	8-15	70	15%
E	<8	162	10%
		341	**100%**
***1 unit = 1 cattle = 1 horse = 3 wieners = 5 pigs = 15 sheep**			

(Source: RMMA, 2002:176)

As can been seen in Table 2.2 there are about 40% of all slaughtering's performed by class A abattoirs and adding the 20% slaughtered by class B abattoirs means that 60% of cattle slaughtered are done by highly regulated abattoirs. This study will focus on empirically investigating an A class abattoir as discussed in Chapter 1.

The distinction between controlled and uncontrolled areas contributed largely towards the irregular slaughtering of animals, before the deregulation of the red meat market. This had favourable consequences for large contract abattoirs in controlled areas. This discrepancy was however obsolete during the deregulation process, resulting in many new and smaller abattoirs in traditional beef producing areas.

This resulted in widespread losses for the formerly privileged abattoirs which forced some of them to close down. The overhead costs for smaller abattoirs are significantly lower than those of larger abattoirs as they don’t necessarily comply with the same regulatory measures as the bigger Class A abattoirs. This has resulted in smaller abattoirs being more competitive and has forced larger abattoirs to take an intensive look at their operating expenses (RMMA, 2002:177).

The following section will take a brief look into these abattoirs’ operating expenses, turnover and profit margins achieved.

2.4 ABATTOIR COST ANALYSIS

The live mass of an animal sourced from a feedlot is around 450kg and will produce a carcass of about 270kg (Between 58% and 60% of the live mass). The average price paid to a supplier in 2012 was around R30.00 per kg for an A2 / A3 class slaughtered carcass. The average cost per head of cattle was therefore R8 100-00 (270kg @ R30.00).

The basic products produced and their value from the slaughtering process is:

- *Primary Products:*

  2x half carcasses weighing 135kg each @ R28-20/kg = R7 614-00

- *By Product*:

  Offal worth R320-00 per set

  Tail weighing 1.1kg @ R41-50/kg = R45-65

  Liver weighing 5.5kg @ R18-50/kg = R79-55

  Tongue weighing 3.1kg @ R29-00/kg = R89-90

Hide weighing 35kg @ R13-50/kg = R456-30

It can be seen from the cost breakdown that the carcass on its own will not be able to cover the purchasing cost of the animal, but together with the by-products it will be able to generate a profit. The by-products form a very important part of the value chain and in revenue is worth around R991-40 per carcass. These by-products include all usable products other than the carcass but do not include the waste products. The total revenue generated per carcass is therefore around R8 605-40 per carcass.

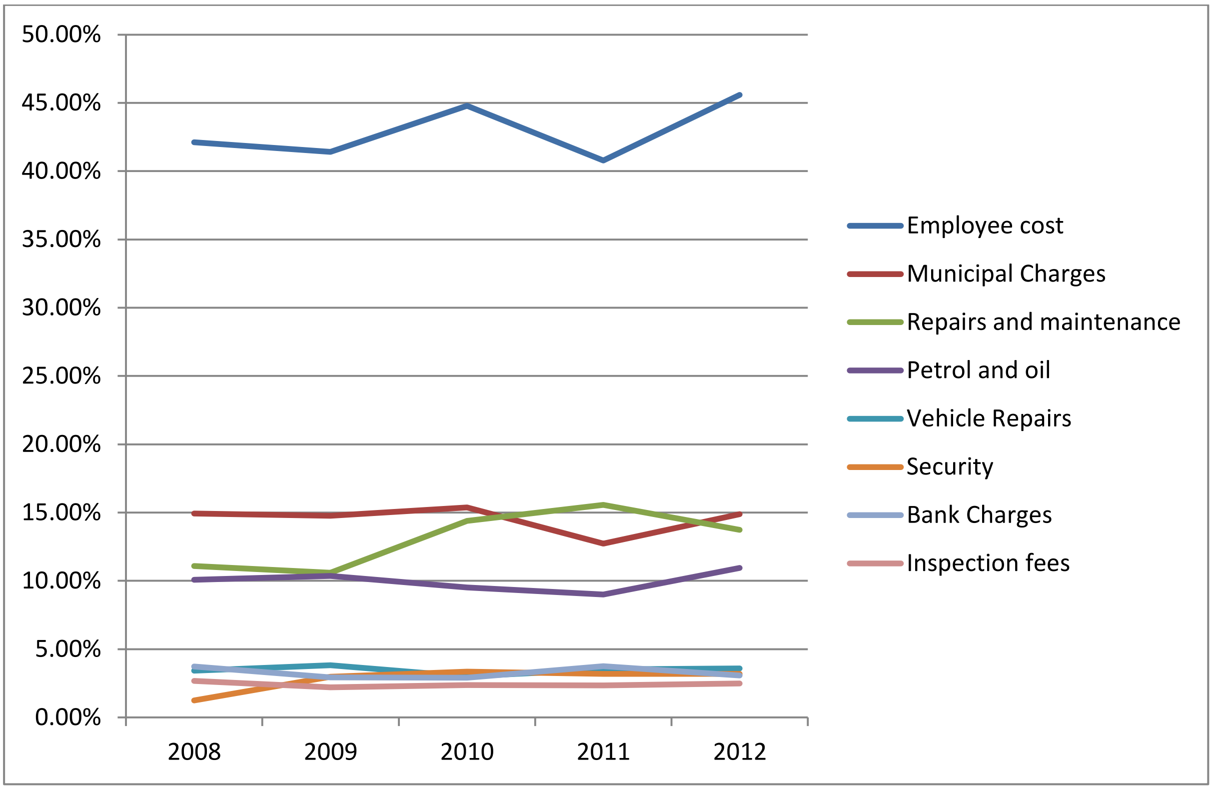
A simplistic cost breakdown for the above activities will therefore look like this:

- Animal Cost = - R8 100-00
- Cost of Value Chain Activities = - R443-00
- Revenue from 2x half Carcasses = + R7 614-00
- Revenue from By-products = + R991-40
- Profit Margin = + R62-40 (0.7%)

Managing the value chain in the red meat industry will maximise profits obtained. The more the carcass and meat is processed, the greater the selling price to the customer. There is however a marginal increase in costs between the various processing methods due to numerous activities involved in the processing. There is nonetheless a significant gain in revenue which potentially can increase the net profit per carcass.

The red meat industry is a highly competitive industry with fierce competition not only from within the industry but also from other industries offering substitute products. In line with competition, are low profit margins achieved and emphasis is placed on controlling operating expenses and to achieving optimal volumes. Gross profit margins are ranging from 8% to 10% due to this competition and utilisation of capacity is the only method to challenge these low margins.

Figure 2.10: Cost breakdown of expenses as percentage of total costs



(Source: Own compilation)

From Figure 2.11 it is evident that employee cost is the main contributor to operating expenses of 40% to 45%. This is followed by municipal charges of which electricity are the main contributor. Municipal charges contribute to about 15% of the total operating expenses and if these costs can be avoided by the use of a biogas plant, it will contribute vastly to achieving a competitive advantage within the industry.

The following section focuses on current waste disposal practices at abattoirs and the environmental concerns about these practises.

2.5 WASTE DISPOSAL AT ABATTOIRS

Waste as defined in terms of the Environment Conservation Act 1989 (Act 73 of 1989) (SA, 1989) are: “Waste means any matter, whether gaseous, liquid or solid or any combination thereof, which is from time to time designated by the Minister by Notice in the Gazette as any undesirable or superfluous by-product, emission, resolve of remainder of any process or activity”.

Waste from abattoirs can be defined as waste or waste water from the slaughter process which could consist of contaminants such as animal faeces, blood, fat, animal trimmings, paunch content and urine (Roberts & De Jager, 2004:1)

The Red Meat Association classifies secondary abattoir waste into two categories; namely solid waste and waste water. Abattoirs generate solid waste that mainly consists of inedible meat products (some can be used as by-products) and waste products such as manure, paunch contents and condemned meat products that needs to be correctly disposed of according to the Meat Safety Act 40 of 2000 (RMMA, 2012:19)

A typical breakdown of the products and solid wastes that are generated from the slaughter of cattle is listed below in Table 2.2. This indicates that from a cow with a live mass of 400kg, the dressed carcass of around 220kg together with the hide and offal of 28kg and 36kg respectively can be sold, while the other products are all regarded as wastes. Abattoirs try to optimise the recovery of edible portions for human consumption from the meat processing cycle. Significant quantities of secondary waste materials are however generated that are not suitable for further consumption as can be further seen in Table 2.2.

Table 2.2: Products and solid wastes from cattle processing

Item	**Weight %**	**Weight (Kg)**
Dressed Carcass	55%	220
Hide / Skin	7%	28
Blood	4%	16
Offal	9%	36
Paunch Contents	15%	60
Other Wastes*	10%	40
Total	100%	400

(Source: RMMA, 2012:19)

Large amounts of water are also used in abattoirs in the slaughtering and cleaning processes. The common disposal method used for waste water is municipal drainage systems (Roberts & De Jager, 2004:2). Table 2.3 below identify the main areas of the abattoir responsible for both water wastage and pollution.

Table 2.3: Water usage at A-grade red meat abattoirs

Operations	**% Water Intake**
Lairages	5 - 12
Slaughter / Carcass dressing	13 - 33
Offal handling	11 - 60
Utilities (steam, hot and cold water)	2 - 36
Services (ablutions, general washing)	1 - 12

(Source: RMMA, 2012:19)

High levels of water are being wasted by washing faeces from the lairages into a drainage system without prior removal of any waste. Solids and other materials are all hosed into the drainage system without any prior subtraction of solids or dry-brush cleaning of slaughter surface extents. Normally where municipal sewage connections do exists, all effluent from the slaughter floor and processing areas are discharged into the municipal sewage system without prior separation or pre-treatment. This effluent being discharged is made up of water and may contain blood, solids, hair, bone pieces, hooves and grease/fat and results in high discharge costs through municipal effluent penalty charges (RMMA, 2012:26).

The traditional methods worldwide for disposal of blood by abattoirs and meat processors are rendering, land application, composting and transfer to a waste water treatment plant. Mittal (2006:1119) further describes rendering as the process of breaking blood, meat pieces and other animal by-products to useful components through heat application. The rendering of condemned meat and blood products result in the processing of blood meat, carcass and bone meal. The blood and carcass meat are used for addition into pet food and bone meat are added to fertilisers used for roses and other flowers (Roberts & De Jager, 2004:1) Rendering plants are also now starting to charge a disposal fee for blood due to user demand and feedstock supply. Due to this fee, rendering is now less attractive and less economical for meat processors (Mittal, 2006:1119).

Large volumes of effluents are additionally produced by slaughterhouses and meat processing plants. These wastewaters generated, usually contains high amounts of biodegradable organic matter, with soluble and insoluble fraction.

The treatability of abattoir wastewater causes significant problems when compared with other agro-processing industries wastewaters. These problems encountered are because of the high suspended solid fats and protein content in the waste water and due to the insolubility which slows the rate of degradation, and the tendency to form scums (Gannoun *et al.*, 2009:263). Anaerobic digestion systems generating biogas provides an opportunity for abattoirs to produce renewable energy from these slaughter wastes and can be a viable option for abattoirs.

According to Salminen and Rintala (cited by Roberts & De Jager, 2004:1) are there internationally various waste management strategies being used, for example, incineration, land filling, anaerobic digestion, rendering or part-rendering of slaughter waste products. Countries world-wide, as with European countries, are moving away from incineration and are investing into alternative waste management systems such as biogas.

The following section will focus on the energy situation in South Africa, one of the main reasons more emphasis is being placed on renewable energy sources.

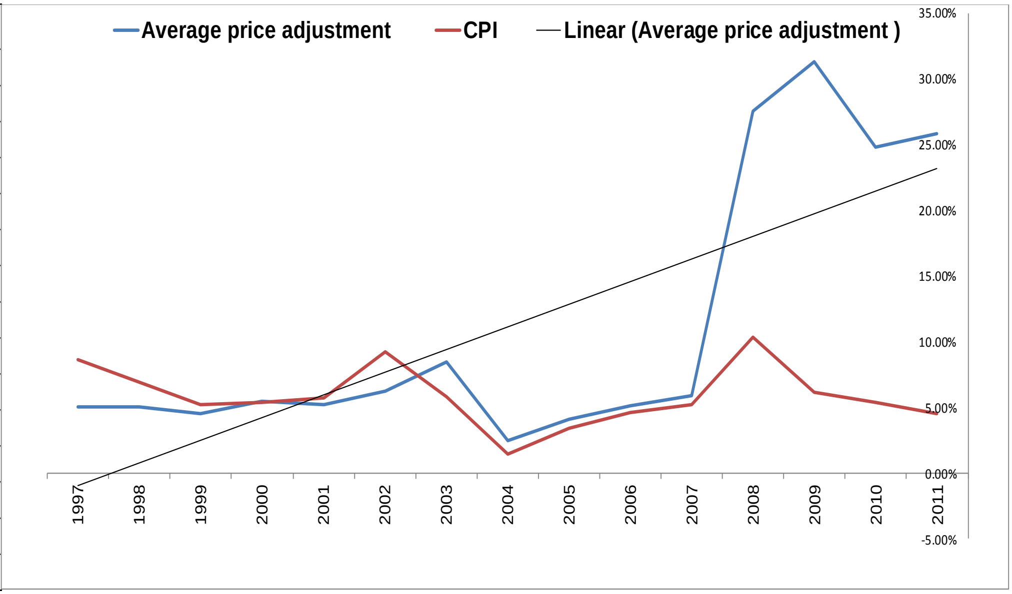
2.6 THE ENERGY SITUATION IN SOUTH AFRICA

The supply of electricity in South Africa is dominated by Eskom that are state owned. Eskom not only owns and operates the national transmission system but also produces virtually all of South African electricity with 95% of the electricity produced by Eskom (Pegels, 2010:4947). The primary energy source used in electricity production is coal (86%), followed by nuclear energy (5%) and various other sources, including certain renewable energy sources such as hydro power (Pegels, 2010:4947). Since 2007 Eskom has experienced a lack of capacity in the generation and reticulation of electricity. As a result of this deficiency in capacity, blackouts and power shortage became common in South Africa in the first quarter of 2008. This had damaging effects on the South African economy, and as a result the economic growth fell to 1.57% in the first quarter of 2008 from 5.4% in the last quarter of 2007 (Inglesi, 2010:1).

Eskom argued that government’s refusal to fund electricity capacity expansion was the main source for these crises and thus requested a multi-billion Rand budget to increase capacity and avoid similar problems in the future. Eskom applied to the National Energy Regulator of South Africa (NERSA) in September 2009 with a proposal consisting of three increases of 45% each, followed by three smaller ones, to be implemented over a five-year period. Eskom later revised these proposals, reducing the initial three increases to 35% after they decided to delay the construction of their Kusile power station (Inglesi, 2010:1).

Figure 2.11: Eskom Tariff Price increase from 1997 to 2011

Year	Average price adjustment	CPI
1997	5.00%	8.62%
1998	5.00%	6.87%
1999	4.50%	5.21%
2000	5.50%	5.37%
2001	5.20%	5.70%
2002	6.20%	9.20%
2003	8.43%	5.80%
2004	2.50%	1.40%
2005	4.10%	3.42%
2006	5.10%	4.60%
2007	5.90%	5.20%
2008	27.50%	10.30%
2009	31.30%	6.16%
2010	24.80%	5.40%
2011	25.80%	4.50%



(Source: Adjusted from Eskom, 2011)

Despite a 27.5% increase in 2008 and a further 31.3% rise in 2009, the price of electricity in South Africa was still among the lowest in the world (Pegels, 2010:4947). South Africa has had historically low electricity tariffs that have been very detrimental to the development of renewable energy generation (Winkler, 2001:34). The accruing price increases have resulted in a much increased electricity tariff that in turn has improved the economic viability of renewable energy sources.

For a country like South Africa, that are fossil fuel based and emission intensive, the challenge of transforming entire economies are enormous. On the contrary, facing climate change impacts in an increasingly carbon constrained world, South Africa has to reduce greenhouse gas emissions intensity soon and decidedly. The most of the emissions problems are contributed by the South African electricity sectors that are a vital part of South Africa’s economy.

The South African government have taken steps to enhance energy efficiency and promote renewable energy; still, they fail to show large-scale effects (Pegels, 2010:4945).

2.7 RENEWABLE ENERGY SOURCES

According to the EU Commission, renewable sources of energy include "wind power (both onshore and offshore), solar power (thermal, photovoltaic and concentrated), hydroelectric power, tidal power, geothermal energy and biomass (including bio fuels and bio liquids). As alternatives to fossil fuels, their use aims at reducing pollution and greenhouse gas emissions. Another role of renewable energy is the diversification of supply, with the potential to reduce dependence on oil and gas" (Commission Communication, 2011).

"One of the most serious problems of this century is climate change". As stated by Meinshausen (cited in Pegels, 2010:4945) the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) point to human activity as one of the major causes of global warming and that business as usual may lead to a disastrous transformation of the planet. An increase in the world population together with improvements in quality of life and the industrialisation of developing nations has dramatically increased the consumption of fossil fuels. The alleviation of greenhouse gas emission and reduction in global warming can be provided by renewable energy technologies through substituting conventional energy sources (Panwar *et al.*, 2011:1513)

Renewable energy technologies are considered as clean sources of energy. Optimal uses of these resources are sustainable based on current and future social and economic needs as they have minimal environmental impacts, and produce minimum secondary waste. These renewable energy sources contribute to 14% of total world energy demand and include biomass, hydropower, geothermal, solar, wind and marine energies (Panwar *et al.*, 2011:1513).

Table 2.4: Expected global energy scenario by 2040

Total consumption (million tons oil equivalent)	**2001**		**2010**		**2020**		**2030**		**2040**	
	Total	**% RES**	**Total**	**% RES**	**Total**	**% RES**	**Total**	**% RES**	**Total**	**% RES**
	10038		**10549**		**11425**		**12352**		**13310**	
Biomass	1080	79.09%	1313	75.22%	1791	66.47%	2483	57.89%	3271	51.50%
Large hydro	22.7	1.66%	266	15.24%	309	11.47%	341	7.95%	358	5.64%
Geothermal	43.2	3.16%	86	4.93%	186	6.90%	333	7.76%	493	7.76%
Small hydro	9.5	0.70%	19	1.09%	49	1.82%	106	2.47%	189	2.98%
Wind	4.7	0.34%	44	2.52%	266	9.87%	542	12.64%	688	10.83%
Solar thermal	4.1	0.30%	15	0.86%	66	2.45%	244	5.69%	480	7.56%
Photovoltaic	0.1	0.01%	2	0.11%	24	0.89%	221	5.15%	784	12.34%
Solar thermal electricity	0.1	0.01%	0.4	0.02%	3	0.11%	16	0.37%	68	1.07%
Marine (tidal/wave/ocean)	0.005	0.00%	0.1	0.01%	0.4	0.01%	3	0.07%	20	0.31%
Total RES	**1365.5**		**1745.5**		**2694.4**		**4289**		**6351**	
Renewable energy source contribution (%)	**13.60%**		**16.60%**		**23.60%**		**34.70%**		**47.70%**	

(Source: Adjusted from Kralova, 2010)

Renewable energy sources are also known as alternative and sustainable energy sources and are expected to increase very significantly between 30 – 80% in 2100 (Fridleifsson, 2001:300). The increase in renewable sources can be seen in Table 2.4 where expected renewable energy source contribution is expected to increase from 13.6% in 2010 to 47.70% in 2040. This 34.10% is a clear indication on the emphasis being placed on renewable energy sources. The contribution of biomass is expected to decrease from 75.22% in 2010 to 51.50% in 2040 but will still be the leading contributor of renewable energy sources.

Table 2.5 beneath indicates the main renewable energy sources and their applications. From this can be seen that biomass, which include biogas applications, can be used for heat and power generation as well as digestion. This clearly indicates that biogas will be an ideal option for abattoirs as it will generate heat that can be used to heat water for the slaughtering process, generate electricity that can be used on site and digest all slaughter waste.

Table 2.5: Main renewable energy sources and usage options

Energy source	Energy conversion and usage options
Hydropower	Power generation
Modern biomass	Heat and power generation, pyrolysis, gasification, digestion
Geothermal	Urban heating, power generation, hydrothermal, hot dry rock
Solar	Solar home system, solar dryers, solar cookers
Direct solar	Photovoltaic, thermal power generation, water heaters
Wind	Power generation, wind generators, windmills, water pumps
Wave	Numerous designs
Tidal	Barrage, tidal stream

(Source: Demirbas, 2006)

The next section will focus on biogas as a source of renewable energy and the benefits involved using biogas.

2.8 BIOGAS AS ALTERNATIVE ENERGY SOURCE

2.8.1 Introduction

Amigan and Von Blottnits (2007:3090) continue the increased awareness and widespread research on new and renewable energy resources, including biogas, driven by the continuous problems arising from the non-sustainable use of fossil fuels. Biogas is a renewable energy source which is produced by digesting bio waste, such as food refuse, manure and slaughterhouse waste (Bagge *et al.*, 2010:1549). Biogas generated from anaerobic digestion of biomass is a renewable and sustainable energy carrier. Biogas can be derived from at least five main biomass (refer to Table 2.5) resources including sewage, landfill, livestock manure, organic wastes and energy crops (Budzianowski, 2012:343) and contains 50-70% methane and 30-50% carbon dioxide, depending on the substrate (Bond and Templeton, 2011:347)

Amiri *et al.* (2013:242) perceive that biogas is produced from organic materials through an anaerobic condition treatment. Biomass as a form of renewable energy is one of the most efficient and effective options among the various other alternative energy sources currently available. When compared to renewable energy generation from biomass, thorough anaerobic digestion, with other renewable sources like hydro, solar and wind, is biomass energy more economical as it requires less capital investment and per unit production cost (Rao *et al.*, 2010:2087).

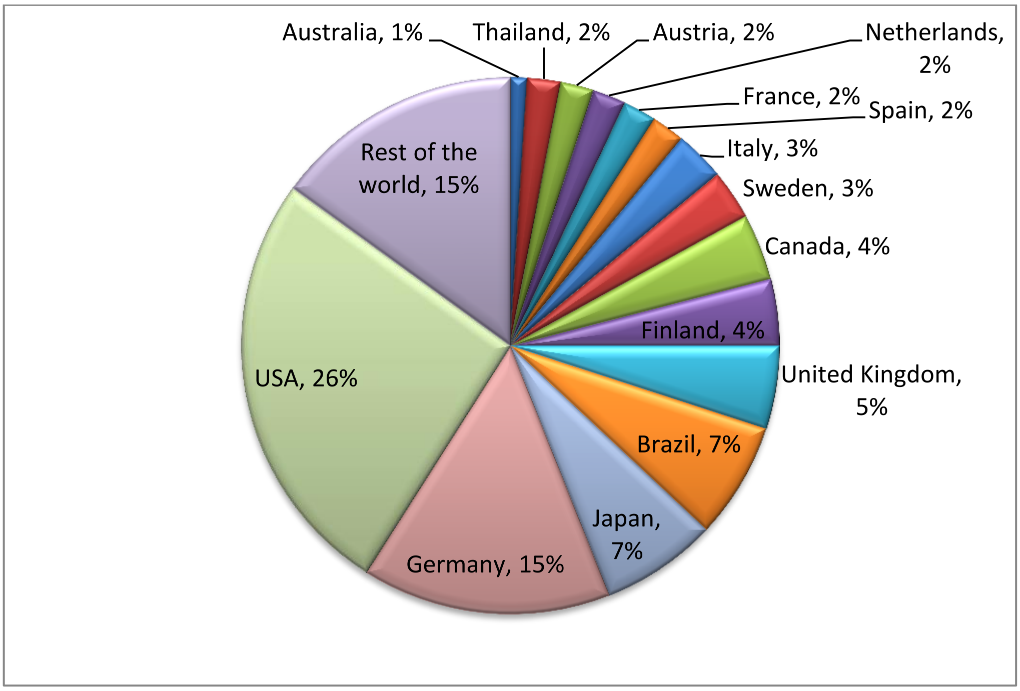
The waste generated from slaughtering activities have related chemical characteristics than that of domestic sewage but are considerably more concentrated in general and are almost entirely organic (Ahmad & Ansari, 2012:1). According to Manjunath *et al.* (cited in Ahmad & Ansori, 2012:1) slaughterhouses contain effluent moderate to high strength complex wastewater comprising about 45% soluble and 55% coarse suspended organics. The number of animals killed will influence the composition and flow. The size of associated biogas plants in Austria range from 18 to 1000 kW. As the size of these plants increase, the investment cost per electricity kW of capacity fall. At the same time the labour requirements increase at a less than proportional rate and the electrical efficiency increases (Walla & Schneeberger, 2008:551).

Biogas is produced by anaerobic fermentation of organic material and is a methane rich gas. Biogas is distinct from other renewable energy sources because of its importance of collecting and controlling organic waste materials. These organic waste materials can cause severe public health and environmental pollution if left untreated. In addition to controlling organic waste materials biogas produced by anaerobic fermentation, also at the same time produce fertiliser and water for use in agricultural irrigation (Amigan & Von Blottnits, 2007:3090).

Biogas production systems, unlike other forms of renewable energy, are relatively simple and can be operated at small and large scales in urban or very remote rural locations (Taleghani, 2005:2).

From Figure 2.13 it can be seen that the United States of America and Germany are at the forefront of biomass applications. The 15% include all other countries that are not listed of which South Africa forms part of.

Figure 2.12: Global distribution of biomass energy consumption in 2013



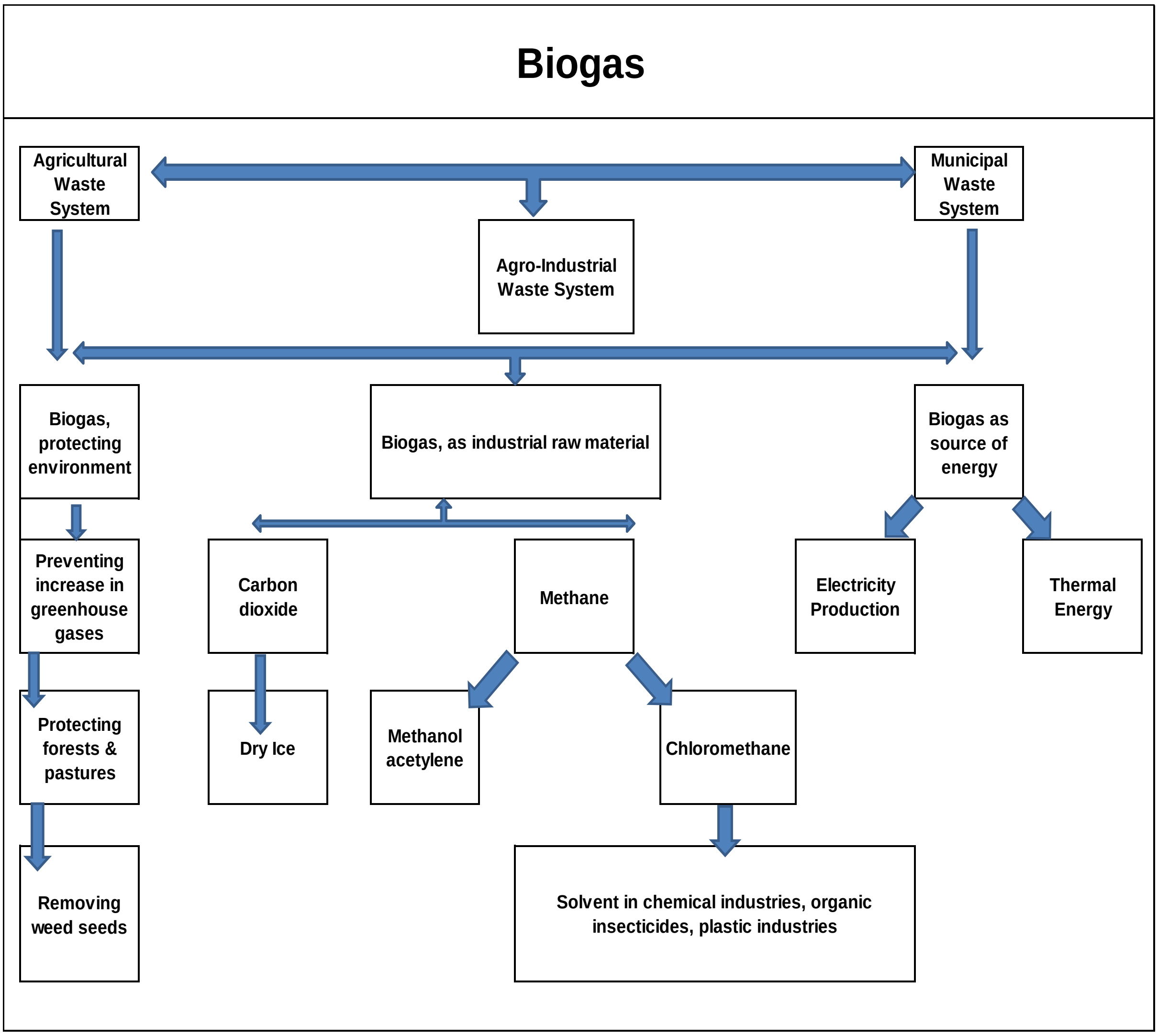
(Source: Adopted from Mohammed *et al.*, 2013)

According to Holm-Nielsen *et al.* (2009:5483) there are various usages for biogas, including:

- Production of heat and/or steam (lowest value chain utilisation)
- Electricity production with combined heat and power production (CHP)
- Industrial energy source for heat, steam and/or electricity and cooling
- Upgraded and utilisation as vehicle fuel
- Production of chemicals and /or proteins
- Upgrading and injection in the natural gas grids
- Fuel for fuel cells

Figure 2.14 below indicate the main benefits, applications and usage of anaerobic digester systems. From this it can be concluded that there are various applications and benefits of biogas, while the main application remain the use of biogas as a source of energy through electricity production and thermal energy.

Figure 2.13: Benefits, application and usage of anaerobic digester system



(Source: Adapted from Amigun & Von Blottnitz, 2007:3091)

For the purposes of this study, the focus will only be on electricity production with combined heat and power production (CHP) as this will secure a constant electricity supply and heat generated that can be use within the abattoir. Biogas produced by anaerobic digestion in various environments composes mainly of CH4 and CO2. By-products of the anaerobic digestion include biogas and sludge (Moletta *et al.*, 2008:595).

2.8.2 Anaerobic Digestion of Slaughter Waste

According to Karagiannidis and Perkoulidis (cited by Khalid *et al.*, 2011:1738) anaerobic digestion of organic waste received has worldwide attention since the introduction of both commercial and pilot anaerobic digestion plant designs during the early 1990s. Anaerobic digestion is a process by which almost any organic waste can be biologically transformed into another form, this being done by the anaerobic bacteria breaking down the organic material in the absence of oxygen (Anderson *et al.*, 2013:85; Khalid *et al.*, 2011:1738; Hall & Howe 2012:204).

Anderson *et al.* (2013:85) maintain that anaerobic digester technology, as a form of renewable energy has a significant upside potential with little public resistance. Anaerobic digestion's ability to turn waste materials, such as slaughter waste and livestock manure, into a clean and local energy source is what is creating such interest into this technology. Two categories of valuable products are produced when organic residues are converted through anaerobic digestion: biogas on the one hand, used as a renewable fuel to produce green electricity, heat or as a vehicle fuel, and on the other hand a digested substrate, commonly termed digestate, such are used as a compost in agriculture when further refined, the digestate can be converted into a concentrated fertiliser, clean water and fibre products (Holm-Nielsen *et al.*, 2009:5479). These valuable products that are produced will affect the economic viability of such a biogas plant as stated in the primary objectives of the study.

Goulding and Power (2013:121) sustains that in many parts of continental Europe anaerobic digestion is a tried and established technology with countries such as Austria and Germany delivering different degrees of anaerobic digestion application success. According to Smyth *et al.* (cited in Goulding & Power, 2013:121) Austria has over 600 anaerobic digestion facilities of which 350 are agriculturally orientated. Germany have at an eminent level, 4500 biogas facilities which employs over 11 000 people and utilise approximately 530 000 hectare of cultivated land area.

According to Anderson *et al.* (2013:85) previous studies generally found that anaerobic digesters to be poor investments for private firms without public assistance. Bishop and Shumway (cited by Anderson *et al.*, 2013:85) further found in their studies of anaerobic digestion on a dairy farm in Washington State that the net present value of the investment was negative but that revenues and consequently financial returns vary with geographic location while Lazarus and Redstram (cited by Anderson *et al.*, 2013:85) found in their studies that the anaerobic digester investment to be financially unfeasible without a significant rise in electricity prices. Similarly Wang *et al.* (2011:4957) found that the feasibility of anaerobic digesters is highly dependent on government grants, enhanced electricity prices, and revenue generated from by-products of the system.

Holm-Nielsen *et al.* (2009:5478) maintain that a biogas production cycle represents an integrated system of renewable energy production, resource utilisation, organic waste treatment and other environmental benefits like less greenhouse gas emission.

The treatment of abattoir waste through anaerobic digestion is not new and the use of systems for demonstration, research and full scale application has been reported since the 1950s. However, traditional anaerobic processes are limited by low rates of organic matter removal, long hydraulic retention time, accumulation of excessive residual matter and large reactor volume requirements. The development of high rate anaerobic biological reactors since then, have overcome many of these limitations (Gannoun *et al.*, 2009:263).

According to Jian and Zhang (cited in Gannoun *et al.*, 2009:263) anaerobic digestion is becoming the subject of current research of organic waste management for several reasons. Anaerobic digestion reduces the pathogens in these wastes and further minimises the odours and helps to convert a large part of the degradable organic carbon to biogas to be used for energy. Matea *et al.* (cited in Gannon *et al.*, 2009:264) mention the advantages of anaerobic digestion: biogas production, low generation of sludge, no aeration cost and the elimination of pathogens.

Table 2.6 below specifies the unfamiliarity of biogas in South Africa and further highlights the implementation barriers and various incentive options that will improve the viability of biogas in South Africa. The high capital cost, lack of feed-in-tariff and lack of knowledge and awareness are the foremost implementation barriers. The objectives of this study are to determine the economic viability of biogas plants at abattoirs in South Africa that are currently fronting the same implementation barriers.

Table 2.6: Barriers in the South African biogas sector

Application of biogas	Implementation barriers	Incentive options
Agricultural	• No operational feed-in-tariff • No turnkey provider • Electricity prices still relative cheap • Current farming techniques not appropriate for Clean Development Mechanism (CDM) • Costs too high to make CDM viable • Access to finance	• Operationalise Rebid • Provide international subsidy for CDM registration and transaction cost • Improve enabling environment to increase demand of biogas units and appropriate financial incentives to increase suppliers • Encourage international technology collaborations
Industrial	• High capital cost • No incentives: Low tipping fees and no CO2 tax • Motivation for biogas digesters are for waste management not energy generation • Municipal by-law limits private sector involvement • Lack of knowledge and awareness • Lack of feed-in-tariff	• Implement environmental policies which increase tipping fees and CO2 tax • Adapt municipal bylaws to encourage public-private partnerships • Operationalize Rebid Build on international expertise
Domestic	• Lack of social awareness • High capital cost – lack of technology suppliers • Relative cheap electricity prices • Lack of knowledge and awareness	• Develop innovative financing packages for end users • Educational and information platforms for end users

(Source: Boyd, 2012:306)

Table 2.7 below shows the industrial biogas plants in South Africa and their various usages. It can be concluded from this that there are not many industrial biogas plants in operation in South Africa.

Table 2.7: Current industrial biogas plants in operation in South Africa

Location	Digester size	Substrate	End use	Year
PetroSA (CDM)	4.2MWe capacity (approximately 25,700 MWh/year	Refinery process waste	Electricity	2007
SA Brewery Alrode	9200 m³ produced each day	Process wastewater and organic waste	Used to power large onsite boilers	2009
SA Brewery Rosslyn (CDM)		Onsite wastewater digester	Substitute part of coal consumption at boiler room	2009
Cato Manor	280 m³	Sewage and chicken litter	Not yet commissioned	
Humphries Pig Farm, Limpopo	Small amount of onsite electrical generation	Waste from piggery	Partly operational and under CDM registration process	2009

(Source: Adjusted from Boyd, 2012:306)

Anaerobic digestion as a sustainable technology for treatment of organic waste and production of bio-energy is gaining increasing attention. Zamanzadeh *et al.* (2013:1559) further describe anaerobic digestion as a “complex process involving the coordination of multiple microbial groups and biochemical reactions. Following hydrolyses of particulate matter; the complex soluble organic matter is converted to volatile fatty acids, which are in turn converted to acetate and hydrogen as the main methanogen substrates.”

2.8.3 Combined heat and power (CHP) units

In several European countries the utilisation of biogas as an energy source is a proven technology. Biogas utilisation through a combined heat and power (CHP) system provides greater economy and efficiency as it produces two energy outputs (heat and electricity) from one operation. Another advantage of utilising biogas through a CHP unit is that no upgrading of the gas is required and the gas can be deployed in the system without modification after it is produced. As the development of biogas to CHP is less complex than utilising biogas as a transport fuel, the infrastructure required is also less (Goulding & Power, 2013:122)

The use of biogas for cogeneration of heat and power is a possibility, but thus for it is only established that biogas produced from highly concentrated substrates, such as agricultural biomass, animal manure, solid waste landfills, industrial effluents and sewage sludge will be usable for this cogeneration (Lobato *et al.*, 2013:159). Waste generated from the slaughtering of animals falls in this high concentrated substrates classification and consequently the use of a combined heat and power generator are promising.

2.9 ENVIRONMENTAL CONCERNS IN THE RED MEAT INDUSTRY

Consumers are increasingly concerned that food production, processing and marketing are undertaken in an environmentally responsible manner. The industry is growing especially in the developing nations such as on the African continent and getting more and more industrialised with vast environmental and social impacts.

The meat industry has a significant impact on global warming. Livestock production accounts for 18% of global greenhouse gas emissions, including 9% of carbon dioxide and 37% of methane gas emissions worldwide. More than two-thirds of all agricultural land is devoted to growing feed for livestock, while only 8% is used to grow food for direct human consumption (Anon, 2013).

If the entire world population were to consume as much meat as the Western world does (80 kg of meat per capita per annum) the global land required would be two-thirds more than what is presently used. The industry also uses substantial amounts of fresh water, destroys forests and grasslands, and causes soil erosion, while pollution and the runoff of fertiliser and animal waste create dead zones in coastal areas and smother coral reefs. In addition, there is concern over increased antibiotic resistance, since livestock accounts for 50% of antibiotic use globally (Anon, 2013).

One solution is for countries to adopt policies that provide incentives for better management practices that focus on land conservation and more efficient water and fertiliser use. Good meat production practices should start at the farm, and include, amongst others, the prevention of soil erosion, economical use of water and discontinuation of the use of crop pesticides (Kajiwara & Tsuru, 2012:1).

The key focus areas for the future is going to be to ensure that farmers are able to run viable livestock enterprises that are environmentally and economically sustainable. Companies operating within the beef supply chain are therefore going to come under increased pressures from consumers to prove that their products are produced in a safe and green manner (Kajiwara & Tsuru, 2012:1).

2.10 ENVIRONMENTAL SUSTAINABILITY

According to Spinelli and Adams (2012:111) entrepreneurs currently require looking at their industries through a sustainability view to recognise new opportunities and devise means on acting on these opportunities. Current continuing business success must be sustained by revenues and earnings, and profits must be reinvested into product and service progresses to drive future growth. Sustainability, however, not only involves the economic viability conception but also refers to the role it plays in supporting communities, improving human health, and protecting ecological systems (Spinelli & Adams, 2012:117). Thompson *et al.* (2012:363) describe sustainable business practices as those capable of meeting the needs of the present without compromising the ability to meet the needs of the future.

With a world population that is expected to double by 2050, the major challenge currently is how to create prosperity for more people worldwide given climate change, urban air pollution, water shortages, energy supply challenges, and the necessity of feeding and providing decent lifestyles for people worldwide (Spinelli & Adams, 2012:117).

Chase and Jacobs (2011:53) describe sustainability as the ability to maintain balance in a system and that management now needs to consider the mandates related to the constant economic, employee, and environmental viability of the firm (triple bottom line). Economically the firm must be profitable while at the same time ensuring employee job security, positive working conditions and essentiality the development of opportunities. A new challenge for operation and supply managers include non-polluting and non-resource-depleting products and processes.

With worldwide consumerism and environmentalism movements mature, marketers in today's environment are being called to develop sustainable marketing practices. Social responsibility and corporate ethics have become crucial parts for almost every business with a renewed and very demanding environmental movement. It is expected from companies to deliver value in a socially and environmentally responsible way by their customers.

Social-responsibility and environmental movements will place harsher demands on companies in the future with various companies only nudging when forced by legislation or consumer uproars (Kotler & Amstrong, 2012:52).

Forward-looking companies, however, readily accept their responsibility to the world around them and view sustainable marketing as an opportunity to do well by doing good. These companies seek ways to profit by serving immediate needs and the best long-run interests of their customers, communities and environment (Kotler & Amstrong, 2012:52).

Kotler and Amstrong (2012:618) state that more and more companies are adopting environmental sustainability policies and further states that environmental sustainability is about generating profits while also helping to save the planet.

A company can practice pollution prevention at the most basic level by pollution control. Companies accentuating prevention have responded with internal "green marketing" programs that are based on crafting and developing ecologically safer products, recyclable and biodegradable packaging, better pollution controls, and more energy efficient operations (Kotler & Amstrong, 2012:618).

Table 2.8 shows on a grid that companies can gauge their progress towards environmental sustainability. It includes both internal and external activities that will pay off for the firm and environment in the short run and also “beyond greening” activities that will pay off in the long run.

Table 2.8: The Environmental Sustainability Portfolio

	Today Greening:	**Tomorrow Greening**
Internal	**Polluting prevention** Elimination or reducing waste before it is created	**New clean technology** Developing new sets of environmental skills and capabilities
External	**Product stewardship** Minimising environmental impact throughout the entire product life cycle	**Sustainability vision** Creating a strategic framework for future sustainability

(Source: Kotler & Amstrong, 2012:618)

Companies can also incorporate environmental sustainability into their strategy by developing a sustainable vision which can serve as a guide to the future showing how the company’s products and services, processes and policies must evolve and what new technologies must be developed to get there. This sustainability vision will provide a framework for pollution control, product stewardship, and new environmental technology for the company and others to follow (Kotler & Amstrong 2012:620).

Thompson *et al.* (2012:363) confirm this by maintaining that many organisations have also begun to incorporate a consideration of environmental sustainability into their strategy-making activities. Environmental sustainability strategies entail deliberate and intensive actions to operate in a manner that protects natural resources and ecological support systems, protections against outcomes that will finally threaten the planet, and is consequently sustainable for centuries.

Containing the adverse effects of greenhouse gases and other forms of pollution so as to reduce global warming are another aspect of sustainability concerns. Other aspects of sustainability include greater reliance on sustainable energy sources, greater use of recyclable materials, environmentally sound waste management practices and increased attempts to decuple environmental degradation and economic growth (Thompson *et al.*, 2012:363).

Thompson *et al.* (2012:366) maintains there are several good reasons why the exercise of social and environmental responsibility may be good for business and includes the following:

- *Such can lead to increased buyer patronage.* An environmental sustainability strategy may help differentiating a company from rivals, giving them an edge over these rivals and will at the same time appeal to consumers who desire to do business with companies that are good corporate citizens.
- *A strong commitment to socially responsible behaviour reduces the risk of reputation-damaging incidents.* Companies that place little importance on operating in a socially responsible manner are more prone to scandal and embarrassment due to environmental, consumer and human rights activist groups that are quick to criticise businesses who they consider to be out of line.
- *Sustainable business practices can lower costs and enhance employee recruiting and retention.* Companies that operate in a sustainable matter are better able to attract and retain employees which can contribute to lower cost for recruitment and better worker productivity. By being environmentally sustainable can also contribute to a company becoming the industry's lowest-cost producer.
- *Opportunities for revenue enhancement may also come from environmental sustainability strategies.* The drive for sustainability can craft other innovative efforts that in turn can lead to new products and other revenue opportunities.

- *Sustainable business practices are in the best long-term interest of shareholders.* Social responsibility and environmental sustainable strategies can work to the advantage of shareholders in several ways. It will help with future legal and regulatory actions, which can be costly and burdensome, being avoided. It will also increase buyer patronage, lower costs, offer revenue-enhancing opportunities, increase productivity, reduce risks of reputation-damaging incidents and finally will contribute to the total value created by the company and improve its profitability.

2.11 SUMMARY

Demand for meat is increasing globally. One reason is the rapid growing global population, which is forecasted to reach 9.3 billion in 2050. An additional factor is that as the per capita income increases in line with economic development, lifestyles and eating habits also change. Beef consumption is expanding in developing countries at a greater pace than it is declining in developed nations, and it’s predicted that consumption will rise to around 73 million tons in the year 2020. Based on this assessment of the global meat market it is evident that there is a lot of growth expected within the developing countries of Africa of which beef specifically will contribute to a massive extent.

The production of livestock in South Africa, as part of agriculture activities, continued to dominate its total contribution of total gross value in the agricultural sector. Statistics has indicated that livestock production contributed to 48% of the total gross value of agricultural production during the 2010/2011 season. The red meat industry in South Africa evolved from a highly regulated environment to a current totally deregulated environment today. Various government policies, such as restrictions and establishment of abattoirs, supply control via permits and quotas, setting of floor prices and the compulsory auctioning of carcasses according to grade and mass in controlled areas were all characteristics of the red meat industry before deregulation commended in the early 1990s. Abattoirs generate vast amounts of waste that includes solid waste mainly consisting of inedible meat products and other waste products such as manure, paunch contents and condemned meat products that need to be correctly disposed of.

The traditional methods worldwide for disposal of blood by abattoirs and meat processors are rendering, land application, composting and transfer to a waste water treatment plant. The treatability of abattoir wastewater causes further significant problems when compared with other agro-processing industries wastewaters. These problems encountered are because of the high suspended solid fats and protein content in the waste water. Anaerobic digestion systems generating biogas provides an opportunity for abattoirs to produce renewable energy from these slaughter wastes and can be a viable option for abattoirs.

Renewable energy technologies are considered as clean sources of energy. Optimal uses of these resources are sustainable based on current and future social and economic needs as they have minimal environmental impacts, and produce minimum secondary waste. These renewable energy sources contribute to 14% of total world energy demand and include biomass, hydropower, geothermal, solar, wind and marine energies. There are several appealing features in the production of biogas. Renewable energy can be created and a variety of environmental concerns associated with slaughter waste disposal can be tempered.

The following chapter will present assumptions and data gathered and from this will be determined if biogas plants at abattoirs in South Africa will be an economically viable option and what concerns will disturb the economic viability of biogas plants. Capital budgeting techniques will be introduced and a framework for the economic viability model developed with various assumptions being made regarding the model.

CHAPTER 3: ECONOMIC VIABILITY: A CASE STUDY

3.1 INTRODUCTION

The previous chapter provided an overview of the red meat industry and other related concepts were introduced as a frame of reference to identify and prioritise the main drivers for biogas plants at abattoirs in South Africa.

In this chapter the issues affecting the economic viability of biogas plants will be empirically investigated. Capital budgeting techniques will be introduced and further a framework for the economic viability model developed with various assumptions being made regarding the model.

The outcome of the empirical study will enable organisations in the red meat industry to identify the various factors influencing the economic viability of biogas plants. In perspective of the empirical investigation, the aim of this chapter is to identify and prioritise these variable factors that will affect the outcome of the economic viability and further to determine, aligned with the objectives of the study, if biogas plants at abattoirs in South Africa are a viable option.

3.2 RESEARCH DESIGN AND METHODOLOGY

This research will primarily focus on a biogas plant at an abattoir slaughtering predominantly cattle but the model provided can also be used at other red meat abattoirs of similar size. For the purposes of this study a Class A abattoir with a slaughtering capacity of 400 cattle per day will be used as a case study. Biogas will be generated through anaerobic digestion and the utilising of the gas for the generation of electricity and heat by means of a CHP generator.

Biogas plants economics is characterised by large investment costs, operation and maintenance costs, mostly free materials and income from the sale of biogas or electricity and heat (Amigan & Von Blottnits, 2007:3091). The income of a biogas plant includes the savings occurred in electricity and heating expenses. Other income streams that can be added include the improved value of the sludge by-product that can be applied as fertiliser.

The installation cost of a typical biogas plant is site-specific with the geography of the area, labour costs, learning curve and the use of the biogas product all being variable factors that will fluctuate depending on the geographic area (Amigan & Von Blottnits, 2007:3091).

Five main capital budgeting techniques will be used to critically analyse and demonstrate the economic viability for the use of a biogas plant at an abattoir. The techniques to be used are the Payback Period, Discounted Payback Period (DPBP), Net Present value (NPV), Internal Rate of Return (IRR) and Profitability Index (PI).

3.2.1 Research objectives

The primary objective of the research is to analyse the economic viability of biogas plants at abattoirs in South Africa and determine if such a biogas plant would be beneficial to an abattoir.

The secondary objectives of the research include:

- Establishing what the dominant variables are that will impact the project as viable or not viable
- To analyse and identify other essential advantages biogas plants may offer at abattoirs in South Africa
- Evaluate the green impact of the biogas plant

3.2.2 Data collection

Data was collected using field work and informal interviews with experts within the field of biogas.

3.2.3 Data analysis

Data analysis will be done by building a Microsoft Excel model that will assist in calculating the various capital budgeting techniques. A case study will be used regarding data collected and assumptions made.

3.3 THE VARIOUS CAPITAL BUDGETING TECHNIQUES

3.3.1 Introduction

Based on diminishing profit margins in addition to the rapid change in technology, successful abattoirs may need to be better strategically placed to take advantage of fluctuations in operating environments. Taking into consideration the limited resources a company may have, there is a growing challenge for companies to achieve greater operational efficiency. Abattoirs in South Africa are currently fronting various challenges but one of foremost challenges they are encountering is the allocation of the company's restricted resources between existing operations and new projects. Therefore it has become essential to make use of the available capital budgeting techniques to evaluate prospective projects to identify which projects are viable to select the most viable option.

Megginson *et al.* (2010:232) describe the terms capital investment and capital spending as the major investments in long-lived assets like plant and equipment, and capital budgeting refers to the process of identifying which of these investment projects the firm should undertake.

The capital budgeting process involves three basic steps (Megginson *et al.,* 2010:232):

1) Identifying potential investments
2) Analysing the set of investment opportunities and prioritising them if necessary and selecting the most viable
3) Implementing and monitoring the investment project selected

According to Seal *et al.* (2009:372) capital budgeting analysis is virtually any decision that involves an outlay of capital at present in order to attain some return (increase in revenue or reduction in costs) in the future. Typical capital decisions include cost reduction decisions, expansion decisions, equipment selection decisions, lease of buy decisions and equipment replacement decisions.

The next sections will briefly describe and discuss the various capital budgeting techniques that will be used in this study.

3.3.2 Payback Period

The payback period technique is, among the capital budgeting decision techniques, the simplest technique and enjoys widespread use, predominantly with smaller firms (Megginson *et al.*, 2010:236). The payback period is the amount of time it takes for a given project's net cash inflows to recover the initial investment. Companies using the payback technique define a maximum acceptable payback period and only projects with a payback period less than the maximum period will be accepted, all others are rejected (Megginson *et al.*, 2010:236).

3.3.3 Discounted Payback Period (DPBP)

The discounted payback period is essentially the same as the payback rule apart from that the cash flows are firstly discounted. The discounted payback method thus calculates how long it takes for a project's discounted cash flows to recover the initial outlay (Megginson et al., 2010:236).

3.3.4 Net Present value (NPV)

The net present value (NPV) of a project equals the sum of its cash inflows and outflows, discounted at a rate that is consistent with the project's risk (Megginson *et al.,* 2010:238). According to Seal *et al.* (2009:373) are the present value of all cash inflows compared to the present value of all cash outflows that are associated with an investment project. Whether or not a project is an acceptable investment are determined by the difference between the present values of these cash flows, called the present value.

The NPV is expressed as:

$$\mathrm{NPV} = \mathrm{CF}_0 + \frac{\mathrm{CF}_1}{(1+r)^1} + \frac{\mathrm{CF}_2}{(1+r)^2} + \frac{\mathrm{CF}_3}{(1+r)^3} + \cdots + \frac{\mathrm{CF}_N}{(1+r)^N}$$

The NPV decision rule states that an organisation should invest when the sum of the present values of future cash inflows exceeds the initial project outlay (Megginson *et al.*, 2010:238).

Simply stated, the NPV decision rule is:

NPV > \$0: Invest and if NPV < \$0: Do not invest.

3.3.5 Internal Rate of Return (IRR)

According to Seal et al. (2009:378) the internal rate of return (IRR) can be defined as "the interest yield promised by an investment over its useful life". It is sometimes referred to simply as the yield on a project while Megginson *et al.* (2010:244) states that the IRR of an investment project is "the compound annual rate of return on the project, given its up-front costs and subsequent cash flows".

Once the IRR has been computed it is compared to the company's required rate of return. The minimum rate of return an investment project must yield to be acceptable is the required rate of return. Quite often the cost of capital is used as the required rate of return. The IRR can be derived using the succeeding formulation:

$$\mathrm{NPV} = \mathrm{CF}_0 + \frac{\mathrm{CF}_1}{(1+r)^1} + \frac{\mathrm{CF}_2}{(1+r)^2} + \cdots + \frac{\mathrm{CF}_{N-1}}{(1+r)^{N-1}} + \frac{\mathrm{CF}_N}{(1+r)^N} = \$0$$

The internal rate of return decision says that if the IRR is greater or equal to the required rate of return the investment is accepted and if less than the required rate of return the project is rejected (Seal *et al.*, 2009:380).

3.3.6 Profitability Index (PI)

Like the internal rate of return, the profitability index (PI) is closely related to the net present value approach. For simple projects that have an initial cash outflow, followed by a sequence of inflows, the profitability index is conveyed mathematically as the present value of a project's cash inflows divided by the initial cash outflow.

The profitability index can be expressed as:

$$\mathrm{PI} = \frac{\dfrac{\mathrm{CF}_1}{(1+r)^1} + \dfrac{\mathrm{CF}_2}{(1+r)^2} + \cdots + \dfrac{\mathrm{CF}_N}{(1+r)^N}}{\mathrm{CF}_0}$$

The profitability decision rule to follow is to invest when the PI is greater than 1.0 and to refrain from investing when the PI is less than 1.0.

If the PI of an investment is above 1.0 then the NPV will be above $0 meaning that the PI and NPV decision rules will always yield the same investment recommendation when a single project is trying to be accepted or rejected (Megginson *et al.,* 2010:257).

3.4 ECONOMIC VIABILITY CRITERIA

From the results obtained using the capital budgeting techniques above the following rules will apply to analyse the economic viability but most emphasis will be placed on the results yielded from the NPV and IRR:

- The payback period of the investment must be less than seven years to be economically viable
- If the discounted payback period is less than ten years the investment is economically viable, if the discounted payback period is more than ten years the investment is not viable according to the discounted payback period
- If a net present value of zero and greater is achieved the investment will be deemed viable, if the NPV is less than zero the investment will not be viable and be rejected
- If a profitability index of greater than 1.0 is achieved the investment will be economic viable and is acceptable, if the profitability index of less than 1.0 is achieved the investment will not be accepted as viable.
- If the internal rate of return (IRR) achieved is higher than the required return rate, the investment will be economically viable and should be accepted, based on the IRR decision rule. If lower than the required rate of return the investment would be considered not viable.

3.5 GENERAL NOTES AND ASSUMPTIONS

The following section will discuss the general notes and assumptions made in determining the economic viability of biogas plants at abattoirs. All the various variables that will influence the viability model are introduced and discussed. These variables will be used in the case scenarios to determine the viability of biogas plants.

3.5.1 Plant Capital Expenditure (CAPEX)

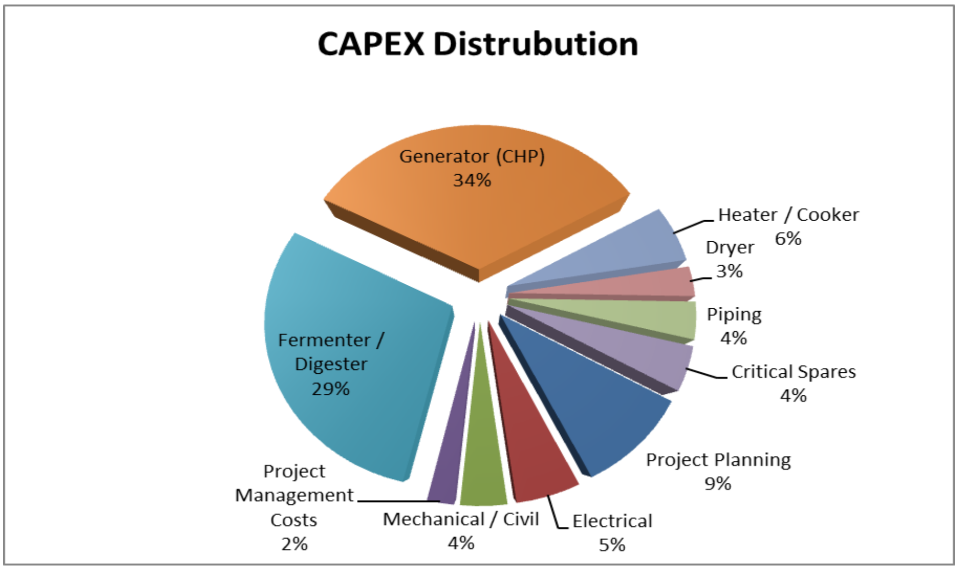
Two viable options (options 1 and 2 in Table 3.1 have been obtained by abattoir X used in the case study. As can been seen in table 3.1 are these two estimates compared against each other. The professional fees include all engineering and consulting fees included in the project. The equipment costs are compiled by the cost of the anaerobic digester, the CHP generator and other critical parts of the biogas plant. The two options fluctuate from R15 099 426 to R15 860 740 for a complete turnkey solution. The impact of the CAPEX amount will be tested with the sensitivity analysis later in the chapter.

Table 3.1: Capital expenditure estimates for a biogas plant

	Option 1	**Cost %**	**Option2**	**Cost %**
Professional Fees	**R 3 242 774.00**	**20.45%**	**R 3 049 570.00**	**20.20%**
Project Planning	R 1 320 036.00	8.32%	R 1 607 178.00	10.64%
Engineering Costs:		0.00%		
Electrical	R 721 027.00	4.55%	R 858 567.00	5.69%
Mechanical / Civil	R 721 027.00	4.55%	R 412 112.00	2.73%
Project Management Costs	R 480 684.00	3.03%	R 171 713.00	1.14%
Equipment Costs	**R 12 617 966.00**	**79.55%**	**R 12 049 856.00**	**79.80%**
Fermenter / Digester	R 4 606 410.00	29.04%	R 4 378 911.00	29.00%
Generator (CHP)	R 5 272 000.00	33.24%	R 5 235 805.00	34.68%
Heater / Cooker	R 1 019 687.00	6.43%	R 750 000.00	4.97%
Dryer	R 500 000.00	3.15%	R 420 000.00	2.78%
Piping	R 619 013.00	3.90%	R 515 140.00	3.41%
Critical Spares	R 600 856.00	3.79%	R 750 000.00	4.97%
Total	**R 15 860 740.00**	100.00%	**R 15 099 426.00**	100.00%

Both estimates provide a similar turn-key solution with differences in professional fees and equipment used. As can be seen the professional fees contribute approximately 20% of total cost with equipment contributing to the remaining 80%.

Figure3.1: CAPEX breakdown of biogas project



(Source: Own compilation)

The breakdown of the CAPEX in figure 3.1 shows that the major cost component of the total capital expenditure are the digester cost (29%) and the generator cost (34%) computing to 63% of the total capital expenditure. For the purposes of this study the CAPEX in the base case used will be R15 500 000.

3.5.2 Operating Expenditure (OPEX)

The operating expenditure for a biogas plant is the sum of the maintenance cost (MC) and the Running Cost (RC) of the plant, in rand per kWhe produced.

Operational cost may be broadly categorised as variable and fixed costs. Variable costs include feedstock purchase, transport and utilities. Fixed costs include amongst others, operating labour and maintenance and plant overheads. As the abattoir waste is available on site, a percentage of capital costs were employed to reflect overheads, labour and maintenance.

Table3.2: OPEX Breakdown

Operation & Maintenance Cost		
Facility overheads, labour & maintenance at 2.75% of CAPEX	R 425 959	R/year
(O&M costs escalate to CPI+1%)		
Generator (CHP) Maintenance	R 128 794	R/year
Total Operating Costs	**R 554 753**	**R/year**
Calculated expected energy generated per annum	1 800 000	kWhe
Operating Costs per unit electricity produced	**R 0.31**	**R/kWh**
	(R554 753 / 1 800 000 kWhe)	

(Source: Own compilation)

3.5.3 Biogas Plant Capacity

The biogas plant is estimated to generate between 1 800 000 kWh and 2 400 000 kWh of electricity per year. These estimations are based on the two professional turn-key solutions the company obtained.

For the base case analysis used in this case study the conservative estimation of 1 800 000 kWh will be used while added estimates will be used in the other scenario analysis. This different scenario analysis will determine the influence the plant capacity will have on the viability of the plant.

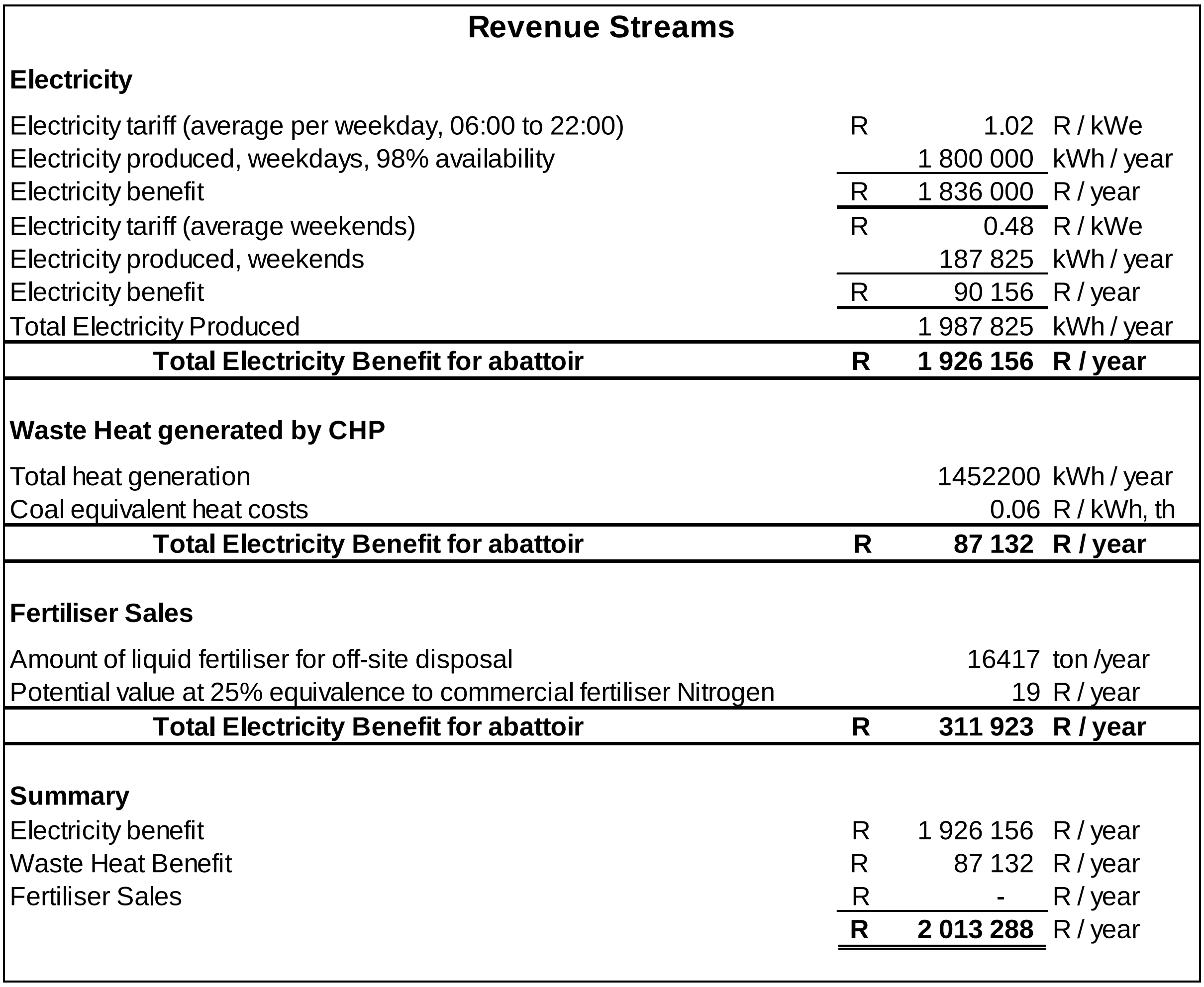
3.5.4 Cash Inflows

Cash inflows do not only involve an increase in revenue but also consist of the savings obtained from reduction in costs. The savings involved for an abattoir by investing in a biogas plant includes:

- **Electricity Savings**

As can be seen in Table 3.3 the biogas plant generates a projected 1 800 000kWh per year with the use of a combined heat and power (CHP) generator. The CHP unit will mainly operate during peak hours (weekdays 06:00 to 22:00) to help obtain maximum savings. If the current electricity tariff of R1.02 per kWh are used to calculate the electricity benefit, a saving of R1 836 000 are attained during peak hours with a further saving of R90 156 over weekends. This contribute to a total saving of R1 987 825 over a year period.

Table 8: Biogas plant revenue streams



Revenue Streams			
Electricity			
Electricity tariff (average per weekday, 06:00 to 22:00)	R	1.02	R / kWe
Electricity produced, weekdays, 98% availability		1 800 000	kWh / year
Electricity benefit	R	1 836 000	R / year
Electricity tariff (average weekends)	R	0.48	R / kWe
Electricity produced, weekends		187 825	kWh / year
Electricity benefit	R	90 156	R / year
Total Electricity Produced		1 987 825	kWh / year
Total Electricity Benefit for abattoir	**R**	**1 926 156**	**R / year**
Waste Heat generated by CHP			
Total heat generation		1452200	kWh / year
Coal equivalent heat costs		0.06	R / kWh, th
Total Electricity Benefit for abattoir	**R**	**87 132**	**R / year**
Fertiliser Sales			
Amount of liquid fertiliser for off-site disposal		16417	ton /year
Potential value at 25% equivalence to commercial fertiliser Nitrogen		19	R / year
Total Electricity Benefit for abattoir	**R**	**311 923**	**R / year**
Summary			
Electricity benefit	R	1 926 156	R / year
Waste Heat Benefit	R	87 132	R / year
Fertiliser Sales	R	-	R / year
	R	**2 013 288**	R / year

(Source: Own compilation)

➢ Waste Disposal Costs

The actual annual costs for the disposal of slaughter waste at the abattoir used in the case study were obtained and are summarised in Table 3.4. As can be seen are the actual cost for the transportation of the waste materials calculated on an average of R17 706 per month with the average cost charged by rendering plants for accepting these waste materials calculated at R13 575 per month. These costs add to a total annual cost of R375 383. These costs will be voided when a biogas plant is operational and is part of the savings attained. However, for the purposes of this study a conservative saving of only R187 500 will be used in the calculations as some waste disposal costs may still occur.

Table 9: Current waste disposal costs

Month		Transport Costs	Rendering Plant Gate Fee
January	1	R 12 921.95	R 28 853.70
February	2	R 15 748.46	R 27 100.00
March	3	R 17 194.24	R 15 800.00
April	4	R 17 337.39	R 13 950.00
May	5	R 10 978.75	R 9 100.00
June	6	R 17 532.36	R 8 250.00
July	7	R 16 521.06	R 9 500.00
August	8	R 19 433.46	R 9 500.00
September	9	R 21 479.17	R 9 500.00
October	10	R 20 880.44	R 10 200.00
November	11	R 21 068.39	R 9 500.00
December	12	R 21 383.95	R 11 650.00
		R 212 479.62	R 162 903.70
Average cost per month		R 17 706.64	R 13 575.31
		Total per month	**R 31 281.94**
		Total per year	**R 375 383.32**

(Source: Own compilation)

3.5.5 Feedstock Cost

The feedstock needed in order for the anaerobic digester to generate biogas is all wastes generated from the slaughter process. As the slaughter waste disposed to the anaerobic digester is essentially a cost saving for the abattoir; the feedstock cost for the biogas plant will be assumed as zero.

3.5.6 Product Price

Biogas has various uses as described in the literature review in Chapter 2 (see section 2.8) but for the purposes of this study the most desirable outcome will be the generation of electricity through a CHP unit which will add a further benefit with heat generated. The heat generated can be used to heat large quantities of water that can be used in the slaughtering process. The main contributor to the viability of a biogas plant for an abattoir is the amount of electricity that is generated. As electricity generated cannot be sold back to the national grid in South Africa, the product price will be determined by the rate at which the abattoir purchases electricity.

The peak electricity tariff for abattoir X used in the case study are R1.02 per kWh and will be used starting with the base year and will escalate using different scenarios as the electricity price is anticipated to change.

3.5.7 Discount Rate

Seal *et al.* (2009:377) mention that a rate of return for discounting cash flows to their present value must be chosen. The firm's cost of capital is usually regarded as the most appropriate choice for the discount rate. The cost of capital can be calculated as the average rate of return a company must pay to its long-term creditors and shareholders for the use of their funds.

For the base case economic assumption of this case study a discount rate of 15% will be adopted. This is calculated by assuming the cost of capital is fixed at prime (8.5%) plus an additional 6.5% for the risk involved. The net present value (NPV) and profitability index (PI) will however also be estimated using 10% and 20% discount rates.

3.5.8 Life Expectancy

Biogas plants are by nature very site specific as custom layouts are required depending on the design of the abattoirs and, apart from the CHP generator, are not portable. With mandatory persistent maintenance to be done on the generator the engine will essentially be overhauled every 3 years. Due to this continuous maintenance, the expected life of such a plant can be well over 20 years but for purposes of this study the life expectancy is estimated at 15 years. With the use of a sensitivity analysis, different outcomes will also be calculated on a pessimistic life expectancy of 10 years and optimistic expectancy of 20 years.

3.5.9 Residual Value (RV)

The residual (or salvage) value represents an estimation of the amount the company expects to recover for the asset upon disposal at the end of its estimated useful life. The residual value may be its expected value if sold to a different user or the value of the asset as salvage or scrap (Libby *et al.*, 2009:408).

As biogas plants are very site specific and the cost of dissembling may be more than the salvage value, the residual value for this study will be assumed as zero.

3.5.10 Depreciation

Libby *et al.* (2009:406) describes depreciation as “the process of allocating the cost of building and equipment over their productive lives using a systematic and rational method”.

As most of the CAPEX include equipment, depreciation can add to the financial value the biogas plant will offer for the company but for the purposes of this study depreciation will not be used in calculating the economic viability of the biogas plant.

3.5.11 Eskom Rebate Grant

A vital rebates or incentive that improves the probable viability of alternative energy projects include an Eskom integrated demand management incentive or rebate. If a current customer generates electricity on-site instead of buying electricity from the national grid, Eskom will in effect pay the business for not buying from the grid. Eskom will pay 120c per kWh for any electricity generated through a renewable energy source and consumed on the site between 6am and 10pm on weekdays.

Assuming the grant is approved, Eskom payment is 70% upfront, 20% in year 2 and the last payment in year 3. The aim of this Eskom rebate is to ease the capital expenditure load for assembling these generating facilities.

This rebate grant is not guaranteed, but for the purposes of this study the analysis will be done based on a rebate grant received. An alternative scenario will also be done where no rebate is received and it will also be tested by a sensitivity analysis.

3.6 A BIOGAS PLANT MODEL DESIGN

The model designed for this study is meant to provide a quantitative tool to evaluate the economic viability of a biogas plant designed to operate at a South African beef abattoir. Several qualitative studies of the use of biogas plants have been done, but very little have been done to quantitatively evaluate the economic viability for South African abattoirs.

An Excel spread sheet model has been designed that exhibits a high level of flexibility. The flexibility is of such a nature that a single plug in of variables grounded on any case situation will generate a different set of outcomes. An essential variable that can be changed and possibly will create different outcomes includes capital costs, product price levels, production capacities, operating expenditures and rebate grants. This economic viability model will provide a framework to evaluate actual project expenses and cost estimates for biogas plants used at abattoirs in South Africa.

3.7 CASE ANALYSIS

A base case with different case scenarios will be used as analysis for this study. The base case will be grounded on assumptions made prior and using actual figures and data obtained. The main variable factors that will be taken in consideration and adjusted in the case scenarios include the following:

- Plant capital expenditure (CAPEX)
- Discount rate
- Life expectancy of a biogas plant
- Change in product price (electricity price escalations)
- Plant capacity
- Influence of Eskom rebate grant
- Operating expenses (OPEX)

The following section will analyse the main findings from the scenarios set and will subsequently view the results obtained from the sensitivity analysis. The analysis will be done against the economic viability criteria set previously in the chapter.

The criteria for the biogas plant to be economically viable were briefly as follow:

- The payback period of the investment must be less than seven years to be economically viable
- The discounted payback period of the investment must be less than ten years to be economically viable
- A net present value of zero or greater must be achieved for the investment to be deemed viable
- A profitability index of greater than 1.0 must be achieved for investment to be economic viable and acceptable
- The internal rate of return (IRR) achieved must be higher than the required rate of return

3.8 ANALYSIS AND INTERPRETATION OF RESULTS

Before the results can be interpreted, a synopsis of the objectives of the research needs to be done.

The primary objective of the research was to:

- Analyse the economic viability of biogas plants at abattoirs in South Africa and determine if such a biogas plant would be beneficial to an abattoir.

The secondary objectives of the research were as follow:

- To analyse and identify other essential advantages of a biogas plant at abattoirs
- Establish what information will be needed to determine the economic viability of a biogas plant
- Evaluate the green impact of the biogas plant

To achieve these objectives a base case scenario was built and used in a case study format. The data used in this scenario are actual figures obtained from the abattoir used in the case study and certain assumptions made.

The base scenario is the most probable scenario with realistic assumptions used where certain data lacked. However, two other scenarios have also been built with different outcomes to determine what impact certain variables will have on the outcomes achieved.

The base case scenario analysis and results will firstly be discussed in the next section followed by a discussion of the two other case scenario results and finally the results obtained in the sensitivity analysis.

3.9 BASE CASE SCENARIO

3.9.1 Base Case Scenario Analysis

The base case scenario will be based on the assumptions as discussed previously in section 3.5. For the base case a plant CAPEX of R15 500 000 will be used with an annual OPEX of R554 753 that will escalate yearly at CPI plus 1%. Plant capacity of 1 800 000kWhe will be used in the base case with an Eskom rebate amount of R3 600 000. The CAPEX will be financed on an 80:20 debt to equity basis with interest rate calculated at prime.

Table 10: Electricity tariff increase assumption for base case

Eskom Tariffs		
Period	Net % Increase	Current R/kWhe
Base Year		R 1.02
Year 1	10.00%	R 1.12
Year 2	11.90%	R 1.26
Year 3	11.90%	R 1.40
Year 4	11.90%	R 1.57
Year 5	11.90%	R 1.76
Year 6	8.50%	R 1.91
Year 7	8.50%	R 2.07
Year 8	8.50%	R 2.25
Year 9	6.00%	R 2.38
Year 10	6.00%	R 2.52
Year 11	6.00%	R 2.68
Year 12	6.00%	R 2.84
Year 13	6.00%	R 3.01
Year 14	6.10%	R 3.19
Year 15	6.10%	R 3.39

(Source: Own compilation)

Table 3.5 above shows the tariff increase calculated at a variable rate. For the purposes of this research a double digit tariff increase is expected for the following five years then the increase will start to stabilise as Eskom demand concerns are expected to be secure. The estimated tariff increase is calculated for a period of 15 years, the same time as the plant's projected life expectancy.

The base case scenario is based on actual figures from abattoir X and predictions as discussed previously in this chapter (see section 3.5). A sensitivity analysis will be done with all variables kept constant while one variable are changed. The following two scenarios are based on a change in two or more defined variables that will result in a different outcome being achieved. These scenarios will also be discussed in the following chapter, but the base case scenario will be used as the main finding.

3.9.2 Base Case Scenario Results

This section will discuss the results achieved in the base case scenario analysis. Table 3.6 summarises the assumptions made for the purposes of the base case scenario as discussed previously in this chapter.

Table 11: Assumptions made for base case scenario

Plant capital expenditure (CAPEX)	R 15 500 000
Discount rate	15%
Life expectancy	15 years
Electricity tariff increase	Variable
Plant capacity	1 800 000 kWhe per year
Eskom rebate grant	R 2 800 000
Operating expenses (OPEX)	R 554 753
Prime Rate	8.50%
CPI + 1%	7.40%
Required Return	13.50%
Debt / Equity	80 / 20
Loan Repayment Years	5 years

(Source: Own compilation)

According to these assumptions the respective IRR, NPV, PI and payback period results were achieved.

The financial model that was developed to support assessing the economic viability of biogas plants at abattoirs can be seen in Table 15. This model uses the cash flows achieved and determines the IRR, NPV and PI. The same model was used for the base case scenario and the two additional scenarios with different variables and assumptions used as discussed previously. Furthermore, it calculates the payback period and in addition calculates the discounted payback period.

The results obtained in the base case scenario will next be discussed in detail according to each capital budgeting technique set out as used in the study. A brief conclusion will also be drawn based on the result.

- **Payback period**

The payback period as described previously is the amount of time it takes for a project's net cash inflows to recover the initial investment. A maximum acceptable payback period is set and only projects with a payback period less than the maximum period will be accepted.

The payback period comprehended in the base case scenario is 7.62 years. The economic viability criteria states that a payback period of seven or less years must be achieved for the project to be economically viable. Although the payback period achieved is marginally higher than the criteria the project will not be deemed unviable on this criteria and a comprehensive look will be taken on the results of the other capital budgeting techniques.

- **Discounted payback period**

The discounted payback period is essentially the same as the payback rule apart from that the cash flows are firstly discounted.

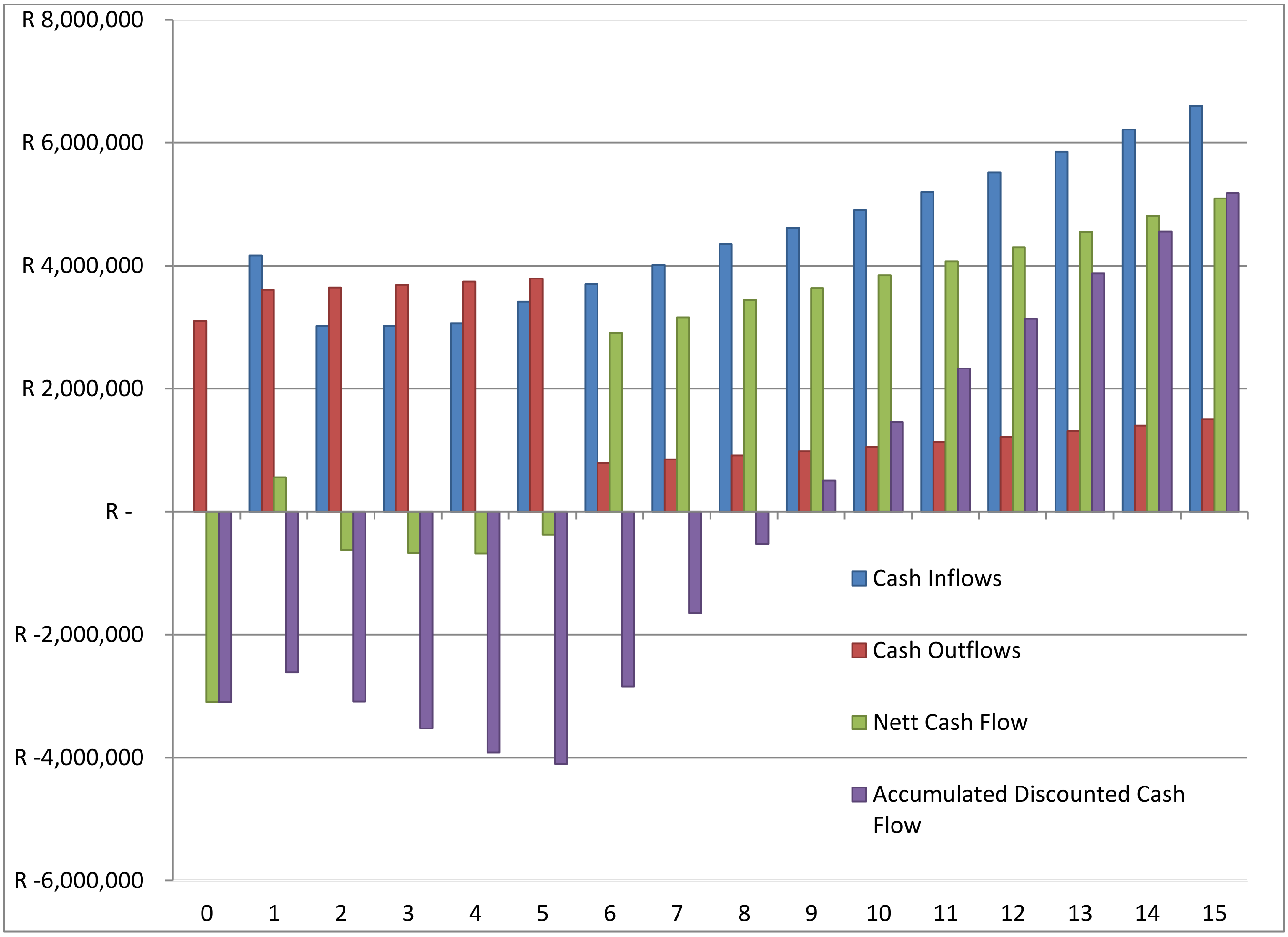
For the project to be considered viable a discounted payback period of 10 years or less must be achieved as per criteria for this study. A discounted payback period of 9.51 years was achieved in the base case scenario. Thus the biogas plant at the abattoir can be seen as economically viable based on the criteria set.

- **Net present value**

As previously discussed in section 3.3 the net present value of a project is equal to the sum of its cash inflows and outflows, discounted at a rate that is dependable with the project's risk.

The net present value was calculated using the cash flows as indicated in Figure 3.2. The project based on the base case scenario have an initial cash outflow, 20% equity for project, of R3 100 000 in the base year.

Figure3.2: Cash flows attained in base case analysis



(Source: Own compilation)

In year 1 the plant is operational and the 70% of Eskom rebate grant is received. This results in a net positive cash flow of R559 487 and an accumulated negative cash flow of R2 540 513. For the first five years of the project a negative net cash flow is realised as the 80% debt is repaid.

Table 12: Results obtained for base case scenario

Eskom Tariffs		
Period	Net % Increase	Current kWh
		R 1.02
Year 1	10.00%	R 1.12
Year 2	11.90%	R 1.26
Year 3	11.90%	R 1.40
Year 4	11.90%	R 1.57
Year 5	11.90%	R 1.76
Year 6	8.50%	R 1.91
Year 7	8.50%	R 2.07
Year 8	8.50%	R 2.25
Year 9	6.00%	R 2.38
Year 10	6.00%	R 2.52
Year 11	6.00%	R 2.68
Year 12	6.00%	R 2.84
Year 13	6.00%	R 3.01
Year 14	6.10%	R 3.19
Year 15	6.10%	R 3.39

Assumptions	
Prime *	8.50%
Discount Rate	15.00%
CPI +1% *	7.40%
Required Return	13.50%

OPEX	**R 554 753**
CAPEX	**R 15 500 000**
Debt	**80.00%**
Equity	**20.00%**
Loan Payment Years	**5**
Eskom Rebate	**R 2 800 000**

NPV	
R	**15%**
CF0	**R 3 100 000.00**
NPV	**R 5 180 590.77**
RR	**13.50%**

IRR	
R	**15%**
CF0	**R 3 100 000.00**
IRR	**26.5%**
RR	**13.50%**

PI	
R	**15%**
CF0	**R 3 100 000.00**
PI	**2.67**
RR	**13.50%**

Discounted Payback Period = 9.51 Years

Payback Period = 7.62 Years

	Inflows (Savings)							**Outflows**								
							Total Inflows	**Loan Repayment**				**Total Outflows / Expenses**	**Net Cash Flow**	**Accumm Cash Flow**	**Discounted Cash Flow**	**Accumm Discounted Cash Flow**
	Year	**kW Biogas**	**R/kW**	**Electricity Savings** **Total kWh Cost**	**Rebate Grant**	**Other Savings**		**Capital**	**Interest**	**Maintenance**						
2013	0	0	R 1.02	R -	R -	R -	R -	R 3 100 000	R -	R -	R 0	R 3 100 000	R -3 100 000	R -3 100 000	R -3 100 000	R -3 100 000
2014	1	1800000	R 1.12	R 2 019 600	R 1 960 000	R 187 500	R 4 167 100	R 2 078 600	R 974 259	R 0.31	R 554 753	R 3 607 613	R 559 487	R -2 540 513	R 486 511	R -2 613 489
2015	2	1800000	R 1.26	R 2 259 932	R 560 000	R 201 375	R 3 021 307	R 2 262 330	R 790 530	R 0.33	R 595 805	R 3 648 665	R -627 357	R -3 167 870	R -474 372	R -3 087 862
2016	3	1800000	R 1.40	R 2 528 864	R 280 000	R 216 277	R 3 025 141	R 2 462 299	R 590 561	R 0.36	R 639 894	R 3 692 754	R -667 613	R -3 835 483	R -438 966	R -3 526 828
2017	4	1800000	R 1.57	R 2 829 799	R -	R 232 281	R 3 062 080	R 2 679 944	R 372 916	R 0.38	R 687 246	R 3 740 106	R -678 026	R -4 513 509	R -387 663	R -3 914 491
2018	5	1800000	R 1.76	R 3 166 545	R -	R 249 470	R 3 416 015	R 2 915 037	R 136 033	R 0.41	R 738 103	R 3 789 173	R -373 158	R -4 886 667	R -185 525	R -4 100 017
2019	6	1800000	R 1.91	R 3 435 702	R -	R 267 931	R 3 703 632	R -	R -	R 0.44	R 792 722	R 792 722	R 2 910 910	R -1 975 757	R 1 258 467	R -2 841 550
2020	7	1800000	R 2.07	R 3 727 736	R -	R 287 758	R 4 015 494	R -	R -	R 0.47	R 851 384	R 851 384	R 3 164 110	R 1 188 354	R 1 189 506	R -1 652 044
2021	8	1800000	R 2.25	R 4 044 594	R -	R 309 052	R 4 353 646	R -	R -	R 0.51	R 914 386	R 914 386	R 3 439 260	R 4 627 613	R 1 124 300	R -527 744
2022	9	1800000	R 2.38	R 4 287 270	R -	R 331 922	R 4 619 191	R -	R -	R 0.55	R 982 051	R 982 051	R 3 637 140	R 8 264 754	R 1 033 902	R 506 159
2023	10	1800000	R 2.52	R 4 544 506	R -	R 356 484	R 4 900 990	R -	R -	R 0.59	R 1 054 722	R 1 054 722	R 3 846 267	R 12 111 021	R 950 738	R 1 456 897
2024	11	1800000	R 2.68	R 4 817 176	R -	R 382 864	R 5 200 040	R -	R -	R 0.63	R 1 132 772	R 1 132 772	R 4 067 268	R 16 178 289	R 874 232	R 2 331 129
2025	12	1800000	R 2.84	R 5 106 207	R -	R 411 196	R 5 517 402	R -	R -	R 0.68	R 1 216 597	R 1 216 597	R 4 300 805	R 20 479 094	R 803 851	R 3 134 980
2026	13	1800000	R 3.01	R 5 412 579	R -	R 441 624	R 5 854 203	R -	R -	R 0.73	R 1 306 625	R 1 306 625	R 4 547 578	R 25 026 671	R 739 109	R 3 874 088
2027	14	1800000	R 3.19	R 5 742 746	R -	R 474 304	R 6 217 050	R -	R -	R 0.78	R 1 403 315	R 1 403 315	R 4 813 735	R 29 840 406	R 680 319	R 4 554 407
2028	15	1800000	R 3.39	R 6 093 054	R -	R 509 403	R 6 602 457	R -	R -	R 0.84	R 1 507 161	R 1 507 161	R 5 095 296	R 34 935 702	R 626 184	R 5 180 591

From year 6 a positive net cash flow starts occurring and this pattern is maintained throughout the life time of the biogas plant. The net present value calculated can be confirmed by the accumulated discounted cash flow and the end of the useful life of the plant. Thus if the estimated useful life of the biogas plant is reached the plant would have generated a profit for the abattoir of R5 180 590 that was discounted at a discount rate of 15%.

The criteria for determining the economic viability of the biogas plant states that if the NPV is more than zero the plant will be viable. The NPV in the base case scenario calculates to R5 180 590 at a discount rate of 15%. Consequently it can be established that the biogas plant will be economically viable if the base case scenario variables are attained.

- **Profitability index**

As defined earlier the profitability index is conveyed mathematically as the present value of a project's cash inflows divided by the initial cash outflow. A profitability index of greater than 1.0 must be achieved for the project to be economic viable and acceptable.

The base case scenario yielded a PI of 2.67 confirming as discussed previously that the PI and NPV decision rules will always yield the same investment recommendation when a single project is trying to be accepted or rejected. Hence it can be established that according to the result achieved for the PI in the base case scenario, the biogas plant can be considered economically viable.

- **Internal rate of Return**

The base case scenario yielded an internal rate of return of 26.49%. The required rate of return used for the purposes of this study was 13.50%, calculated as the cost of debt (prime rate) plus 5% added for risk involved in the project.

According to internal rate of return decision rule, if the IRR is greater or equal to the required rate of return the investment is accepted and if less than the required rate of return the project is rejected. The same rule was used in this study's criteria to determine the economic viability of a biogas plant.

If the IRR computed for the base case scenario is compared to the company's required rate of return it can be seen that the calculated rate yielded is almost double that of the required rate. Thus for the purposes of this study, in relation to the IRR rule, the project is seen as viable.

From the findings in this section it can be concluded that biogas plants at abattoirs in South Africa appears to be economically viable. This is based on the assumptions made for the base case and as discussed in the next sections will the outcome change as different variables are changed.

3.10 ALTERNATIVE CASE SCENARIO ANALYSIS

3.10.1 Case Scenario 1 Analysis

This base case scenario presents a plant output of 1 500 000kWhe with no Eskom rebate grant considered and a flat annual electricity tariff increase of 10%.

The following variables are kept constant for this scenario:

- CAPEX = R15 500 000
- CPI = 7.40% (calculated at CPI plus 1%)
- Rate of interest = 8.5%
- Required rate of return = 13.50%
- Life expectancy of biogas plant = 15 years
- Discount rate = 15%
- OPEX = R554 753 escalating at CPI plus 1%
- Debt to equity = 80/20
- Loan repayment term = 5 years

This scenario is based on *more pessimistic* outcomes transpiring with a reduced plant capacity output and no rebate grant received. A full analysis on this scenario will be done in the following chapter.

3.10.2 Case Scenario 2 Analysis

In this case scenario the plant output has been increased to 2 000 000kWhe with an increase in electricity tariff linked to CPI of 6.4%. Additionally the debt to equity ratio has been changed to 20% debt and 80% equity.

This scenario is *more optimistic* than scenario one with both increased capacity and rebate grant received but with a tariff increase in electricity of only 6.40%.

The following variables were kept constant in this scenario:

- CAPEX = R15 500 000
- CPI = 7.40% (calculated at CPI plus 1%)
- Rate of interest = 8.5%
- Required rate of return = 13.50%
- Life expectancy of biogas plant = 15 years
- Discount rate = 15%
- OPEX = R554 753 escalating at CPI plus 1%
- Debt to equity = 80/20
- Loan repayment term = 5 years

The results of these two scenarios will now be discussed but will only be regarded as supplementary analysis for the base case scenario.

3.11 RESULTS FROM ADDITIONAL SCENARIOS

The following two scenarios are based on a change in two or more distinct variables that will result in different outcomes being reached. These scenarios will assist in drawing final conclusions about the economic viability of biogas plants for similar size abattoirs; however, the results obtained in the base case scenario will be used as the primary conclusion.

Table 16 above summarises the assumptions made in these two scenarios. The results from each scenario will be discussed and a brief conclusion will be drawn.

Table 13: Assumptions made in additional case scenarios

Assumptions	**Case scenario 1**	**Case scenario 2**
Plant capital expenditure (CAPEX)	R 15 500 000	R 15 500 000
Discount rate	15%	15%
Life expectancy	15 years	15 years
Electricity tariff increase	10% annually	6.40% annually
Plant capacity	1 500 000 kWhe per year	2 000 000 kWhe per year
Eskom rebate grant	R 0	R 2 800 000
Operating expenses (OPEX)	R 554 753	R554 753
Prime Rate	8.50%	8.50%
CPI + 1%	7.40%	7.40%
Required rate of return	13.50%	13.50%
Debt to Equity	80 / 20	20 / 80
Loan Repayment Years	5 years	5 years

(Source: Own compilation)

3.11.1 Case Scenario 1 Results

The economic model design computing the results for scenario 1 can be seen in Annexure 1.

The variables changed in this case scenario has a more pessimistic stance with no Eskom rebate grant received and a reduced plant capacity to only 1 500 000kWhe generated annually. Based on these assumptions the biogas plant appears not to be as economically viable as in the base case analysis.

From this model the following results are attained:

- Payback period achieved is 9.99 years, this is more than the required 7 year payback period
- Discounted payback period is more than 15 years, consequently the discounted payback of the project will be longer than the estimated useful life of the plant
- NPV achieved is negative R51 969, this is less than zero and the project on base on these assumptions appears not economically viable
- PI is 0.98 and is marginally less than the required PI of 1.0
- IRR achieved is 14.90% that are still more than the required rate of return of 13.50%. Based on the IRR rule, the project still appears to be viable

3.11.2 Case Scenario 2 Results

Annexure 2 summarise the model design and results according to assumptions made in scenario 2.

From the assumptions in scenario 2 the following results are attained:

- Payback period achieved is 7.30 years, this is marginally more than the required 7 year payback period
- Discounted payback period is calculated at 13.07 years, consequently the project do not appear viable as indicated in the criteria discussed previously
- NPV achieved is R1 627 724, this is more than zero and the project on base on these assumptions appears to be economically viable
- PI is 1.13 and is slightly more than the required PI of 1.0
- IRR achieved is 17.30% that are still more than the required rate of return of 13.50%. Based on the IRR rule, the project still appears to be viable, however, not as confidently viable as in the base case scenario.

As indicated previously these two scenarios, however, will only supplement the results achieved in the base case scenario in determining the economic viability of biogas plants. From these two scenarios it can be deduced that changes in more than one of the key variables can have a vast effect on the viability results.

3.12 SENSITIVITY ANALYSIS

According to Megginson *et al.* (2010:333) most capital budgeting decisions require various assumptions before arriving at a final end result. Management need to estimate the effects of different outcomes that will most likely not occur as predicted in their initial calculations. A sensitivity analysis is one of various ways of doing this. The sensitivity analysis explores the importance of each individual assumption, holding all other assumptions fixed in the calculation of the final conclusion (Megginson *et al.,* 2010:333).

A sensitivity analysis will be done in this study with a pessimistic and optimistic outcome of the key variables described above. By repeating the process for all variables in the calculation, it can be interred how sensitive the final outcome is to changes in baseline assumptions.

The key variables that will be altered in the sensitivity analysis include:

- Capital expenditure (CAPEX)
- Operational expenditure (OPEX)
- Life expectancy
- Plant capacity
- Electricity tariff increase
- Eskom rebate grants
- Discount rate

This sensitivity analysis will add to defining the economic viability by detecting the dominant variables that can disturb the conclusions attained.

3.12.1 Sensitivity analysis results

As discussed above, a sensitivity analysis was done based on a pessimistic and optimistic outlook for seven key variables as described previously. As can be seen in Table 3.9 the sensitivity analysis indicates which of the variables disrupt the economic viability of the biogas plant most.

Table 14: Sensitivity analysis results

IRR	NPV	PI	Pessimistic	Assumption	Optimistic	IRR	NPV	PI
26.49%	R 5 180 591	2.67	**-**	**Base Case Analysis**	**-**	26.49%	R 5 180 591	2.67
24.24%	R 4 560 591	2.23	**R 18 600 000.00**	**CAPEX**	**R 14 500 000.00**	27.32%	R 5 380 591	2.86
18.12%	R 1 422 874	1.46	**R 1 000 000.00**	**OPEX**	**R 450 000.00**	28.52%	R 6 064 667	2.96
20.23%	R 1 456 897	1.47	**10 years**	**Life Expectancy**	**20 years**	31.46%	R 9 480 604	4.06
13.63%	R -609 693	0.80	**1 200 000**	**Plant Capacity (kWhe per year)**	**2 200 000**	40.19%	R 10 970 874	4.54
13.34%	R -603 706	0.81	**4%**	**Electricity Tariff Increase**	**12%**	30.42%	R 8 316 082	3.68
20.06%	R 2 868 698	1.93	**R -**	**Eskom Rebate**	**R 4 000 000.00**	30.51%	R 6 171 402	2.99
26.49%	R 2 211 583	1.71	**20%**	**Discount Rate**	**10%**	26.49%	R 10 190 998	4.29

(Source: Own compilation)

As argued previously in this section are only one variable changed at a time to determine which of the key variables will have the foremost effect on the results obtained. The result achieved from the sensitivity analysis will be discussed below:

- **Capital expenditure (CAPEX)**

  A pessimistic outlook of CAPEX of 20% more than the expected expenditure of R15 500 000, in the second row of Table 3.9 of R18 600 000, indicates an IRR of 24.24%, NPV of R4 560 591 and PI of 2.23. This indicates that even with a 20% increase in the capital expenditure the biogas plant will still be viable. An optimistic view of R1 000 000 under the anticipated CAPEX will result in an IRR of 27.32% and a NPV of R5 380 591 and a PI of 2.86 (results shown in the second row of Table 3.9, this shows a slight improvement on the base case results in the first row of Table 3.9).

- **Operational expenses (OPEX)**

  If OPEX increase, for an unforeseen reason, to R1 000 000 in the base year with an annual increase of 7.40%, will an IRR of 18.12%, NPV of R1 422874 and PI of

1.46 be obtained. An optimistic outlook of R450 000 OPEX annually generate a NPV of R6 064 667, PI of R2.96 and an IRR of 28.52%. This indicates that the OPEX of the biogas plant will have a greater impact on the final outcome than CAPEX.

This is due to an annual increase calculated at CPI plus 1%. This is consequently important for the investor to determine the precise maintenance cost involved for the specific plant from the start.

- **Life expectancy**

Base case analysis was conducted on a life expectancy of 15 years as per external consultants. A pessimistic assumption of 10 years and optimistic outcome of 20 years were used in the sensitivity analysis. As can been seen in Table 3.9 the IRR will decrease to 20.23% and NPV to R1 456 897 on the pessimistic outlook.

With an optimistic outlook of 20 years life expectancy will a IRR of 31.46%, NPV of R9 480 604 and PI of 4.06 can be achieved. The results achieved highlight the essential need for regular maintenance to be done on the plant to increase the expected life of the biogas plant.

- **Plant capacity**

The plant capacity of the biogas plant is considered to be one of the most vital aspects of the viability of a biogas plant. This determines the amount of output the plant will generate and can be seen as the income generated by the plant.

As discussed previously the electricity generated cannot be sold back to the national grid in South Africa and all electricity generated must be used on site.

This contributes to a saving in the electricity bill rather than generating an income. For the purposes of this study the electricity savings attained will be seen as an income stream. The base case scenario assumes a plant capacity of 1 800 000kWhe generated annually. This is based on conservative assumptions made by external consultants.

A pessimistic view of a 30% decrease, than the anticipated 1 800 000kWhe less electricity generated, as the base case assumption, computes to 1 260 000kWhe (1 800 000kWhe – 540 000kWhe) of electricity generated annually.

This has a substantial impact on the viability of a biogas plant with an IRR of 13.63%, NPV of negative R609 693 and a PI of 0.80. This indicates that the plant capacity plays a decisive role in determining the economic viability of a biogas plant.

An optimistic outlook, that are not unrealistic as an increase in slaughter volumes will lead to increased waste disposal which in turn would lead to more biogas generated, will contribute to an IRR of 40.19%, NPV of R10 970 874 and PI of 4.54. As can be seen from the summary the optimistic outcome on plant capacity contribute to the best possible outcome regarding IRR and NPV values realised.

- **Electricity tariff increase**

For the purposes of this study in determining the economic viability of a biogas plant a pessimistic point of view regarding electricity tariff increases is a lower annual increase. As the plant capacity will determine the amount of electricity that can be generated, the electricity tariff increase will determine how much the organisation will save in electricity costs. If the increase is lower as anticipated then the annual savings the biogas plant will contribute will also be lower as projected.

With a pessimistic result of 4% electricity tariff increase for the following 15 years, the IRR achieved will be 13.34% that is lower than the required rate of return of 13.50%. This will also result in a negative NPV of R603 706 achieved. An optimistic outlook of a 12% annual tariff increase for the following 15 years, is however a more probable outcome as discussed in chapter 2. With a 12% increase an IRR of 30.42%, NPV of R8 316 082 and PI of 3.68 are achieved.

This confirms as previously stated that the higher the Eskom electricity tariff increase the more economic viable the biogas plant become.

- **Eskom rebate grant**

With a pessimistic outcome resulting in no Eskom rebate grant the IRR declines to 20.06%, NPV to R2 868 698 and the PI to 1.93. This noticeably indicates that the project will still be viable without any given rebate grant received.

The Eskom rebate amount as discussed previously (see section 3.5.11) will be interrelated with the amount of electricity the plant generates. If the plant capacity can be increased the amount received for the rebate grant will also increase.

With a R4 000 000 Eskom rebate grant an IRR of 30.51%, NPV of R6 171 402 and PI of 2.99 will be realised.

- **Discount rate**

In the base case scenario a discount rate of 15% were used to determine the NPV and PI respectively. As discussed previously in the assumptions (see section 3.5.7) a pessimistic discount rate of 20% and optimistic rate of 10% will also have been tested centred on the sensitivity analysis.

With a pessimistic discount rate of 20% the project continues to be viable with a NPV of R2 211 583 and a PI of 1.71. With a lower discount rate of 10% a NPV of R10 190 998 and PI of 4.29 are achieved.

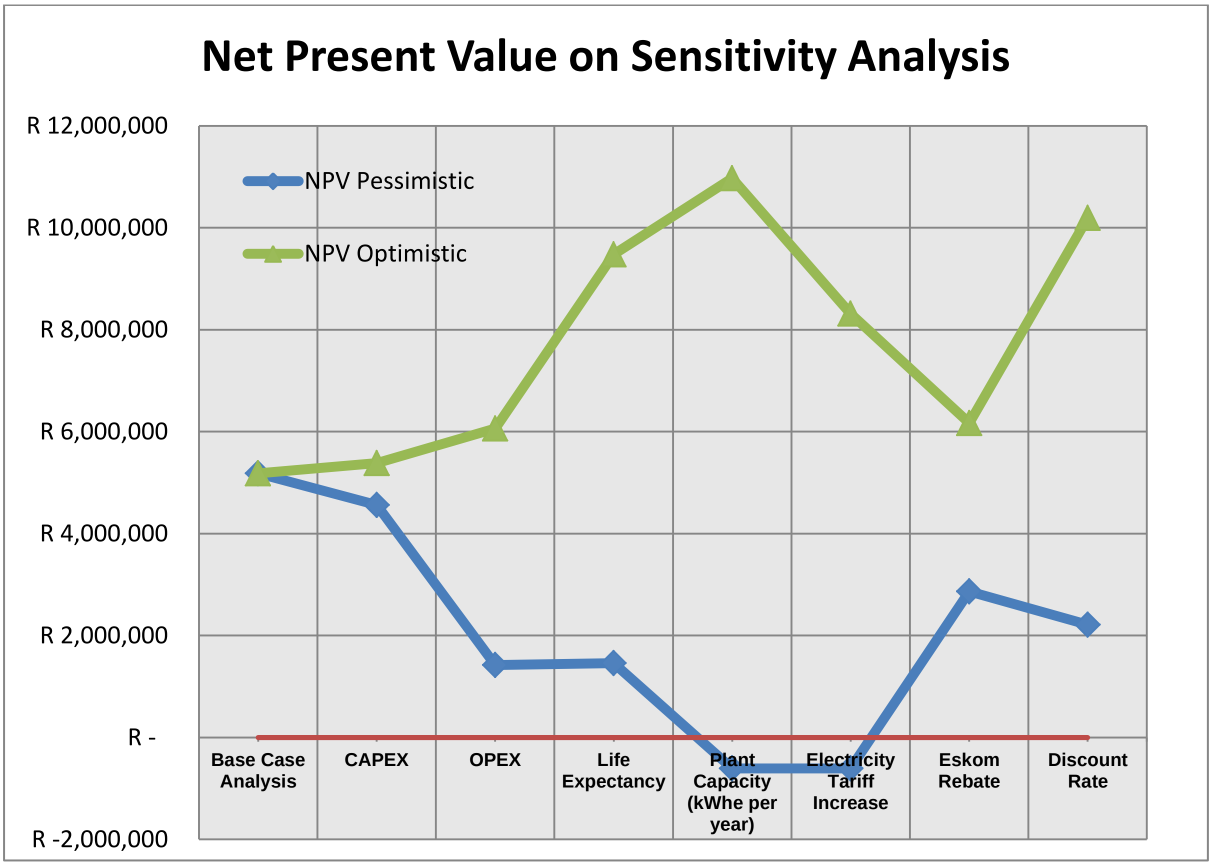
Figure 3.3 graphically highlights the various outcomes of the sensitivity analysis founded on the different net present values achieved. This provides a good indication of which of the key variables produces the most significant result on the economic viability of biogas plants at abattoirs.

As can be perceived from Figure 3.3 a life expectancy of 20 years, increased plant capacity of 30% to 2 200 000kWhe and a discount rate of 10% offer the highest net present values. This is indicated in the graph were the NPV pessimistic line is at the peak at approximately R10 000 000.

This validates that emphasis must be placed on these variables to achieve maximum results on the project. Inversely it also indicates that lower than expected plant capacity and electricity tariff increases can result in a negative net present value that will consider the project not viable.

This is clear from Figure 3.3 where the NPV pessimistic line is at the bottom and descends below the minimum of R0 line indicated.

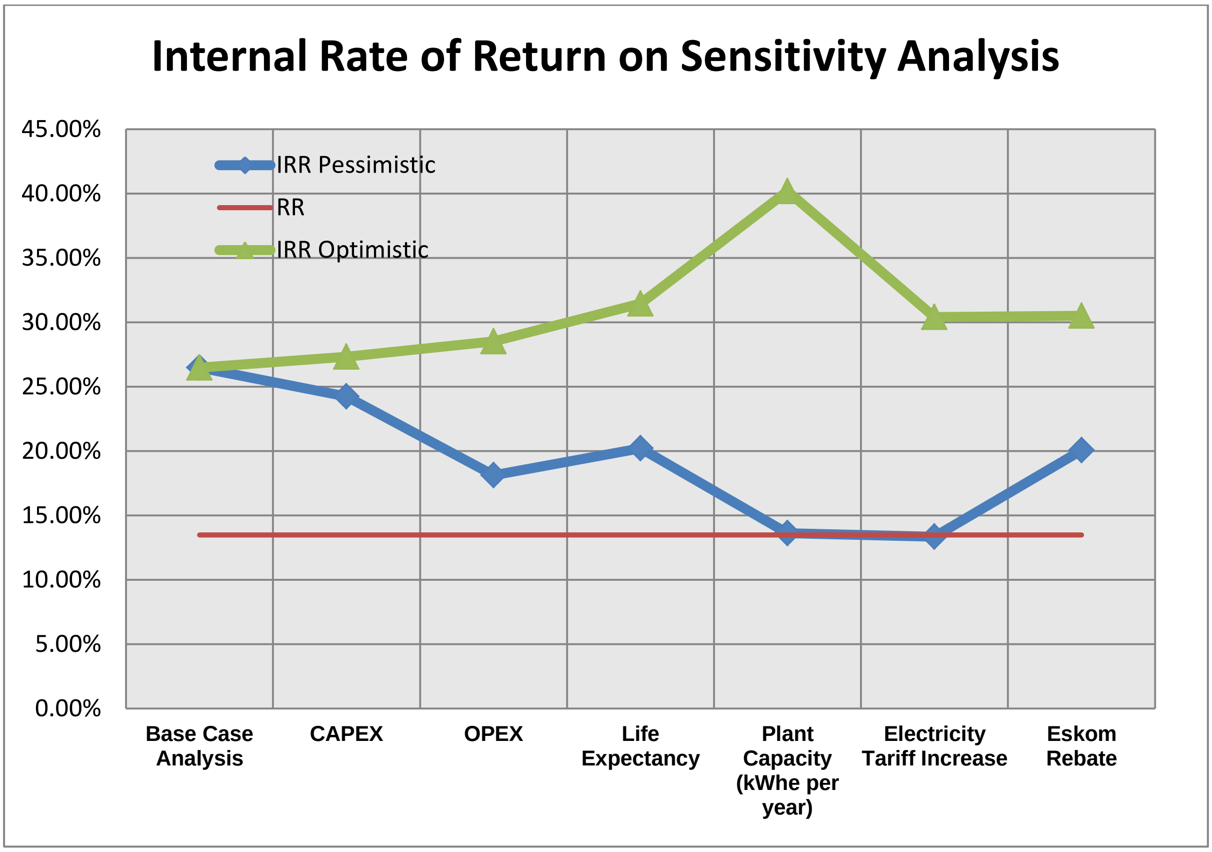
Figure3.3: Net present values based on sensitivity analysis



(Source: Own compilation)

In Figure 3.4 it can be seen that only the pessimistic outcomes of plant capacity and electricity tariff increases resulted in an internal rate of return lower than the required rate of return. An optimistic outcome of plant capacity generated the highest IRR with 40.19% followed by life expectancy of 20 years with an IRR of 31.46%. The IRR pessimistic line confirm the findings from Figure 3.3 above that a pessimistic outcome on plant capacity and electricity tariff will result in the biogas plant not being economically viable.

Figure3.4: IRR change based on sensitivity analysis



(Source: Own compilation)

This confirms the findings from the net present values attained that the most viable results will be created if there is an increase in plant capacity and the life expectancy can be improved to 20 years.

3.13 POSITIVE ECONOMIC SPILL OVERS OF BIOGAS PLANTS

Additional advantages of biogas plants include:

- Less waste disposal concerns
- Marketing the abattoir as an environmentally friendly organisation
- Supplementary heat generated by the generator can used in various parts of the abattoir
- As most abattoirs in South Africa are vertically integrated, the sludge produced can be used as fertiliser on own feedlots and farms

3.14 SUMMARY

In this chapter all assumptions and different variables that will affect the viability of a biogas plant have been discussed. The different capital budgeting techniques that were used in the study were also briefly discussed. Economic viability criteria have been discussed that will determine if biogas plants at abattoirs in South Africa are economically viable.

This chapter founded that according to the assumptions and data acquired previously, biogas plants at abattoirs in South Africa are an economically viable opportunity. The key variables that can influence the viability the greatest have also been identified. Emphasis must be placed on accurately evaluating these variables to ensure supreme productivity from the biogas plant. In conclusion, the economic viability model as established in this chapter shows evident suggestions that the investment into a biogas plant is indeed viable and fits a general tendency in support of developing these biogas plants at abattoirs in South Africa. With the results obtained in this chapter and the flexibility revealed by the Excel model, it could help simplify decision-making with regards to the economic viabilities of such biogas plants at abattoirs through South Africa.

The next chapter will conclude the study with conclusions made based on results obtained during the analysis in this chapter. Recommendations will then be made based on the conclusions drawn.

CHAPTER 4 - CONCLUSIONS AND RECOMMENDATIONS

4.1 INTRODUCTION

This study will be concluded in this chapter with a discussion of the conclusions and recommendations based on the conceptions in determining the economic viability of biogas plants at abattoirs in South Africa as calculated during the literature study (Chapter 2) and the empirical study (Chapter 3). It will be followed by evaluating the achievement of the objectives. This chapter will be concluded by suggestions for future research and finally a summary of the study.

4.2 MAIN FINDINGS

This section reviews the main findings of the study and discusses the contributions of effectively achieving both the primary and secondary objectives.

- **Base case scenario**

The base case scenario, which is regarded as the most realistic outcome, yielded the following outcomes:

A payback period of 7.62 years was achieved that is longer than the required 7-year period. Although the payback period is slightly higher than required the project will not be deemed unviable based on this criterion. The discounted payback period achieved was 9.51 years and is actually an improvement on the payback period as it accounts for the time value of money by discounting the cash inflows of the plant project.

The criteria for determining the economic viability of the biogas plant states that if the NPV is more than zero the plant will be viable. The NPV in the base case scenario calculates to R5 180 590 at a discount rate of 15%. Consequently it can be established that the biogas plant will be economically viable if the base case scenario variables are attained based on the NPV results.

The base case scenario yielded a PI of 2.67 confirming as previously discussed that the PI and NPV decision rules will yield the same investment recommendation when a single project are trying to be accepted or rejected. Therefore it can be established that according to the result achieved for the PI in the base case scenario, the biogas plant can be considered economically viable. As the PI is a ratio it however ignores the scale of investment and provides no indication of the size of actual cash flows.

The base case scenario yielded an internal rate of return of 26.49%. The required rate of return used for the purposes of this study was 13.50%, calculated as the cost of debt (prime interest rate) plus 5% added for risk involved in the project. According to the internal rate of return decision rule, if the IRR is greater or equal to the required rate of return the investment is accepted and if less than the required rate of return the project is rejected.

From this it can be concluded based on the assumptions in the base case scenario that the biogas plant will be economically viable for abattoirs in South Africa.

- **Alternative Case scenarios**

Results from case scenario 1 achieved the following results: Payback period achieved is 9.99 years, this is more than the required 7 year payback period and discounted payback period is more than 15 years, consequently the discounted payback of the project will be longer than the estimated useful life of the plant.

The NPV achieved is negative, R51 969, this is less than zero and the project on base on these assumptions appears not economically viable with the PI of 0.98 confirming the unviability of the project based on the changed variables. IRR achieved is 14.90% that are still more than the required rate of return of 13.50%. Based on the IRR rule, the project still appears to be viable.

From this can be concluded that the plant capacity and Eskom rebate grant will play a very influential role in determining the viability of the biogas plant.

Case scenario 2 yielded the following results: Payback period achieved is 7.30 years, this is marginally more than the required 7-year payback period with a discounted payback period is calculated at 13.07 years; consequently the project does not appear viable as indicated in the criteria discussed previously. NPV achieved is R1 627 724, this is more than zero and the project on base on these assumptions appears to be economically viable with PI is 1.13 and is slightly more than the required PI of 1.0. IRR achieved was 17.30% that is still more than the required rate of return of 13.50%. Based on the IRR rule, the project still appears to be viable; however, not as confidently viable as in the base case scenario.

4.3 RECOMMENDATIONS

The key variables in determining the economic viability of biogas plants at abattoirs in South Africa were identified and prioritised by the use of a case study. From the case study it became evident that a gap exists in determining the precise plant capacity and estimating the electricity tariff increases.

Recommendations for companies in the red meat industry considering establishing biogas plants:

- Determine precisely what costs savings will transpire when a biogas plant is established
- Continue with research to confirm the importance of biogas plants as a source of renewable energy within the red meat industry in South Africa
- Emphasis must be placed in confirming that key variables are calculated properly. As perceived in this study a decline in one of these key variables can have devastating effects on the sustainability of the plant
- Align the commitment towards environmental sustainability via renewable energy sources available

4.4 SUGGESTIONS FOR FUTURE RESEARCH

Research on biogas as a renewable energy source, particularly research on the applications of biogas in different industries in South Africa, is lacking behind other fields of study. This is evident in the fact that the definition of biogas is commonly unfamiliar to many in South Africa. This study attempted to introduce the application of biogas plants in the red meat industry and further attempted to determine the economic viability of these biogas plants.

The following are some recommendations for future studies:

- Future studies can be done in determining the customer perception of environmentally friendly abattoirs.

- As the main purposes of this study was determining the economic viability of biogas plants, no scientific emphasis was placed on the exact output that will be generated by the slaughter waste. A future study must be done in determining the amount of biogas that will be generated per slaughter unit.

- Future studies can also include the impact slaughter wastes have on the environment.

- This study concentrated only on the benefits for organisations within red meat industry. Further studies can be conducted into other industries.

4.5 EVALUATION OF THE STUDY

The primary objective of the study was to assess the economic viability of biogas plants at abattoir in South Africa. An empirical investigation was conducted using a case study and all necessary data was obtained through fieldwork. A model was designed to aid in determining the respective capital budgeting techniques and according to the criteria for each technique the viability of the project was determined. From the findings in Chapter 3 it can be concluded that biogas plants at abattoirs are economically viable.

The secondary objectives of the study were to:

- Establish what are the dominant variables that will impact the project as viable or not viable
- To analyse and identify other essential advantages biogas plants may offer at abattoirs in South Africa
- Evaluate the green impact a biogas plant may have on the abattoir

The first objective, to determine the dominant variables that will impact the viability of the project was achieved using a sensitivity analysis in Chapter 3.

The second secondary objective of identifying other advantages of biogas plants was achieved through the literature study in Chapter 2 and findings in Chapter 3. The third secondary objective was achieved in the literature study in part 2.8 by deliberating on the advantages of pursuing an environmentally sustainable strategy.

The conclusion can be made that all the secondary objectives were achieved and based on realising the economic viability in Chapter 3, it can also be concluded that the primary objective of this study was achieved.

4.6 CONCLUSION

In this study the concept of biogas plants in the red meat industry were researched with the purpose of determining the economic viability of these plants. In determining the viability of the biogas plant the key variables that will impact the viability was also identified and discussed. Based on the data gathered and assumptions that was made it was concluded that a biogas plant will be beneficial to an abattoir and was considered economically viable.

The progression of this study can be summarised as follow:

- Chapter 1 started with a brief historic background of biogas and the need for renewable energy sources. This was followed by the problem statement that steered the primary and secondary objectives of the study. The research methodology was discussed together with the limitations of the study. The chapter was concluded by a layout of the study and summary of the following chapters.

- In Chapter 2 a literature study was conducted providing an overview of the global meat industry and also a breakdown of the South African industry and the value chain within the industry. The literature review further placed emphases on current waste disposal methods used by abattoirs, the energy situation in South Africa and current renewable energy sources available. It lastly concentrated on the use of biogas as a renewable energy source and the impact on the company’s environmental sustainability.

- Chapter 3 involved a discussion on the various capital budgeting techniques that was used with a brief description of each. It further consisted of various assumptions and calculations made that were used in the scenarios. Further were the results obtained in the research using the assumptions and scenario’s was discussed and probable recommendations in regard to the different scenarios were also provided.

The contribution of this study is significant due to the flexibility shown in the model that was designed to determine the economic viability of biogas plants at abattoirs in South Africa. The study did not only determine that biogas plants will be a viable option for abattoirs but also highlighted the additional benefits involved. Furthermore, the study not only recognised the key variables that will influence the viability of such a biogas plant but also prioritised these variables.

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ANNEXURES

Annexure 1: Case scenario one results

Eskom Tariffs		
Period	Net % Increase	Current kWh
		R 1.02
Year 1	10.00%	R 1.12
Year 2	10.00%	R 1.23
Year 3	10.00%	R 1.36
Year 4	10.00%	R 1.49
Year 5	10.00%	R 1.64
Year 6	10.00%	R 1.81
Year 7	10.00%	R 1.99
Year 8	10.00%	R 2.19
Year 9	10.00%	R 2.41
Year 10	10.00%	R 2.65
Year 11	10.00%	R 2.91
Year 12	10.00%	R 3.20
Year 13	10.00%	R 3.52
Year 14	10.00%	R 3.87
Year 15	10.00%	R 4.26

Assumptions	
Prime *	8.50%
Discount Rate	15.00%
CPI +1% *	7.40%
Required Return	13.50%

OPEX	R 554 753
CAPEX	R 15 500 000
Debt	**80.00%**
Equity	**20.00%**
Loan Payment Years	**5**
Eskom Rebate	**R 0**

NPV	
R	**15%**
CF0	**R 3 100 000.00**
NPV	**-R 51 969.99**
RR	**13.50%**

IRR	
R	**15%**
CF0	**R 3 100 000.00**
IRR	**14.9%**
RR	**13.50%**

PI	
R	**15%**
CF0	**R 3 100 000.00**
PI	**0.98**
RR	**13.50%**

Discounted Payback Period = 16.08 Years

Payback Period = 9.99 Years

	Inflows (Savings)						Total Inflows	Outflows				Total Outflows / Expenses	Net Cash Flow	Accumm Cash Flow	Discounted Cash Flow	Accumm Discounted Cash Flow
				Electricity Savings	Rebate Grant	Other Savings		Loan Repayment		Maintenance						
	Year	kW Biogas	R/kW	Total kWh Cost				Capital	Interest							
2013	0	0	R 1.02	R -	R -	R -	R -	R 3 100 000	R -	R -	R 0	R 3 100 000	R -3 100 000	R -3 100 000	R -3 100 000	R -3 100 000
2014	1	1500000	R 1.12	R 1 683 000	R -	R 187 500	R 1 870 500	R 2 078 600	R 974 259	R 0.37	R 554 753	R 3 607 613	R -1 737 113	R -4 837 113	R -1 510 533	R -4 610 533
2015	2	1500000	R 1.23	R 1 851 300	R -	R 201 375	R 2 052 675	R 2 262 330	R 790 530	R 0.40	R 595 805	R 3 648 665	R -1 595 990	R -6 433 102	R -1 206 797	R -5 817 330
2016	3	1500000	R 1.36	R 2 036 430	R -	R 216 277	R 2 252 707	R 2 462 299	R 590 561	R 0.43	R 639 894	R 3 692 754	R -1 440 047	R -7 873 150	R -946 855	R -6 764 185
2017	4	1500000	R 1.49	R 2 240 073	R -	R 232 281	R 2 472 354	R 2 679 944	R 372 916	R 0.46	R 687 246	R 3 740 106	R -1 267 752	R -9 140 902	R -724 841	R -7 489 026
2018	5	1500000	R 1.64	R 2 464 080	R -	R 249 470	R 2 713 550	R 2 915 037	R 136 033	R 0.49	R 738 103	R 3 789 173	R -1 075 623	R -10 216 525	R -534 775	R -8 023 801
2019	6	1500000	R 1.81	R 2 710 488	R -	R 267 931	R 2 978 419	R -	R -	R 0.53	R 792 722	R 792 722	R 2 185 697	R -8 030 828	R 944 937	R -7 078 864
2020	7	1500000	R 1.99	R 2 981 537	R -	R 287 758	R 3 269 295	R -	R -	R 0.57	R 851 384	R 851 384	R 2 417 911	R -5 612 917	R 908 982	R -6 169 881
2021	8	1500000	R 2.19	R 3 279 691	R -	R 309 052	R 3 588 743	R -	R -	R 0.61	R 914 386	R 914 386	R 2 674 357	R -2 938 560	R 874 252	R -5 295 630
2022	9	1500000	R 2.41	R 3 607 660	R -	R 331 922	R 3 939 582	R -	R -	R 0.65	R 982 051	R 982 051	R 2 957 531	R 18 971	R 840 715	R -4 454 915
2023	10	1500000	R 2.65	R 3 968 426	R -	R 356 484	R 4 324 910	R -	R -	R 0.70	R 1 054 722	R 1 054 722	R 3 270 187	R 3 289 158	R 808 340	R -3 646 574
2024	11	1500000	R 2.91	R 4 365 269	R -	R 382 864	R 4 748 132	R -	R -	R 0.76	R 1 132 772	R 1 132 772	R 3 615 360	R 6 904 518	R 777 097	R -2 869 477
2025	12	1500000	R 3.20	R 4 801 795	R -	R 411 196	R 5 212 991	R -	R -	R 0.81	R 1 216 597	R 1 216 597	R 3 996 394	R 10 900 912	R 746 955	R -2 122 523
2026	13	1500000	R 3.52	R 5 281 975	R -	R 441 624	R 5 723 599	R -	R -	R 0.87	R 1 306 625	R 1 306 625	R 4 416 974	R 15 317 886	R 717 882	R -1 404 641
2027	14	1500000	R 3.87	R 5 810 172	R -	R 474 304	R 6 284 477	R -	R -	R 0.94	R 1 403 315	R 1 403 315	R 4 881 161	R 20 199 047	R 689 848	R -714 793
2028	15	1500000	R 4.26	R 6 391 190	R -	R 509 403	R 6 900 592	R -	R -	R 1.00	R 1 507 161	R 1 507 161	R 5 393 432	R 25 592 478	R 662 823	R -51 970

Annexure 2: Case scenario one results

Eskom Tariffs		
Period	Net % Increase	Current kWh
		R 1.02
Year 1	6.40%	R 1.09
Year 2	6.40%	R 1.15
Year 3	6.40%	R 1.23
Year 4	6.40%	R 1.31
Year 5	6.40%	R 1.39
Year 6	6.40%	R 1.48
Year 7	6.40%	R 1.57
Year 8	6.40%	R 1.68
Year 9	6.40%	R 1.78
Year 10	6.40%	R 1.90
Year 11	6.40%	R 2.02
Year 12	6.40%	R 2.15
Year 13	6.40%	R 2.28
Year 14	6.40%	R 2.43
Year 15	6.40%	R 2.59

Assumptions	
Prime *	8.50%
Discount Rate	15.00%
CPI +1% *	7.40%
Required Return	13.50%

OPEX	**R 554 753**
CAPEX	**R 15 500 000**
Debt	**20.00%**
Equity	**80.00%**
Loan Payment Years	**5**
Eskom Rebate	**R 2 800 000**

NPV	
R	**15%**
CF0	**R 12 400 000.00**
NPV	**R 1 627 724.25**
RR	**13.50%**

IRR	
R	**15%**
CF0	**R 12 400 000.00**
IRR	**17.3%**
RR	**13.50%**

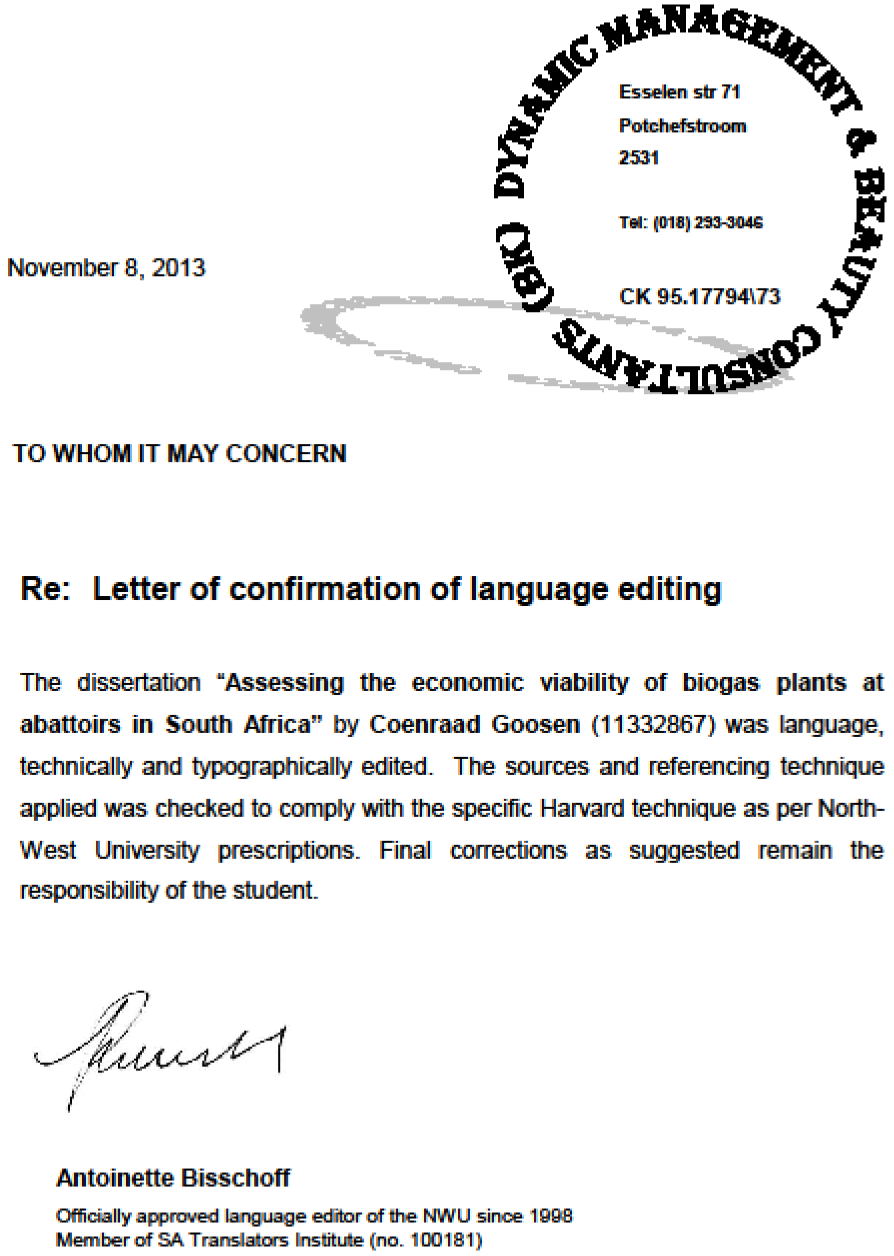
PI	
R	**15%**
CF0	**R 12 400 000.00**
PI	**1.13**
RR	**13.50%**

Discounted Payback Period = 13.07 Years

Payback Period = 7.30 Years

	Inflows (Savings)						Total Inflows	Outflows				Total Outflows / Expenses	Net Cash Flow	Accumm Cash Flow	Discounted Cash Flow	Accumm Discounted Cash Flow
				Electricity Savings	Rebate Grant	Other Savings		Loan Repayment		Maintenance						
	Year	kW Biogas	R/kW	Total kWh Cost				Capital	Interest							
2013	0	0	R 1.02	R -	R -	R -	R -	R 12 400 000	R -	R -	R 0	R 12 400 000	R -12 400 000	R -12 400 000	R -12 400 000	R -12 400 000
2014	1	2000000	R 1.09	R 2 170 560	R 1 960 000	R 187 500	R 4 318 060	R 519 650	R 243 565	R 0.28	R 554 753	R 1 317 968	R 3 000 092	R -9 399 908	R 2 608 776	R -9 791 224
2015	2	2000000	R 1.15	R 2 309 476	R 560 000	R 201 375	R 3 070 851	R 565 582	R 197 633	R 0.30	R 595 805	R 1 359 020	R 1 711 831	R -7 688 077	R 1 294 390	R -8 496 834
2016	3	2000000	R 1.23	R 2 457 282	R 280 000	R 216 277	R 2 953 559	R 615 575	R 147 640	R 0.32	R 639 894	R 1 403 109	R 1 550 450	R -6 137 627	R 1 019 446	R -7 477 388
2017	4	2000000	R 1.31	R 2 614 548	R -	R 232 281	R 2 846 830	R 669 986	R 93 229	R 0.34	R 687 246	R 1 450 461	R 1 396 368	R -4 741 259	R 798 378	R -6 679 010
2018	5	2000000	R 1.39	R 2 781 879	R -	R 249 470	R 3 031 349	R 728 759	R 34 008	R 0.37	R 738 103	R 1 500 870	R 1 530 479	R -3 210 780	R 760 919	R -5 918 091
2019	6	2000000	R 1.48	R 2 959 920	R -	R 267 931	R 3 227 851	R -	R -	R 0.40	R 792 722	R 792 722	R 2 435 128	R -775 651	R 1 052 773	R -4 865 318
2020	7	2000000	R 1.57	R 3 149 355	R -	R 287 758	R 3 437 112	R -	R -	R 0.43	R 851 384	R 851 384	R 2 585 729	R 1 810 077	R 972 071	R -3 893 247
2021	8	2000000	R 1.68	R 3 350 913	R -	R 309 052	R 3 659 965	R -	R -	R 0.46	R 914 386	R 914 386	R 2 745 579	R 4 555 656	R 897 535	R -2 995 713
2022	9	2000000	R 1.78	R 3 565 372	R -	R 331 922	R 3 897 293	R -	R -	R 0.49	R 982 051	R 982 051	R 2 915 243	R 7 470 899	R 828 694	R -2 167 019
2023	10	2000000	R 1.90	R 3 793 556	R -	R 356 484	R 4 150 039	R -	R -	R 0.53	R 1 054 722	R 1 054 722	R 3 095 317	R 10 566 216	R 765 115	R -1 401 904
2024	11	2000000	R 2.02	R 4 036 343	R -	R 382 864	R 4 419 207	R -	R -	R 0.57	R 1 132 772	R 1 132 772	R 3 286 435	R 13 852 650	R 706 397	R -695 507
2025	12	2000000	R 2.15	R 4 294 669	R -	R 411 196	R 4 705 865	R -	R -	R 0.61	R 1 216 597	R 1 216 597	R 3 489 268	R 17 341 918	R 652 169	R -43 338
2026	13	2000000	R 2.28	R 4 569 528	R -	R 441 624	R 5 011 152	R -	R -	R 0.65	R 1 306 625	R 1 306 625	R 3 704 527	R 21 046 445	R 602 089	R 558 751
2027	14	2000000	R 2.43	R 4 861 978	R -	R 474 304	R 5 336 282	R -	R -	R 0.70	R 1 403 315	R 1 403 315	R 3 932 966	R 24 979 411	R 555 841	R 1 114 592
2028	15	2000000	R 2.59	R 5 173 144	R -	R 509 403	R 5 682 547	R -	R -	R 0.75	R 1 507 161	R 1 507 161	R 4 175 386	R 29 154 797	R 513 132	R 1 627 724

LETTER FROM EDITOR



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November 8, 2013

TO WHOM IT MAY CONCERN

Re: Letter of confirmation of language editing

The dissertation **"Assessing the economic viability of biogas plants at abattoirs in South Africa"** by **Coenraad Goosen** (11332867) was language, technically and typographically edited. The sources and referencing technique applied was checked to comply with the specific Harvard technique as per North-West University prescriptions. Final corrections as suggested remain the responsibility of the student.

Antoinette Bisschoff
Officially approved language editor of the NWU since 1998
Member of SA Translators Institute (no. 100181)