WASTE MANAGEMENT AT FREE STATE ABATTOIRS

by

JAN WILLEM SWANEPOEL

(M.Sc. Agric)

Field study

submitted in partial fulfilment of the degree

MASTER'S IN BUSINESS ADMINISTRATION

in the

BUSINESS SCHOOL

FACULTY OF ECONOMIC AND MANAGEMENT SCIENCES

at the

UNIVERSITY OF THE FREE STATE

BLOEMFONTEIN

SUPERVISOR: Mnr. Jacques van Wyk

NOVEMBER 2014

DECLARATION

"I declare that the Field Study hereby submitted for the Magister in Business Administration at the UFS Business School, University of the Free State, is my own independent work and that I have not previously submitted this work, either as a whole or in part, for a qualification at another university or at another faculty at this university.

I also hereby cede copyright of this work to the University of the Free State."

J.W. Swanepoel

ACKNOWLEDGEMENTS

With this opportunity I would like to express my gratitude to everyone who supported me throughout the course of this MBA project.

To my field study advisor, Mr Jacques van Wyk, I am thankful for your aspiring guidance, invaluably constructive criticism and friendly advice during the project work. I am sincerely grateful to you for sharing your truthful and illuminating views on a number of issues related to the project.

To all the facilitators of the business school and Professor Helena that made this journey a very pleasant and intellectually stimulating one, I express my warm thanks.

A special thanks to my friends and family that supported and prayed for me during the past three years. Sorry for neglecting you and not being the friend I am supposed to be.

To my mother and father, your prayers for me was what sustained me thus far. Thanks for teaching me to never give up and work hard! You are my pillars of strength. Thank you for your great example! Also to my sister and brother in law, thank you for support!

Words cannot express the appreciation to my beloved wife Karen. Thank you for all the sacrifices that you've made on my behalf and all your support during the past three years! You are a woman of substance.

To my beautiful princess, Jana, thank you for your smiles! You are the reason I did this, so this one's for you!

Then last but not least, I thank my Heavenly Father for the strength, courage and wisdom He provided me with! I can't take one step without His blessing and grace.

Thank you,

J.W.

Joshua 1:9

Have not I commanded you? Be strong and of a good courage; be not afraid, neither be you dismayed: for the LORD your God is with you wherever you go.

TABLE OF CONTENTS

DECLARATION II

ACKNOWLEDGEMENTS III

TABLE OF CONTENTS V

LIST OF TABLES IX

LIST OF FIGURES X

LIST OF APPENDICES XI

ABSTRACT 1

CHAPTER 1 3

RESEARCH PROPOSAL 3

1.1. INTRODUCTION 3

1.2. PROBLEM STATEMENT 10

1.3. OBJECTIVES 10

1.3.1. Primary Objective 10

1.3.2. Secondary Objectives 10

CHAPTER 2 11

LITERATURE STUDY 11

2.1. Definitions 11

2.1.1. Abattoir waste: 11

2.1.2. Energy efficiency: 11
2.1.3. Biomass: 12

2.2. Introduction 12

2.3. Global Red meat industry 13

2.4. Red meat industry of SA 16

2.5. Abattoir Waste 24

2.6. Waste management 27

2.7. Laws & regulations 29
2.7.1. The Environmental Conservation Act 73 of 1989 (ECA) 30
2.7.2. National Environmental Management Act 107 of 1998 (NEMA) 30
2.7.3. National Water Act 36 of 1998 (NWA) 30
2.7.4. The Meat Safety Act 40 of 2000 (MSA) 31

2.8. Economic overview 31

2.9. Renewable energy technologies 32
2.9.1. Mass burn incineration 34
2.9.2. Air curtain burners 34
2.9.3. Alkaline hydrolysis 34
2.9.4. Gasification 35
2.9.5. Biogas 35
2.9.6. Pyrolysis 35

2.10. Conclusion 37

CHAPTER 3 39

RESEARCH METHODOLOGY 39

3.1. Introduction 39

3.2. Research Design 39

3.3. Sampling 40

3.4. Location of study **41**

3.5. Demarcation **42**

3.6. Data Collection **43**

3.7. Data analysis **43**

3.8. Ethical Considerations **44**

3.9. Conclusion **44**

CHAPTER 4 ..... **46**

RESULTS AND FINDINGS **46**

4.1. Introduction **46**

4.2. Results **46**

4.2.1. Capacity 47

4.2.2. Operations 49

4.2.2.1. Electricity 49

4.2.2.2. Water 50

4.2.3. Waste management 51

4.2.3.1. Manure 51

4.2.3.2. Blood 52

4.2.3.3. Condemned Meat 53

4.2.3.4. Horns & Hooves 53

4.2.3.5. Non product waste 54

4.2.3.6. Specific Risk Materials (SRM) 54

4.2.4. Expansion 55

4.2.5. Alternatives in waste management 55

4.2.6. The fifth quarter 57

4.2.7. Research on possible waste-to-energy techniques 57

4.2.8. Relevance of the questionnaire 58

4.3. Comparative study 58

4.3.1. Alkaline Hydrolysis 59

4.3.2. Incineration 59

4.3.3. Gasification 60
4.3.4. Biogas 60
4.3.5. Pyrolysis 61
4.3.6. Plasma Arc Gasification 61
4.3.7. Cost Benefit Analysis 61

CHAPTER 5 65

CONCLUSION 65

5.1. INTRODUCTION 65

5.2. CONCLUSIONS AND SUGGESTIONS 65
5.2.1. Manure 66
5.2.2. Blood 66
5.2.3. Condemned meat 67
5.2.4. Waste water 68
5.2.5. Horns and hooves 68
5.2.6. General 68
5.2.7. Waste to energy 69
5.2.8. Current waste management at abattoirs 70

5.3. Final remarks 71

5.4. Further investigation 72

LIST OF REFERENCES 73

APPENDICES 85

APPENDIX 1 – QUESTIONNAIRE 85

APPENDIX 2 – LETTER TO PARTICIPANTS 93

LIST OF TABLES

Table 2.1. Cattle numbers, numbers slaughtered and average prices of beef from 1970 to 2012.

Table 2.2. Sheep, lambs and goats: numbers slaughtered at abattoirs, average prices of mutton, production and consumption

Table 2.3. Quantifiable unit standards for slaughter units

Table 2.4. Animal waste products showed as percentage or mass of the average market weight for pigs, cattle and sheep.

Table 2.5. Different groups of abattoir waste with its by-products and their industrial uses

Table 2.6. The most common waste to energy methods used at municipalities and abattoirs with their advantages and disadvantages.

Table 2.7. A comparison between different waste to energy technologies with pricing and energy conversion.

Table 3.1. Red meat abattoirs in the Free State sorted according to their throughput

Table 4.1. Summary of the responses of each abattoir contacted.

LIST OF FIGURES

Figure 1.1. Different parts of the typical slaughtered cattle.

Figure 2.1. Beef market value chain

Figure 2.2. Beef production per province

Figure 2.3. Sheep production per province

Figure 2.4. Per Capita consumption of major food items in developing countries, 1961-2006

Figure 2.5. The proposed waste management model for red meat abattoirs

Figure 3.1. Map of the Free State

Figure 4.1. Cost benefit analysis of pyrolysis

Figure 4.2. Cost benefit analysis of biogas digester

LIST OF APPENDICES

Appendice 1. Questionnaire

Appendice 2. Letter to participating abattoirs

ABSTRACT

South African red meat abattoirs currently rehabilitate waste poorly. This is due to a lack of resources, poor management and low prioritization. Ineffective waste management can result in considerable environmental damage and health risks. When alternative ways to manage or dispose of waste are implemented, this could result in both financial and environmental gain. The generation of power in South Africa is expensive, whilst electricity is one of the biggest expenses at an abattoir. It is thus important to research other means to generate power at an abattoir.

There are many benefits to improved waste processing and management. These include decreased costs of waste treatment and disposal, income generation from by-products and a reduced environmental impact associated with waste disposal. Livestock by-products have significant economic and nutritional value that needs to be utilized.

Landfilling, the most common form of abattoir waste disposal is becoming limited in regards to space and stricter regulations for waste management. Alternative technologies should be applied to optimize recycling targets and to ensure that the production of energy is optimized in such a way that a maximum return on investment is achieved. The impact on the environment should always be considered and the technology risks carefully assessed.

High throughput abattoirs are much more inclined to implement new waste management systems. Most systems are very expensive, but fortunately many realize the importance and future return on investment after implementing such a system. The same applies for low throughput abattoirs slaughtering high numbers of units and thus producing a lot of waste. Many abattoirs do implement some waste management techniques whereby they generate additional income or saving on disposal expenses. The implication of this, prove to be very advantageous for some of these abattoirs. Low-throughput abattoirs find it costly and not viable to establish any of the researched

plants to generate energy from waste. It is thus advisable to still do everything possible to process waste and minimizing the amount of waste products going into the municipal sewerage system and landfills.

This study provides abattoirs with viable methods of getting rid of waste and in the same time using waste to produce energy at the abattoir. Since few abattoirs are informed about the newest technology that is available with regards to waste to energy, this study serves as an introduction to these new technologies.

Abattoirs can save money by generating their own power, have a means of getting rid of waste, building up carbon points as well as doing their part in slowing down, stopping or even reversing global warming.

WASTE MANAGEMENT AT FREE STATE ABATTOIRS

CHAPTER 1
RESEARCH PROPOSAL

1.1. INTRODUCTION

Since the creation of Earth, it has had a cyclical trend in warming and cooling down. This occurred because the earth received less or more sunlight when it shifts in its orbit. According to Riebeek (2010) during the past century, one force has added to the change in climate, i.e. the human race.

The risk of climate change caused by human activity is evaluated by an Intergovernmental Panel on Climate Change (IPCC, 2007). This group's work is thorough and one of the most intensive scientific processes at present. The IPCC defined climate change as the following:

"Climate change in IPCC usage refers to a change in the state of the climate that can be identified (e.g. using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer. It refers to any change in climate over time, whether due to natural variability or as a result of human activity. This usage differs from that in the United Nations Framework Convention on Climate Change (UNFCCC), where climate change refers to a change of climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and that is in addition to natural climate variability observed over comparable time periods."

According to the 2007 IPCC report, scientists are more than 95% certain that humans are contributing to climate change to such an extent that land, ocean and atmosphere temperatures are rising, resulting in rising sea levels because snow and ice is melting due to higher temperatures.

Riebeek (2010) reported that studies by NASA showed an average surface temperature increase of up to 0.9 °C during the last decade up to 2005. The increase in temperature has doubled during the previous 50 years. They predict a sharp increase of temperatures in the near future.

Action is needed to get commitment from countries globally to reduce future warming to below a limit of 2 °C for pre-industrial levels. Across the world, countries implemented some regulatory policies to reduce greenhouse gas and carbon emissions such as emissions trading schemes, carbon taxes, rebates on green developments and other strategies.

The People's Republic of China (PRC, 2011) pledged to reduce greenhouse gas emission by up to 45% by 2020. This includes the reduction in the use of fossil fuels, reduction of energy usage and CO2 emissions. (PRC, 2011) They are the largest emitter of greenhouse gasses (GHG).

In 2010 the Indian government published a document titled: "India: Taking on climate change." (IPCC, 2007). A panel of experts was formed to develop strategies in reducing GHG emissions in India. Some of these strategies included eco-restoration, electricity generation using solar, renewal of the transportation system, better waste management and other energy efficiency promoting initiatives.

The USA which is the 2nd largest greenhouse gas producer (16% globally) and the 10th highest per capita in the world committed to emissions up to 17% less than the 2005 levels by 2020 and up to 42% lower than in 2005 by 2030 (IPCC, 2007).

The European Union and Brazil are respectively the 3rd and 4th largest producers of GHG's in the world, with the EU accounting for almost 12% of the world's emissions. Both countries pledged substantial reductions in emissions.

On the 27th of September 2013, the IPCC released the first of four reports. As reported by Fakir (2013), it concluded that the world-wide energy systems that are already established and are to be established would define the world's climate change path for future generations. To quote the IPCC:

"Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia. The challenge for South Africa and for all of the world's countries is this: "do we have more than a moral obligation to act?" We have no choice anymore." A resilient business can only be built on a resilient ecosystem. We call this a green business. "

During the 17th Conference of the Parties (COP 17) (2011), the South African Government committed to reduce greenhouse gas (GHG) emissions to a level of 34% below the usual trajectory by 2020 and up to 42% by 2025. South Africa is under the top 20 countries in the world with regards to absolute carbon dioxide (CO2) emissions.

The National Climate Change Response White paper includes a carbon budget approach to allocate the country's share of emissions within the economy. To help stay within these numbers, various efforts will be undertaken to reduce carbon emissions, including the introduction of a carbon tax to direct behaviour away from carbon intensive activities. (Department of environmental affairs, 2011)

In May 2013, Department of National Treasury of South Africa released the Carbon Tax Policy Paper with the title: "Reducing greenhouse gas emissions and facilitating the transition to a green economy." (National Treasury of South Africa, 2013)

Some initiatives that the South African government is taking to reach their proposed goals of the transitioning to a low-carbon and green economy include the following:

- Carbon Pricing - will be applied to encourage a shift in production patterns to technology that requires low carbon and fuel-or-energy-efficient alternatives.

- Services and products that require carbon intensive means for production will be replaced by alternatives requiring low carbon emitting processes.

- A carbon tax rate of R120 per ton of CO_2e will be implemented in the first phase and this amount will increase at 10 percent annually. When the tax-free threshold and additional relief are taken into account, the effective tax rate will approximate R12 to R48 per ton of CO_2 and zero for Agriculture and Waste.

- Energy Efficiency and Demand-Side Management (EEDSM) programs by government are implemented by using alternative technologies for energy efficiency and renewable energy. Water heating by means of solar, aimed at households, and the tax incentive that is applicable to businesses, provide tax deductions when energy saving can be verified.

The government also launched a funding mechanism to support the Renewable Energy Independent Power Producer (REIPP) programs (Eberhard et al. 2014).

Funding will apply to concessional loans and target small-scale renewable energy projects (1–5 MW installed capacity).

Eskom has established goals to support clients in their drive towards more optimal energy consumption. Eskom understands that reducing energy demand within industry may require investments in newer technologies, processes and equipment.

Eskom's Integrated Demand Management (IDM) programme therefore makes funding available to its clients in support of reduced energy consumption (Eskom, 2014).

Waste-to-energy (WTE) is a term used for converting waste streams into energy in the form of either heat or electricity. According to the South African Institute of Race Relations (2013), about 66% of people in South Africa live in urban areas as a result of growing urbanization. The number of people in urban areas increased from 52% in 1990 to 62% in 2011. This contributes drastically to the higher amounts of municipal waste needed to be managed. Moreover, the unavailability of open land in close proximity to waste dumpsite areas has made land filling a less attractive option (Hartmann and Ahring, 2006).

According to research by Pike Research (2012) the global population in urban areas generated almost 2 billion tons of municipal solid waste. It was estimated that this number will climb with almost 50% by 2022. Pike Research (2012) also stated that nearly 75% of all waste generated ended up in open pits or landfills. This often includes waste from abattoirs.

Globally more than 800 thermal WTE plants operate in 40 countries. Led by Asia-Pacific and Europe, this number is expected to grow rapidly over the next decade, potentially treating 396 million tons of MSW annually by 2022 with an estimated output of 151 terawatt hours (TWh) of electricity.

The question is thus: “Can the same methods of energy generating be applied to the waste management in abattoirs?”

Abattoirs produce high amounts of waste. Patkie et al. (2000) acknowledged abattoir waste to comprise of blood, condemned organs, hides, condemned carcasses, carcass trimmings and paunch content and condemned meat. Offal not suitable for human consumption includes foetuses, the gall bladder, hoofs, horns, skin, ears and hair.

Visser (2002) stated that waste can be classified in two types. The first type is general waste, which may pose an environmental, as well as a health threat due to pollution, potentially caused as a result of decomposition or infiltration. Hazardous waste is the second type of waste which includes abattoir waste due to its bio-hazardous properties. Food borne diseases and other potential health hazards me be a result of this. According to Bradshaw et al. (1992), abattoirs are a big contributor hereto. Waste generated by abattoirs is categorized as organic waste. Since it is organic, it is classified as hazardous waste because it is not safe for consumption by humans and animals.

Farming and the meat industries, which include the slaughtering of animals, play a big role in the economy of a country. South Africa has approximately 495 abattoirs (Department of Agriculture, Fisheries and Forestry, 2012).

In South Africa around 6,242million sheep and 2,88million cattle are slaughtered annually. On average a slaughter unit delivers about 4kg of manure, 19 kg blood, 37 kg stomach waste and 21 kg slaughter waste. This totals to an average of 80 kg per animal (Department of Agriculture, Fisheries and Forestry. 2011). The Department of Agriculture and Rural Development (2009) identified a quantifiable standard to determine the throughput of abattoirs in terms of slaughter units. These unit standards are identified as in table 2.3.

Omole and Ogbiye (2013) noted the different parts of the typical slaughtered cattle as presented in Figure 1. If the average weight of cattle slaughtered is 350kg, it can be divided into the following:

- Edible meat - 122.5 kg (35%)
- Edible offal (heart, lungs kidney, tongue and liver) - 19.2 kg (5%)
- The bones (skeleton, head, horns, hooves and feet) – 119 kg (34%)
- The blood and other body fluids - 10.5 kg (3%)
- The gut (intestines and stomach) - 10.5 kg (3%)
- The animal hides - 24.5 kg (7%)
- The manure and undigested paunch contents - 10.5 kg (3%)
- The fat (edible and inedible) - 36.7 kg (11%)

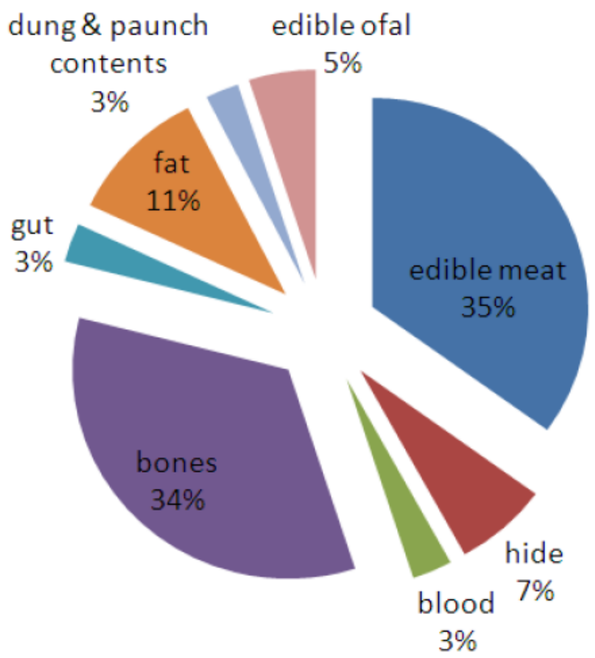

Figure 1.1. Different parts of the typical slaughtered cattle.

As seen above, about 30 – 50% of the animal can be converted into products that are edible. Between 30 and 50% of the by products can be utilized and used for other applications. The remaining 10 – 20% is waste.

During the last decade it was proven that anaerobic digestion is a very good alternative for the treatment of animal waste products (Salminen & Rintala, 2002). This was confirmed by Rodriguez-Martinez et al., (2002) who stated that methane-rich gas produced by slaughterhouse wastewater and other waste can be used as a fuel at significantly lower costs than comparable aerobic systems.

As such, the following thermal and biological technology segments are examined:

- Incinerators and combustion applications
- Advanced thermal technologies
- Anaerobic digesters

The purpose of this study is thus to research and recommend alternatives for improved waste processing and management in high and low throughput red meat abattoirs.

1.2. PROBLEM STATEMENT

Abattoirs in South Africa struggle to rehabilitate waste due to a lack of resources, bad management and low prioritization. The ineffective management of animal waste products could cause substantial environmental damage. Uncontrolled spillage could lead to health risks and instability as well. Animal blood is dumped into streams, and can cause health risks or unpleasantness due to odours and smoke. Is there an alternative way to manage or disperse of abattoir waste, saving money and the environment?

The second problem comprise of the fact that the main means of power generating in SA are getting very expensive, and the main expense at an abattoir is electricity. Therefore, what is the most viable, cheapest and greenest method to generate power at an abattoir?

1.3. OBJECTIVES

1.3.1. Primary Objective

To research and recommend alternatives for improved waste processing and management in high and low throughput red meat abattoirs.

1.3.2. Secondary Objectives

To determine the current waste management methods applied at high and low throughput red meat abattoirs.

To identify different waste to energy generating methods for high and low throughput red meat abattoirs.

CHAPTER 2
LITERATURE STUDY

2.1. Definitions

2.1.1. Abattoir waste:

Abattoir waste is defined by Weiers and Fischer (1978) as the collective by-products of an abattoir. This waste occurs as a result of slaughtering and operational activities at the slaughterhouse. It is therefore categorised into the following:

- Carcass waste – This is the remainder of meat/carcasses not used for human consumption. This becomes waste as it is unfit for consumption or because it is refused by the consumer for reasons associated with consumer habits. Abattoir waste includes condemned meat/carcasses.

- Other waste is generated by the animals that are stabled some days before slaughtering. This waste comprises of faecal matter and urine. The waste water is also considered a problem, as considerable quantities of waste (blood, contents of stomach and intestines, bristles, etc.) are disposed of via the waste water system at many abattoirs.

2.1.2. Energy efficiency:

Energy efficiency is when less energy is consumed to produce the same outputs or services. The goal of energy efficiency is to preserve energy, use less fossil fuel, and reduce the emission of greenhouse gas to reduce the impact thereof on the environment. (Red Meat Abattoir Association (RMAA), 2011)

2.1.3. Biomass:

All living matter on earth is called biomass. Substances in which solar energy can be stored such as plants produce biomass by photosynthesis. Biomass products include wood, wood waste, animal waste, agricultural crops and its waste, municipal solid waste and waste from aquatic plants, algae and food processing. (McKendry, 2002)

2.2. Introduction

According to The Food and Agriculture Organization (FAO, 2014), livestock contribute significantly to climate change by its emission of different greenhouse gasses. It contributes to up to 18% of the total amount of greenhouse gas that is produced globally, and is estimated to amount to 7.1 billion tonnes of CO_2 produced by livestock. Gas from the natural digestive process of animals (methane), manure management (Nitrous oxide), gas from fertilizer use for feed production (Carbon dioxide) and other sources of emissions from the livestock sector e.g. waste management of by-products from abattoirs are produced.

Renewable energy is needed to cope with rising global energy demands as well as to compensate for the depleting non-renewable resources (Spence, 2012). Varela (2006) predicted that available oil reserves and natural gas supply are projected to reach their peaks by 2014 and 2030 respectively. Varela also stated that uranium supplies used to generate nuclear power would last for about 60 years. The world's coal resources could be exhausted by 2050. It is thus inevitable that the price of fossil fuels will increase dramatically, forcing the implementation of renewable energy recourses into current energy markets.

According to Saidur et al. (2010), Australia is one of the world's biggest producers of greenhouse gasses. These emissions occur when electricity is generated by burning coal. Currently the Australian government is taking steps to reduce greenhouse gas emissions and advance to the generating of renewable energy. (Department of the environment, Australian Government, 2013)

The EU Landfill Directive (1999/31/EC) contributed to the fact that there was a 15% decline of UK domestic waste disposed to landfill sites between 2005 and 2010. The UK is obligated to have 35% of its biodegradable municipal waste produced in 1995 sent to landfill by 2020 (Department for Environment, Food & Rural Affairs, UK, 2010). After the European Landfill Directive, it was suggested that as many as 170 new incineration plants in the UK could be required to meet the 2020 target (Burnley, 2001).

The South African Government committed to the reduction of greenhouse gas (GHG) emissions to a level of 34% below the usual trajectory by 2020 and up to 42% by 2025. This was done at the 17th Conference of the Parties (COP 17). South Africa is under the top 20 countries in the world with regards to absolute carbon dioxide (CO2) emissions.

2.3. Global Red meat industry

Professor Mooney from the Woods Institute for the Environment at Stanford was quoted saying the following: "People aren't going to stop eating meat." (Brooks, 2013). The global meat industry is enormous and ever expanding. The social and environmental impact of the meat industry will increase, as Brooks projected that the global consumption of meat will double by 2020.

The constant population growth leads to an increase in the demand for meat products, resulting to the increased production and slaughtering of livestock. According to Akinro et al. (2009) the increased frequency of these production processes, also increases pollution substantially.

The Department of Agriculture, Fisheries and Forestry (2012) established that one of the fastest growing sectors in agriculture is the livestock sector. Livestock contributes to almost 40% of the agricultural sector globally. About one billion lives are reliant on the livestock sector for the provision of income and food security. The livestock sector is one of the most valuable assets in the world since many rely on it as security for credit when times are difficult and otherwise it may serve as a store of wealth. Figure 2.1. shows the slaughter process flow diagram (Divac, 2004). According to the Department of Agriculture, Fisheries and Forestry (2012), livestock contributes for 15 and 25 percent of the global food energy and dietary protein respectively.

BOVINE SLAUGHTER:
PROCESS FLOW DIAGRAM

(FOR SMALL & MEDIUM SIZE ABATTOIRS)

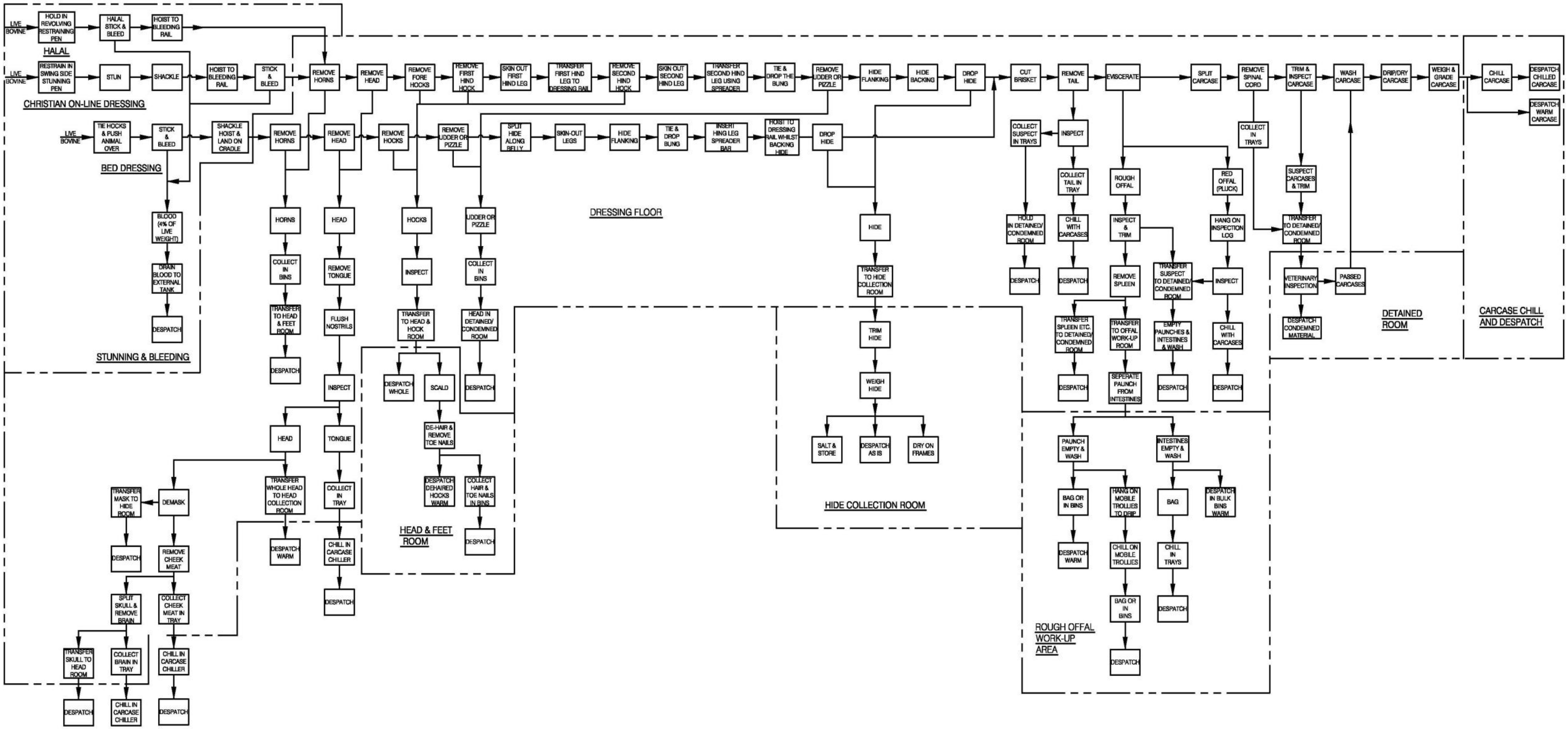

Figure 2.1. Beef market value chain

2.4. Red meat industry of SA

South Africa's ground surface is 122.5 million hectares. 84% thereof is available for farming, whereof only 11% of this can be used for the cultivation of crops. Thus, the major part can only be used for livestock farming including cattle, goats, sheep or game (The Butcher Website, 2013). The red meat industry in South Africa is one of the main producers of red meat in Africa. South Africa contributes to 21.4% and 1% of meat production in Africa and globally respectively. Red meat provides for more than a third of the protein needs for the African population.

The Red Meat Research and Development (2012) stated that during the period from 1998 to 2010, livestock contributed to nearly 50% of the total gross value of agricultural production. The red meat industry's contribution increased from 11% in 1998 to 15 % in 2010. Beef forms the largest part of the red meat industry, followed by sheep, goat and pork.

Stock farming is the only viable agricultural activity that can be practised over a large part of the country due to the South African climate. About 80% of the country's agricultural land is predominantly suitable for extensive grazing (Department of Agriculture, Fisheries and Forestry, 2012).

Between 1994 and 2004 cattle production increased from 12.6 million to 17.6 million heads. Grazing area decreased rapidly, since the expansion of human settlements, mining, crop farming and nature conservation projects started. According to sources (Department of Agriculture, Fisheries and Forestry, 2012), commercial farmers own almost 60% of the 14.1 million cattle currently in South whilst the rest is owned by emerging, small and communal farmers.

Beef is produced throughout South Africa. The number of cattle in an area is not the determining factor of the amount of beef produced in that area, but is more dependent on the number of feedlots and abattoirs in the specific area. Due to the well-developed transport system in South Africa, beef can be easily distributed all over the country and to neighbouring countries. In 2010 Mpumalanga produced the highest volume of beef in South Africa (22%), whereby the Free State produced 19% followed by Gauteng with 13%. The distribution of beef production throughout South Africa, per province is shown in Figure 2.2 (Department of Agriculture, Fisheries and forestry, 2011).

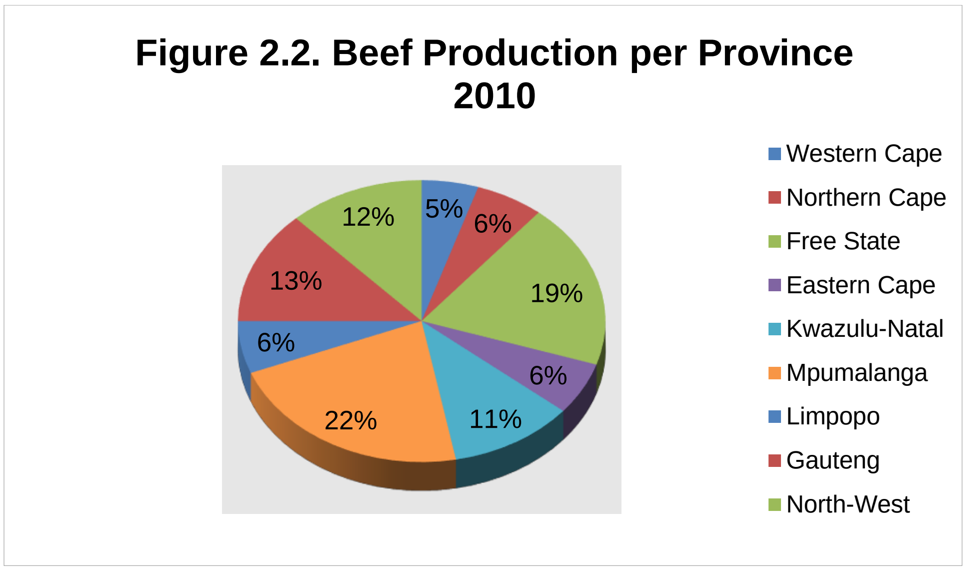

Figure 2.2. Beef production per province

Figure 2.3. shows the distribution of sheep in South Africa (Department of Agriculture, Fisheries and forestry, 2011). As seen in the figure, 75% of sheep are produced in the dryer areas of South Africa (Free State, the Northern Cape and the Eastern Cape). These provinces produce 20%, 25% and 30% respectively.

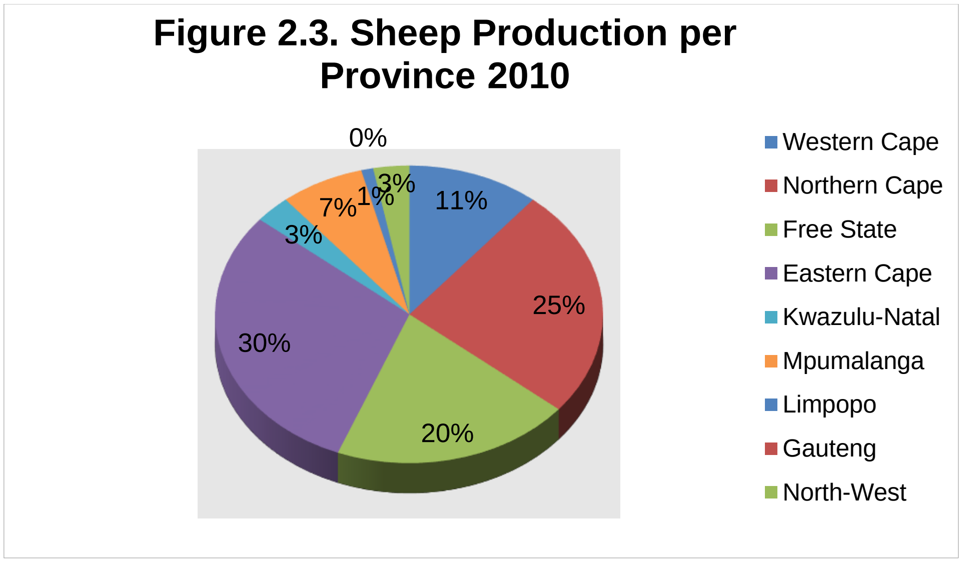

Figure 2.3. Sheep production per province

Table 2.1. shows the number of cattle, number of cattle slaughtered and the average price beef obtained during the time period from 1970 to 2012. There are about 495 abattoirs in South Africa. Most abattoirs slaughter animals from feedlots.

Year	Cattle numbers	Slaughterings[1]		Ave price[2]
July to June	(31 August)	Cattle	Calves	
	Million	1 000		c/kg
1970/71	7,9	2 022	239	44,9
1971/72	7,8	2 137	241	44,4
1972/73	8,0	2 274	226	58,6
1973/74	8,2	2 076	169	80,7
1974/75	8,5	1 814	147	89,3
1975/76	8,8	1 979	167	87,2
1976/77	9,1	2 217	183	93,6
1977/78	9,3	2 424	199	93,5

1978/79	9,1	2 738	212	96,9
1979/80	8,7	3 195	200	119,0
1980/81	12,9	2 434	158	202,4
1981/82	12,9	2 558	131	212,2
1982/83	13,1	2 788	144	211,4
1983/84	12,7	2 853	138	222,9
1984/85	11,9	2 806	146	228,4
1985/86	12,0	2 682	144	257,3
1986/87	12,2	2 657	126	353,4
1987/88	12,4	2 266	99	451,6
1988/89	12,8	2 237	88	482,6
1989/90	13,3	2 573	93	473,6
1990/91	13,5	2 844	106	474,9
1991/92	13,5	2 970	109	522,0
1992/93	13,1	2 960	111	521,4
1993/94	12,5	2 629	95	599,6
1994/95	12,6	2 112	70	823,4
1995/96	13,0	2 171	71	752,7
1996/97	13,4	2 118	67	820,9
1997/98	13,7	2 095	64	820,6
1998/99	13,8	2 197	61	786,8
1999/00	13,6	2 666	60	837,9
2000/01	13,5	2 247	55	837,7
2001/02	13,5	2 452	58	1 000,0
2002/03	13,6	2 478	57	1 277,5
2003/04	13,5	2 544	57	1 325,5
2004/05	13,5	2 616	57	1 436,3

2005/06	13,5	2 915	57	1 647,2
2006/07	13,9	3 020	57	2 097,5
2007/08	13,9	2 644	57	2 087,6
2008/09	13,8	2 783	58	2 215,1
2009/10	13,7	2 839	58	2 216,7
2010/11	13,7	2 822	58	2 431,6

[1] Commercial market and own consumption slaughtering

[2] Purchase price of chilled carcasses, including the fifth quarter

Table 2.1. Cattle numbers, numbers slaughtered and average prices of beef from 1970 to 2012.

As seen in Table 2.1., the number of slaughtered cattle has increased significantly (26% to 59%) over the 10 year period from 2000/01 to 2009/10. The same trend could be noticed in the slaughtering of sheep as well. There was an increase of sheep slaughtered in 2005/06 to 2006/07. The number of sheep slaughtered declined again the next year, but increased again up to 2009/10. This positive trend might be due to the higher demand in meat. The downward trend in demand for sheep during 2007/08 might be due to the global recession. This data can be seen in Table 2.2.

Year July to June	Slaughtering at abattoirs1			Average price[2]	Total Production RSA origin	Meat imports	Consumption	
	Auction markets	Non-auction markets	Total[1]				Total	Per capita
	1000			c/kg	1000t			kg
1975/76	4 579	1 712	6 291	118,2	162,0	6,6	166	6,3
1976/77	4 359	1 679	6 038	129,3	156,8	6,0	160	5,9
1977/78	4 664	1 757	6 421	119,2	166,5	5,6	169	6,1

1978/79	5 174	1 926	7 100	120,9	174,2	5,1	177	6,2	
1979/80	5 119	2 004	7 123	144,3	182,6	4,4	184	6,3	
1980/81	5 084	1 766	6 850	195,0	172,3	9,3	179	6,0	
1981/82	5 565	1 787	7 352	213,7	183,3	13,4	195	6,3	
1982/83	6 221	2 059	8 280	206,9	212,1	7,5	217	6,9	
1983/84	5 958	2 287	8 245	233,4	211,5	6,4	216	6,7	
1984/85	6 220	2 434	8 654	256,3	219,9	8,7	225	6,8	
1985/86	5 457	1 997	7 454	308,7	193,3	13,2	204	6,0	
1986/87	5 079	1 649	6 728	384,0	180,8	12,5	191	5,5	
1987/88	5 100	1 936	7 036	474,2	166,7	16,6	181	5,1	
1988/89	4 743	1 882	6 625	531,1	164,3	14,1	177	4,9	
1989/90	5 399	2 244	7 643	503,6	168,2	17,7	184	5,0	
1990/91	6 188	2 910	9 098	478,6	191,2	17,3	206	5,5	
1991/92	5 444	3 061	8 505	564,5	176,1	25,1	199	5,2	
1992/93	4 334	3 453	7 787	621,6	167,4	23,6	189	4,9	
1993/94	#	#	7 694	771,1	135,3	22,7	156	4,0	
1994/95	#	#	5 203	877,1	94,8	24,9	118	3,0	
1995/96	#	#	5 904	826,1	106,3	38,1	143	3,5	
1996/97	#	#	5 655	1 057,3	102,6	41,1	142	3,4	
1997/982	#	#	5 536	1 064,5	96,9	49,2	145	3,4	
1998/99	#	#	5 905	1 012,6	104,9	51,1	154	3,6	
1999/00	#	#	6 115	1 300,2	108,3	56,8	163	3,7	
2000/01	#	#	5 964	1 462,4	105,4	55,1	159	3,6	
2001/02	#	#	5 964	1 522,3	105,1	42,2	146	3,3	
2002/03	#	#	6 012	1 818,1	114,4	33,2	146	3,2	
2003/04	#	#	6 117	2 012,6	120,3	34,8	154	3,3	
2004/05	#	#	6 192	2 100,5	115,5	35,2	149	3,2	

2005/06	#	#	6 279	2 336,7	117,2	43,0	158	3,4
2006/07	#	#	6 693	2 941,9	141,1	44,1	183	3,9
2007/08	#	#	6 700	2 917,3	141,4	30,2	170	3,5
2008/09	#	#	6 865	3 105,6	146,5	19,9	164	3,4
2009/10	#	#	7 018	3 227,9	149,2	12,3	160	3,2
2010/11	#	#	6 316	4 048,3	134,7	7,8	141	2,8
2011/12	#	#	6 242	#	140,2	10,1	149	2,9

[1] Commercial market and own consumption slaughtering

[2] Purchase price of chilled carcasses, including the fifth quarter

TABLE 2.2. Sheep, lambs and goats: numbers slaughtered at abattoirs, average prices of mutton, production and consumption

Although the current economic condition of the South African market is in a slow growth phase, growth in demand for meat outperformed most of the other food groups. According to Sagcot, (2013) the consumption of meat increased by more than 70% over the past 50 years in developing countries. This trend is shown in figure 2.4. and is expected to remain in the future (SAGCOT, 2013).

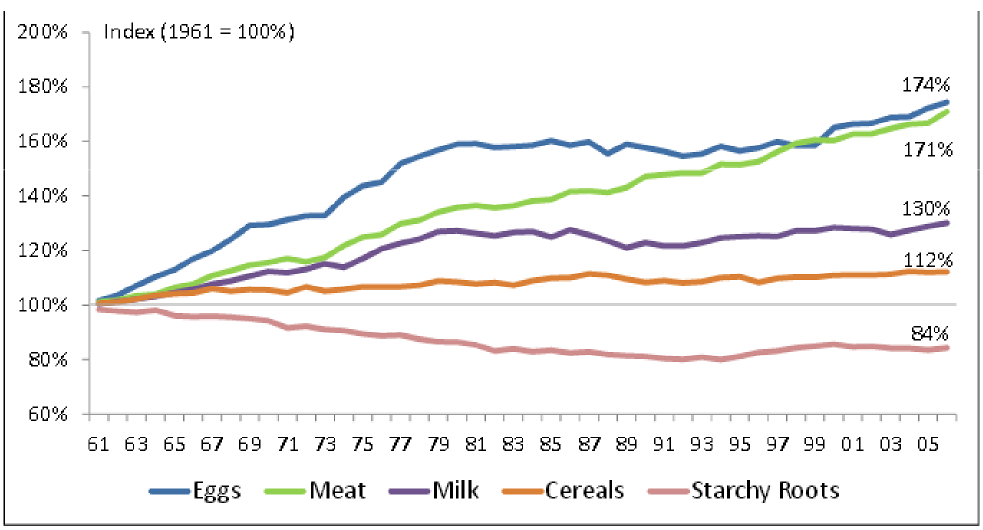

Figure 2.4. Per Capita consumption of major food items in developing countries, 1961-2006.

Abattoirs in South Africa are graded by the amount of units that can be processed in a specific time frame. According to the Department of Agriculture and Rural Development (2009), abattoirs use a quantifiable standard to determine the throughput of abattoirs in terms of slaughter units. These unit standards are identified as in table 2.3.

Category	One slaughter unit equals
Red Meat	1 Cow, ox or bull (including heifers) 2 Calves (younger than 6 months) 1 Horse 6 sheep or goats 4 small pigs 2 bacon pigs 1 sausage pig
Poultry	1 fowl, duck, pheasant or guinea fowl 4 pigeons 2 partridges 12 quails 3 baby fowl (petit pousons) Whereas 1 goose equals 2 units, and 1 turkey equals 4 units
Game	1 Category A (large) game with special protocol only 1 Category B (medium) game 6 Category C (small) game
Ostriches	2 ostriches
Crocodiles	1 crocodile
Rabbits	1 rabbit

Table 2.3. Quantifiable unit standards for slaughter units

An abattoir is graded according to the throughput and structural requirements thereof. Meat South Africa accordingly rates the abattoirs in the following categories:

- Rural abattoirs – 0-2 Slaughter units per day;
- Low throughput abattoirs – 3- 20 Slaughter units per day;
- High throughput abattoirs - >20 Slaughter units per day.

Previously, the Department of Agriculture and Rural Development (SA) (2009) has set much more categories (A-E) for the throughput number of slaughter units. They were graded in the following categories:

- Grade A – more than 100 slaughter units;
- Grade B - 51–100 slaughter units;
- Grade C - 16–50 slaughter units;
- Grade D - 9–15 slaughter units;
- Grade E - 1–8 slaughter units.

2.5. Abattoir Waste

The main purpose of an abattoir is to recover the edible part of animals brought to slaughter. (RMAA, 2010) This is mainly for human consumption. During this process, substantial quantities of waste materials are generated. This may include organic as well as inorganic solid products.

Solid waste comprises mainly of the following:

- bones;
- foetuses.

Liquids comprise of:

- blood;
- urine;
- water;
- dissolved solids;
- gut contents.

Patra et al., 2007 remarked that abattoirs may add to the pollution of underground as well as surface water. This indirectly affects the health of people that live in close proximity of abattoirs.

The Department of water Affairs (South Africa, 1998) classified waste produced at abattoirs as putrescible organic waste and thus to be unsafe for consumption by either humans or animals. This is according to the Minimum Requirements for Waste Disposal by Landfilling. A study by Bello and Oyedemi (2009) revealed that the health and quality of life of people in the vicinity where abattoir activities take place are negatively impacted. This might be due to some food-borne diseases that might be associated with meat and its by-products. (Bradshaw et al. 1992)

According to Jayathilakan et al. (2012) livestock by-products, of sheep, cattle and pigs expresses 68%, 66% and 52% respectively as a percentage of the live weight. By products in this study from America included bones, blood, organs, intestines, skin and feet. The different by-products as presented by the United States Department of Agriculture (2001) are showed in table 2.4.

Item	Sheep		Pigs		Cattle	
	%	kg	%	kg	%	kg
Market live weight	60		100		600	
Whole carcass	62.5	37.5	77.5	77.5	63.0	378.0
Blood	2.4		3.0	3.0	18.0	4.0
Fatty tissue	3.0	1.8	3.0	3.0	4.0	24.0
Hide or skin	15.0	9.0	6.0	6.0	6.0	36.0
Organs	10.0	6.0	7.0	7.0	16.0	96.0
Head			5.9	5.9		
Viscera(chest and abdomen)	11.0	6.6	10.0	10.0	16.0	96.0
Feet	2.0	1.2	2.0	2.0	2.0	12.0
Tail			0.1	0.1	0.1	6.0
Brain	2.6	0.156	0.1	0.1	0.1	6.0

Table 2.4. Animal waste products showed as percentage or mass of the average market weight for pigs, cattle and sheep.

Abattoirs contribute significantly to the pollution of water. According to the Red Meat Abattoir Association (RMAA) (2011), South Africa is a water-scarce country and that projections show that by the year 2020 the demand for water will equal the supply thereof. In addition to this are the fact that water quality is rapidly deteriorating due to pollution. Abattoirs consume large volumes of water daily, of which 84% is discharged as waste water, and with more than 450 abattoirs in South Africa, this amounts to millions of litres per day. Gauri (2006) confirmed that abattoirs also use large quantities of water for cleaning and other hygienic purposes resulting in more waste water, containing liquid waste and suspended solids.

According to Chukwu et al. (2011) some of the main characteristics of waste produced at an abattoir are:

- the organic strength;
- relatively high temperature (20 to 30°C);
- organic biological nutrients;
- alkalinity.

The above characteristics make abattoir wastewaters ideal for anaerobic treatment. Due to the high nitrate concentration of abattoir wastewater makes it suitable biological treatment as well.

Generating electricity also consumes vast amounts of water. Alternative methods are necessary to re-utilise or treat water by extracting energy from the waste.

The Department of Agriculture and Rural Development (2009) identified the following purposes for the different main groups of by-products, considering their agro-industrial significance:

Group	By-product	Use
Soft organs	stomachs, intestines, lungs, carcass trimmings, reproductive structures, floor sweepings, drainage trappings, condemned meat	meat/bone meal; feeding to crocodiles
Hard organs	horn and hoof	horn/hoof meal fertiliser, pet-chew toys, gelatine
Blood	Blood	blood meal, used in animal feed
Gut contents and manure	Gut contents and manure	compost or fertiliser; biogas production.
Feathers / pig hair	Feathers / pig hair	protein meals

Table 2.5. Different groups of abattoir waste with its by-products and their industrial uses.

2.6. Waste management

Roberts and De Jager (2008) developed a waste management model. Figure 2.5. shows their proposed model for red meat abattoirs.

The model is implemented in four parts or processes. The four processes are the following:

- Blood – by hygienically slaughtering livestock with a hollow knife would reduce contamination drastically and blood can thus be used for human consumption in the making of blood sausages and other products (Food Safety Authority of Ireland, 2013). It can also be used for pig feeding and as fertilizer for grapes.

- Stomach Contents – According to Roberts and De Jager (2008) the general method of getting rid of stomach contents of abattoirs in the Free State, is to bury it. Other methods include disposal at landfill sites or spreading onto fields. Roberts and De Jager (2008) proposed to convert stomach contents into compost.

- Waste water – Untreated waste water is usually disposed into municipal drainage systems or used as irrigation. The treatment of waste water would be advantageous in the sense that it can be reintroduced to system to be used for cleaning purposes or for the recycled water to be used on slaughter floors.

- Condemned products – After sterilising bone meal and carcass meal can be manufactured, hooves can be sold for pet consumption etc.

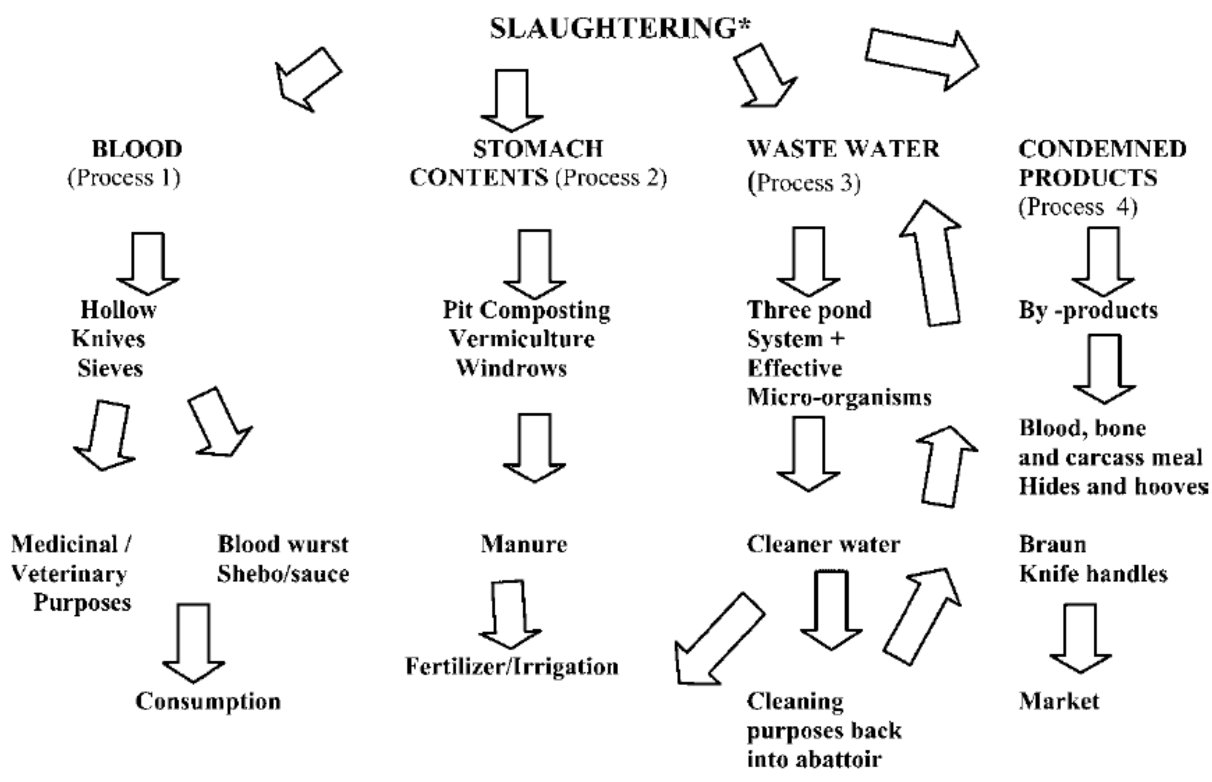

Figure 2.5. The proposed waste management model for red meat abattoirs

In South Africa, the most common method of waste disposal of condemned products is burying. The second most common method is burning of waste products, while some abattoirs do a combination of both methods (Roberts and De Jager, 2008).

According to Bridle (2011) major research, to improve waste management practices by the reduction of disposal costs as well as the minimising of fuel consumption at abattoirs, is underway. This research includes the investigation of the potential for abattoirs to utilize waste products and produce renewable energy.

2.7. Laws & regulations

The abattoir industry in South Africa has experienced several policy changes with regards to regulatory practices applied. This caused several challenges for the abattoir business in South Africa. It is important, but seldom achievable, for abattoirs to experience stability and predictability (The Butcher Web, 2013).

A number of laws and legislation exist to regulate the abattoir industry. Laws with regards to the compliance of waste management are administered by several governmental departments.

According to the RMAA (2011), abattoir waste is mainly regulated by either the Environment Conservation Act (ECA) or by the National Water Act (NWA). The ECA of 1998 included the regulations on the protection of the environment as a whole, including water, humans, fauna and flora, air and soil, while the NWA includes the predominant protection of water.

The main acts are summarized here:

2.7.1. The Environmental Conservation Act 73 of 1989 (ECA)

The main purpose of the Environmental Conservation Act is to make provision for the environment's protection and regulated use thereof. This act serves as the main legislation concerning waste disposal whereby dealing with permits for waste facilities and the disposal of waste. Generators of waste are therefore required to transport waste to the facilities with a permit.

2.7.2. National Environmental Management Act 107 of 1998 (NEMA)

NEMA deals with environmental management in South Africa. This act covers the following:

- the prevention of pollution;
- principles regarding with environmental management;
- incident management;
- environment authorizations.

2.7.3. National Water Act 36 of 1998 (NWA)

The National Water Act includes legislation with regards to the protection of South Africa's water resources as well as the prevention of pollution. The NWA dictates that in the event of a possible pollution, the individual must take all possible steps and apply all possible measures to prevent such pollution from occurring, continuing or recurring. This includes the discharge of waste containing water into another water resource such as a river or the sea.

2.7.4. The Meat Safety Act 40 of 2000 (MSA)

The Meat Safety Act promotes the safety of the use of meat and animal products. It also serves as a guideline to maintain national standards with regards to abattoirs. These include the handling, storage and disposal of condemned material. It also includes requirements for the management of hygiene especially waste.

In terms of the act, the following practises are approved ways for the disposal of condemned meat products:

- incineration;
- burial at a secure site, permitted by local government,
- processing at a registered sterilizing plant.

According to the RMAA (2011) any waste generating instance should follow the waste hierarchy whereby the following practices should be applied:

- avoid the production of waste;
- disposal of waste to should be the last resort;
- reduce, recycle or reuse waste;
- treat waste.

2.8. Economic overview

Vecchiatto (2013) reported that ESKOM, South Africa's electricity provider, was given permission to increase tariffs with 8% per annum for five years up to 2018 by the National Electricity Regulator of South Africa. This was only 50% of the tariff ESKOM initially asked for. Over the past six years South Africa's electricity prices shot up with over 170%.

2.9. Renewable energy technologies

Global warming and the rising price of energy, especially electricity, results in sensitive discussions. Therefore the constant search for other alternative ways to convert waste to energy is very relevant at the current stage of time. According to Omoh and Neayor (2010) alternative resources for renewable energy are needed desperately to provide in rising energy demands.

Table 2.6. shows some of the most popular waste to energy methods used at municipalities and abattoirs with their advantages and disadvantages.

Waste Treatment Method	Advantages	Disadvantages
Air Curtain Burners	reduce waste to residual ash reduced emissions	energy sources (fertilizers) not recovered or utilized greenhouse gasses or toxins released
Alkaline Hydrolysis	Beneficial by-products are produced. cleaner emissions than incineration sterilisation and digestion destruction of pathogens suited to small scale application	expensive technology, with a high knowledge requirement generates a fairly high level of effluent
Gasification	volume of waste is reduced by 90% Other waste streams may also be processed benefit of energy generation	Capital costs are high negative energy value due to high moisture content
Biogas	Collecting biogas reduces the emissions Sludge, a by-product of the digestion process, is a better fertilizer than manure or synthetic fertilisers, and is cheaper than manufactured products	require a lot of water to function Methane can explode if care is not taken Often not economic

Pyrolysis	Create syngas Syngas used to combust engines Used with organic waste Any organic material can be used as fuel no pollutants are generated	Capital costs are high

Table 2.6. The most common waste to energy methods used at municipalities and abattoirs with their advantages and disadvantages.

As seen in table 2.7, a comparative study was done on different waste to energy technologies. There is a lot of variance within different technologies. For the purpose of this study similar sizes with regards to price and output were compared.

Technology	Land Req (HA)	Capital Cost (US$ 00000)	Cost of power generation (US$/kW h)	Waste Type	Energy production (kW h / 100t MSW)	Power generation capacity (MW)	Operating cost (US$/t of MSW)
Bio-methanization	0.8 [a]	29.85-33.17 [b]	0.08 [d]	Source separated waste only	-	30-40 [c]	<9.12 [c]
Incineration	0.8 [a]	21.56-23.22 [b]	0.05 [c]	All Waste since air cleaning technology is good	450-544 [ae]	20-30 [c]	>90.53 [c]
Biogas	0.1	2 [f]- 5 [g]	0.07 [f]	Organic matter, sewerage.	540[h]-950[i]		
Pyrolysis / gasification	0.8 [a]	72.97-82.92 [b]	-	Source separated dry waste only unless combined with better cleaning technology	500-571 [ae]	30-45 [c]	>49.74 [c]
Plasma arc gasification	2 [a]	99.5-116.09 [b]	0.07 [c]	All waste is acceptable	816 [a]	80-90 [c]	12435.75 [c]

Table 2.7. A comparison between different waste to energy technologies with pricing and energy conversion.

Alternative waste treatment methods include the following:

2.9.1. Mass burn incineration

The combustion of waste generates heat which in turn can generate electricity. This process is a source of air pollution, but modern plants meaningfully reduced emissions. Vapours may be harmful, but this method of waste treatment is very effective. Proper operation and regular maintenance is therefore very important to control the quality of the air (Jewaskiewitz, 2008).

2.9.2. Air curtain burners

Air Curtain Burners is a type of incineration using very high temperatures to efficiently reduce waste to residual ash safely and with reduced emissions. Air curtain burners have a refractory-lined fire box which is essential to enable the system to burn wastes at very high temperatures.

2.9.3. Alkaline hydrolysis

From The Ground Up Resource Consultants Inc. 2009 termed alkaline hydrolysis as the following: "Alkaline Hydrolysis uses sodium hydroxide or potassium hydroxide to catalyse the hydrolysis of biological material (protein, nucleic acids, carbohydrates, lipids, etc.) into a sterile aqueous solution consisting of small peptides, amino acids, sugars and soaps. Heat is applied to accelerate the process (150ºC). The only solid by-products are the mineral constituents of the bones and teeth of vertebrates. Even these can easily be crashed into a powder and used as soil additive."

2.9.4. Gasification

Gasification is the process when destruction of biomass or organic matter by burning at temperatures of higher than 850°C for at least 15 minutes resulting in the production of ash and a combustible gas mixture. The organic matter is heated in insufficient supply of air (Goyal et al., 2008). The synthetic gas produced is used as fuel or in chemical processes

Dickenson (2006) concluded and recommended that gasification to be considered seriously for waste disposal. He stated that the process runs efficiently when optimal levels of operating temperatures are reached and thus emits greenhouse gasses well within the acceptable standard range for municipal wastes. Some functional failures and shortfalls were experienced in testing this technology.

2.9.5. Biogas

The anaerobic breakdown of organic material by bacteria in devices called digesters produce biogas. Gases formed are a mixture of methane, carbon dioxide, hydrogen, oxygen, nitrogen and hydrogen sulphide in quantities of 60%, 36% and 4% for the rest respectively. The yield and constitution of the different gasses may differ by modification.

2.9.6. Pyrolysis

The pyrolysis process is the process of converting of carbonaceous materials e.g. biomass or petroleum into a synthetic gas or liquid fuel, thus a thermo-chemical conversion process. In the absence of oxygen, biomass is thermally broken down. The temperatures in heating the biomass ranges from 350 ^{o}C to 550 ^{o}C and can go up to 700 degrees centigrade.

The composition of the formation of the different products is a result of the different proportions of fuel (Goyal et al. 2008).

Almost any organic matter can be used as fuel in the pyrolysis system. This may include the following (individually or mixed):

- timber and crops (either specifically grown for the process, or waste from existing industries);
- abattoir and food processing waste;
- sewage sludge (animal slurries and urban wastes);
- municipal solid waste (msw), and miscellaneous, pre-sorted industrial waste;
- bio-fuels;
- plastics;
- forestry waste;
- peat;
- lignite (coal and peat);
- clinical waste;
- bio mass;
- commercial and industrial waste;
- lubricants.

The output products as a result of this process are the production of the following:

- useful liquid oil;
- gas mixture i.e. synthetic gas and
- solid products.

Each of the above has the potential to be used as fuels, either directly or after the upgrading of the output products, in different types of transport, power generation and combined heat and power generating. Liquid oil can be used in internal combustion engines to generate electricity. The solid products or char produced is utilized for heating, soil fertiliser and co-firing in a coal plant. Pyrolysis gas can be useful in boilers which is gas-fired, turbines and spark ignition or dual-fuel engines.

A study conducted by Barth & Kleinert (2008) showed that opportunities exist for fuels produced from biomass pyrolysis to be used sustainably for internal combustion engines.

In a pilot test conducted by Bridle for Meat & Livestock Australia (2011) it was concluded that the processing of abattoir solid wastes can be technically viable with pyrolysis, gasification and combustion. In the trials conducted, it was found that the processing materials can be successfully dried, char suitable for agricultural use can be produced and greenhouse gasses can be reduced.

2.10. Conclusion

The industrial sector has an important role to play with regard to their responsibility to control pollution and waste. The industrial and agricultural sectors consume about 21% and 65% of available water resources consecutively, with only 14% used for domestic use. (Nixon et al. 2013) It is thus eminent that all sectors should be more accountable and aware that the disposal of waste is a matter of responsibility.

Although regulations with regards to pollution were not strict in the past, the recent introduction of environmental legislation resulted in positive efforts to reduce, limit or eliminate pollution and the discharge of waste products into natural resources.

Jewaskiewitz (2008) mentioned that the development time for a new technology is lengthy and that it takes long to pilot test it and implement it. It is therefore important to implement technology according to the following criteria:

- Technology must be established and proven – Other similar plants in operation, treating similar wastes, should serve as reference.
- Environmental performance – Technology should run clean and be very effective in terms of greenhouse gas emission reductions.
- Complexity - Low maintenance cost, easy operation and low staff numbers.
- Waste handling – The intended waste should be effectively converted to energy.
- Value recovery – The technology should generate energy and thus recover value effectively.

Many processes have been used for the treatment of waste over the past decades. Processes like aerobic composting, anaerobic digestion, bioreactor, conventional landfills, mass burn incineration, and gasification, autoclaving and plasma arc are some of the more common processes used to treat waste. There are no pyrolysis machines installed at abattoirs in South Africa yet, although some abattoirs are looking into the possibility to install pyrolysis systems. According to Bridle (2011) there are numerous successful waste pyrolysis plants operating on a commercial level in mainly Japan and Europe. The pyrolysis business in Australia is emerging with eight companies already established. Although waste streams of paunch and DAF sludge are used for pilot studies are being done at Australian abattoirs. The initial assessments of pyrolysis technologies for using dried paunch and DAF sludge to generate electricity proved to be economically viable.

CHAPTER 3
RESEARCH METHODOLOGY

3.1. Introduction

Chapter two provides a broad overview on research done on waste management applied at abattoirs around the world. Some of the most common technologies used for converting waste, especially municipal waste, to energy were identified and studied with regards to their input, output, effectiveness and relating costs.

This section is done to determine what waste management systems and waste-to-energy systems are used at South African abattoirs and thus make recommendations in this regard.

3.2. Research Design

A list of Free State abattoirs was obtained from the website from Chief Directorate Animal Production and Health Department of Agriculture, Forestry and Fisheries (2014).

For the first part of the study a qualitative research method will be used. The reason for this is that more focus was placed on observation, description and analysis than on quantitative aspects. The research questions raised are consistent with those of a descriptive exploratory research and done by means of short telephonic interviews and questionnaires. As seen in appendix 1, the questionnaires contained both open ended and close ended questions. The purpose of the questionnaire was to determine and acquire valuable information with regards to waste management of the abattoirs.

A comparative study will be done according to literature to determine which technology would be the most appropriate alternative option for turning abattoir waste into energy. Capital cost, running cost, conversion efficiency, input products (fuel) and output products (by products e.g. electricity, oil, gas etc.) are taken in consideration.

During this research, horse abattoirs were excluded, since the slaughter of horses are governed by processes very different to that of slaughter processes of common food animals such as sheep, cattle and pigs.

3.3. Sampling

Yount (2006) recommended seven steps to follow when doing sampling. The seven steps with their applications in this study are the following:

a. Define the population of interest – The population of interest is determined to be red meat abattoirs in the Free State;

b. Decide on a data collection method – Data will be collected via the distribution of questionnaires to managers of red meat abattoirs;

c. Decide on the sampling frame - The 79 Free State abattoirs were divided into their respective grades. Rural abattoirs were excluded from the study since the number of animals slaughtered per day is too low to consider for the purposes of this study. For this reason only low and high throughput abattoirs' information were used;

d. Decide on a sampling method - Non-probability sampling will be applied for this study. The type of non-probability sampling that will be used in this study is by means of purposive sampling. With purposive sampling, participants will be chosen on grounds of their knowledge and theoretical perceptions in the field of abattoirs, thus collecting data regarding waste management, treatment and power generating;

e. Decide on the sample size – Questionnaires were sent to all the abattoirs in the population of interest. All the abattoirs in each category that returned the questionnaires were considered for the study. The sample size for this study included 79 abattoirs, as indicated showed in Table 3.1.

Abattoir Grade	Number of abattoirs	Representation
High throughput	20	8
Low and Rural throughput	59	7
Totals	79	15

Table 3.1. Red meat abattoirs in the Free State sorted according to their throughput

f. Determine and specify an operational plan for selecting sample elements

g. Implementation of the sampling plan.

Feedback was obtained from 15 abattoirs, whereby eight of them were high throughput (HT) and seven of them low throughput (LT) abattoirs. These represent 40% of the high TP, 11% of the low TP and 19% of the total population of Free State abattoirs.

3.4. Location of study

The Free State is situated in the heart of South Africa. It is a very good agricultural area since the soil is rich and the climate suitable therefor. Almost the whole of the province lies above 1000 m above sea-level. Agriculture activities dominate the province, with 87 000km^2 of grazing veld and 32000km^2 of cultivated land. The grassy plains provide ideal conditions to farm with cattle and sheep. (The Free State Government, 2014)

Figure 3.1. Map of the Free State

3.5. Demarcation

A study will be done on alternative means of waste management, converting abattoir waste into energy and the cost required to do this. Abattoirs in the Free State and other progressive abattoirs, already implementing some means of energy generating will be used in his study. Mostly red meat abattoirs will be used.

3.6. Data Collection

The abattoirs were contacted by the researcher telephonically to introduce and explain the study to the managers of the respective abattoirs. The questionnaires were then distributed via e-mail to the managers of the abattoirs willing to partake in the study. Abattoir managers were thought to be most suited to complete the questionnaires since the questionnaire focused on operations of the abattoir as a whole. The questionnaires included the following main parts:

- General Questions – General questions with regards to the background of abattoir, management and facilities;

- Finances – Financial questions relating to energy usage, waste disposal etc.;

- Animals – Questions with regards to number and types of animals slaughtered to determine waste production;

- Waste – Questions concerning quantities and handling of abattoir waste

3.7. Data analysis

Once the questionnaires were done and received back, the findings from the questionnaires were tabulated. The two categories' results were thus recorded separately in a table enabling the researcher to get a broad overview of the results. This was done to explain and analyse the results. Conclusions were drawn from these results and recommendations were made in this regard.

3.8. Ethical Considerations

Due to the fact that competition between abattoirs is very high, the study can be very sensitive; therefore the ethical considerations linked to the study are vital.

The following ethical aspects will be taken into account during the duration of the study:

- Neutrality / Objectivity:

  The author aims to avoid bias in every aspect of the study. This includes the capturing, analysis and reproduction of the data.

- Voluntary participation:

  Each interviewee will be interviewed, solely on a voluntary basis. Participants will not be misled or forced to participate.

- Informed consent:

  The purpose, benefits, process and rights of the study will be explained fully to the participants. Each participant will receive an explanatory letter to explain the procedure. See appendicle 2 for the letter to the participant.

- Confidentiality and respect:

  Due to the nature of the project, the rights of the participants would be protected by keeping their names and positions anonymous, except if they give written consent to the author to publish their names.

3.9. Conclusion

This research focused on red meat abattoirs only. At the time of conducting this study the Free State had 79 registered abattoirs. These abattoirs were segmented in terms of their throughput. Abattoirs are graded according to the throughput of animals as set by the Meat Safety Act, Act No. 40 of 2000 (South Africa, 2000). They are graded in the following:

- Rural abattoirs – 0-2 Slaughter units per day
- Low throughput abattoirs – 3- 20 Slaughter units per day
- High throughput abattoirs - >20 Slaughter units per day

Units are determined by slaughter units. A description of slaughter units are showed in table 2.3.

The results of the questionnaires and a detailed analysis thereof will follow in the next chapter.

CHAPTER 4
RESULTS AND FINDINGS

4.1. Introduction

This chapter contains the results and findings of the telephonic interviews and questionnaires received from the participants.

4.2. Results

The list of Free State abattoirs, obtained from the website from Chief Directorate Animal Production and Health Department of Agriculture, Forestry and Fisheries was surely outdated since 15 of the 79 abattoirs on the list was confirmed to have closed down and 24 of them could not be reached. The abattoirs could not be reached because the numbers did not exist anymore. In some instances calls to these numbers were not answered at all. Table 4.1 shows a summary of the responses of each abattoir contacted.

The sample size for the number of high throughput abattoirs was thus 19 whereof 17 of them were reached telephonically. The purpose of the study was explained to these abattoirs and they were asked to participate in the study. All of the 17 high throughput abattoirs agreed to partake in the study, but only eight eventually completed the questionnaire. This added up to 42% of the total population of high throughput abattoirs. This was a reasonable response. Although abattoir managers and owners of the high throughput abattoirs are very busy, the general response was very good since all of them could recognize the importance of alternative handling of abattoir waste, saving energy costs with the added benefit of contributing to the environment by decreasing carbon footprint.

Abattoir Grade	Number of abattoirs	Reached	Nr does not exist/ not reached	Horses only	Closed confirmed	Participants
High throughput	20	17	2		1	8
Low throughput	59	20	23	3	14	7
Totals	79	37	24	3	15	16

Table 4.1. Summary of the responses of each abattoir contacted.

With regards to the low and rural throughput abattoirs, 59 were listed, whereof 14 of them were confirmed to be closed upon telephonic enquiry. There were 22 of the low and rural throughput abattoirs that could not be reached. A further three of them were excluded from the study as they slaughtered horses only. A total of 20 low and rural throughput abattoirs were reached telephonically whereof only 7 of them contributed towards the study. The participants contributed towards 19% of the population of low and rural throughput abattoirs.

This low response rate in the low and rural throughput abattoirs group might be attributed to the fact that these abattoirs do not have troubling volumes of waste to dispose of. The overall response from them suggested that they are content with their current waste management methods. Some of the larger low-throughput abattoirs (10 to 20 slaughter units per day) expressed interest in alternative waste management methods. The feedback from the rural throughput abattoir was not considered as it would add no value to the study. Therefor data from only six low throughput abattoirs' was used for analysis in the study.

4.2.1. Capacity

The capacity in terms of slaughter units slaughtered per annum at the participating high-throughput (HT) abattoirs ranged from 12316 units to up to 90000, with an average of

40865 slaughter units per year. The total capacity of these high-throughput abattoirs were 326921 slaughter units. Four of the participated abattoirs slaughter sheep and cattle, while two of the participated high throughput abattoirs slaughter only sheep, one of them only pigs and the other only cattle.

The low-throughput abattoirs averaged between 520 and 5200 slaughter units per annum. Three of these abattoirs slaughter cattle and sheep, while the other three slaughter sheep cattle and pigs.

The number of employees employed at the participating HT abattoirs ranged from 20 to 150 depending on the number of units slaughtered at the abattoirs. On average there was one employee per two slaughter units per day. The LT (low-throughput) abattoirs employ between 4 and 25 people depending on the number of units slaughtered. These abattoirs, especially the smaller ones slaughtered manually. These abattoirs are located in rural areas on farms, and require more employees per slaughter unit.

On average, the HT abattoirs are operating 224 days of the year, while low throughput abattoirs are in production 247 days per year.

With regards to the size of the HT abattoir's liarages, all participants adhere to the size requirements as set by the Department of Agriculture, conservation, environment and land affairs. About 75% of the participants mentioned that they have more land that can be allocated for expansion if needed. This can be advantageous if the need arises to build and implement waste to energy conversion systems on the premises. The liarages of LT abattoirs are small, and also comply with standards.

Since hygiene management is very important at any abattoir all participants from both the high and low throughput abattoirs have a hygiene management system in place and comply with the hygiene management system as regulated by the Meat safety act, Act 40 of 2000 (South Africa, 2000). These methods include scooping of manure and solids with spades, washing surfaces with pressure cleaners, soap and water, and sweeping with brooms. Much of the manure can be utilized for other uses such as compost, or generation of energy.

4.2.2. Operations

4.2.2.1. Electricity

Electricity and water are the two of the most costly overhead expenses an abattoir can have. The cost of these two expenses is directly linked to the amount used per slaughter unit.

All the HT abattoirs use three-phase electricity, since the electricity requirements is much higher in the case of high throughput abattoirs because of heating, cooling and other activities taking place at an abattoir. According to the feedback received, a wide range of electricity usage per slaughter unit was reported. These values were 8.3kWh, 9.2kWh, 24.7kWh, 25kWh and 38 kWh respectively for electricity used per unit slaughtered. There is a big difference between the first two values (8.3 kWh and 9.2 kWh), the middle two values (24.7 kWh and 25 kWh) and the highest value (38 kWh). The reason might lie in the type of method used for slaughtering, the time and effectivity of the slaughterers, the overall energy consumption of the abattoir and some other factors.

Only two of the LT abattoirs could provide information with regards to electricity used per slaughter unit. These amounts are 49.5 kWh and 78.3 kWh respectively, which are interestingly, much higher than the HT abattoirs.

All of the participants agreed that the electricity provision is a big risk factor for them, since load shedding, power interruptions, theft of power cables and the ever increasing price per electric unit are all factors that could cause a halt in production. Back-up generators are costly to run. Participants expressed hope that cost effective and sustainable alternative methods of generating electricity could be applied to their abattoirs.

4.2.2.2. Water

The other essential resource used at abattoirs is water. Two of the HT participants use municipal water in conjunction to water from their own boreholes; four of them are dependent on the municipality to supply them of water and two of the participating abattoirs use boreholes only to provide in daily water need.

Two of the LT participants indicated that they use municipal water; while three of them pointed out that they utilize boreholes to provide water. On average, the participating HT abattoirs consume about 836l of water per slaughter unit. The water used per slaughter unit includes water used for flushing of blood, and washing and cleaning purposes. This means that the participating abattoir utilize almost 90 000l of water per day.

Three of the abattoirs do not treat their waste water at all, and it just runs into the municipal sewerage system. Four of the participants treat the water by filtering and removing the solids such as fat, manure and other solids, where after the rest of the waste water enters the municipal sewerage system. Three of the abattoirs are thus levied for introducing the waste water back to the municipal sewerage system. One of the abattoirs participated use the filtered water for irrigation of pastures, while the solids are composted.

The LT abattoirs reported a wide range of water usage per unit slaughtered. The reported amounts are 148l, 300l, 800l and 1000l respectively. Two of the participants stated that no action is taken with regards to treating wastewater and that it is disposed of via the municipal sewerage system. Two of them treat the water by means of catching solids such as blood, fat and manure with traps, one of the abattoirs let the water run to the veld while another participant dispose of waste water into a septic tank then into an evaporation pit. Only one abattoir is levied for wastewater by the municipality.

All of the participating abattoirs agree that the saving of water by either recycling or reusing thereof is important. There was consensus that water is very costly and water reserves especially from municipalities could not always be trusted, while bore holes may also be at risk during drought spells as is often the case in South Africa.

4.2.3. Waste management

4.2.3.1. Manure

Digestive and excretory wastes of slaughter animals are usually collectively referred to as manure. This is a mixture of manure and urine and is mostly collected via the sweeping of liarages. The total mass of manure produced per slaughter unit differed between abattoirs.

Animals for slaughter are accepted into liarages at the abattoir where they wait to be slaughtered. The time they are kept in the liarages before slaughter and type of animal to be slaughtered determines the amount of manure produced. The amount of manure produced reported by the participants ranged from 8.5kg up to 25kg per slaughter unit.

Six of the eight participants stated that they dispose of the manure. Two of the participants utilize manure for agricultural purposes. These participants compost the manure to use it as fertilizer. Of the six HT abattoirs that dispose manure, one of them bury the manure in a hole and cover it. The others take it to the municipal landfill site where the manure is dumped.

A wide range of manure mass was reported in the LT category. The number of kilograms per slaughter unit was estimated to be between 12 kg and 150 kg. All of the LT abattoirs disposed of their manure by means of burial in a manure pit or dumping at the landfill site.

None of the abattoirs utilize manure for the generation of energy. The abattoirs spend a lot of money to transport manure to landfill sites.

4.2.3.2. Blood

The participating LT abattoirs reported 12 to 15 litres of blood obtained per slaughter unit. This is consistent with studies conducted by Gregory et al (1988). Only two of the eight high throughput abattoirs reported processing of blood. One of the abattoirs processes blood by sterilizing it with steam. It is then dried and made into blood meal so that it can be handled and incorporated into rations for dog food. Composting of blood takes place at another abattoir. This product is thus used for fertilizing pastures. All of the other abattoirs' blood is disposed of. Two of them bury blood in trenches and cover it afterwards, one of them perform clotting via coagulation and together with all the other abattoirs blood is either flushed into the municipal sewerage system or dumped on allocated areas at the municipal landfill sites.

One of the abattoirs, releasing blood with wastewater into the municipal sewerage system, is very adamant in finding an alternative solution for the blood since their municipality threatened to close them down because of this reason. They are also levied for the amount of blood and wastewater released into the municipal sewerage system.

The LT abattoirs reported an average of 14 litres of blood per slaughter unit. These abattoirs disposed blood by means of washing it into a waste water dam or pit, washing it into the municipal sewerage system, or dumping it in municipal landfill areas.

One of the LT abattoirs sterilizes the blood with steam, and dries it into blood meal.

Since blood that is not treated correctly may be a health hazard it is very important to handle blood correctly. As mentioned by one of the abattoirs the cost of processing blood into blood meal is less than half of the income it generates. This creates another avenue of income by means of waste processing into a product.

4.2.3.3. Condemned Meat

Meat is classified as condemned meat when, upon inspection, it is found to be unfit for human consumption. The volume of condemned meat produced per abattoir could range significantly due to a lot of variables. Condemned meat may include small bits of meat as well as whole carcasses.

Half of the HT abattoir participants dispose of condemned meat. These HT abattoirs incinerate or burn meat before it is disposed of by burying and covering it. Two of the HT abattoirs provide condemned meat to lion farms for feed. The remainder of high throughput abattoirs report processing the condemned meat. One of the abattoirs processes this meat by sterilizing and drying it into a carcass meal to be used in dog food. Through this process a 50% GP margin is made on the carcass meal. At another abattoir, condemned meat is treated at a rendering plant whereby the waste tissue is processed into value added materials like lard and tallow. At another HT abattoir condemned meat is processed by means of composting. The resulting compost is utilized in pastures.

As in HT abattoirs, the participating LT abattoir displayed a wide range of condemned meat quantities. Three of the LT abattoirs disposed of their condemned meat by burial. One incinerated the condemned meat while another participant processed the condemned meat by deboning and mincing. The resulting product is sold as pets mince and generates revenue from an otherwise useless source. This same participant also distributed condemned meat to a lion farm as lion food.

4.2.3.4. Horns & Hooves

In the HT class, the average weight of horns and hooves produced per livestock unit was reported to be approximately 0.5kg. Horns and hooves are sold for R3 per kg to R4 per kg or with heads etc. Some HT abattoirs choose to dispose horns and hooves at the municipal dumpsite.

In the LT class no consistent hoof-and-horn mass was reported. Two of the LT abattoirs disposed of the horns and hooves at either a landfill site, or by means of burial in trenches.

At two LT abattoirs the horns and hooves were sold as part of the offal.

4.2.3.5. Non product waste

All the HT participants mentioned that their facility produces waste plastic, paper, boxes and other non-production waste. None of these materials are re-used or recycled by the abattoirs. It is dumped at the dumpsite or burned. It is removed by the municipality and moved to the landfill site where it is often burned and or buried.

Participating HT abattoirs complained that the municipal services often lack to render the service of taking waste to the landfill site or only take a specific maximum number of waste bags from each levy payer's site. This cause waste drums and bags to overflow and thus creating a health and hygiene problem. Some of the HT abattoirs arrange or use their own transport to take non-production waste to landfill sites in order to keep the abattoir area clean.

All LT abattoirs reported normal garbage disposal of plastic, paper and boxes and other non-production waste.

4.2.3.6. Specific Risk Materials (SRM)

Only one of the eight HT participants separate specific risk materials (SRM). SRM is the tissue that potentially contains the infective agent, known as a prion, which causes Bovine Spongiform Encephalopathy (BSE) or Mad Cow Disease. SRM is mainly associated with the nervous system and includes the brain and spinal cord; it represents less than 10% of the waste from red meat abattoirs. Of the seven high throughput abattoirs that do not separate SRM, six mentioned that they could separate SRM and only one would not be able to separate SRM.

Two of the six LT abattoirs mentioned that SRM is separated from other waste. It was reported by four that this procedure was not followed, but they would be able to separate SRM.

4.2.4. Expansion

With regards to expansion possibilities of the HT abattoirs that participated in the study almost all of them expect to increase production in the future. This would increase waste production and escalate issues related to the removal thereof.

4.2.5. Alternatives in waste management

When the HT participants were asked about altering their current methods of waste management 50% of the high throughput abattoirs confirmed that they would be able to change these methods. These HT abattoirs confirmed that the regulations with regards to hygiene and waste management at abattoirs might constrict slaughter practices and result in financial penalties or the close down of numerous abattoirs not adhering to these future laws. All participants acknowledge the importance of nature conservation, providing motivation for them to change their current ways of waste management.

The HT participants not able to alter current waste management methods provided the following reasons:

- Due to location inside a residential area, expansion would be difficult;
- One respondent did not want to change methods, as being satisfied with current waste management methods;
- One participant assumed change too costly, taking into consideration the fact that all the waste is currently removed by the municipality.

Three LT participants demonstrated interest in changing their current waste management protocols and provided the following reasons:

- It could ensure better income;
- It could decrease running costs;
- It could provide alternative energy.

Two of the LT participants replied that they are not interested in modifying waste management methods, as they are satisfied with the current procedures. As these facilities have insignificant volumes of waste there might not be enough waste to make processing a viable initiative.

All of the HT participants showed interest in applying waste-to-energy conversion methods to cut down on overhead costs and to dispose of waste products. The participants stated that it would be an advantage to gain financially through utilization of waste into energy.

Two of the HT abattoirs showed interest in implementing pyrolysis plants. Two high throughput abattoirs mentioned bio-gas digesters, and one suggested utilizing solar energy. All agreed that the chosen waste-to-energy method should be economically viable.

Two LT abattoirs mentioned that they would possibly implement waste-to-energy methods, and singled out biogas as a possibility. The rest of the participants did not suggest any alternative method to generate energy from waste.

4.2.6. The fifth quarter

Four of the high throughput abattoirs would not use the fifth quarter for energy generation, since the fifth quarter is a main income source to the abattoir. On the other hand, two responded that they would utilize the fifth quarter for energy purposes, if it showed to be financially viable and thus giving larger profits per slaughter unit. Two HT abattoirs refrained from answering this question.

The fifth quarter use was not considered for use in energy generation by the LT abattoirs, for the following reasons:

- One abattoir stated that it was their main source of income.
- Another stated that it was easier to sell the fifth quarter than to process it for energy.
- The third abattoir replied that it was used solely for consumption.

4.2.7. Research on possible waste-to-energy techniques

The HT abattoirs were questioned on which waste-to-energy methods they had researched. Only two abattoirs indicated that they had researched the above mentioned topic. One HT abattoir had investigated pyrolysis and biogas, and the other had only investigated the possibility of biogas methods.

None of the LT abattoirs had investigated alternative methods to convert waste to energy.

Despite having done some research on the topic, not one of the HT abattoirs had implemented any waste management methods. One did indicate that they were in the process of implementing pyrolysis and another HT abattoir is in the process of introducing an alkaline hydrolysis or tissue processing system to convert organic products to tallow.

Low throughput abattoirs would only consider implementing waste-to-energy methods in the event of electricity price increases and if the current electricity provider was proven to be unreliable in regards to providing electricity supply.

4.2.8. Relevance of the questionnaire

All participating abattoirs in the HT category stated that the questionnaire was very relevant, because all abattoirs need solutions for better waste management practices and better alternatives for energy conservation, the information from this study would prove relevant to all participants

When relevance of the questionnaire was assessed in the LT abattoirs, it was reported that the study should produce results and relevant suggestions that will be cost-effective and make the abattoirs less reliant on Eskom. There was also a general consensus that any methods applied must save costs and protect the environment.

4.3. Comparative study

During the comparative study, different technologies were compared to determine which would be the most appropriate option for turning abattoir waste into energy.

The following were taken into consideration:

- capital cost;
- running cost;

- conversion energy;
- input products (fuel);
- output products (electricity, oil, gas).

The waste treatments and waste-to-energy conversion methods that were assessed are discussed below:

4.3.1. Alkaline Hydrolysis

Waste treatment methods like air curtain burners and alkaline hydrolysis are methods to process abattoir waste products into useful by-products. Air curtain burners incinerate waste at high temperatures, reducing the waste to residual ash. This is a safe process with reduced emissions. Volume reduction can be close to 90%, and the resultant ashes are safe and can be beneficially re-used as a soil amendment.

Sodium hydroxide or potassium is used to catalyse the hydrolysis of biological material (protein, nucleic acids, carbohydrates, lipids, etc.) into a sterile aqueous solution consisting of small peptides, amino acids, sugars and soaps. Up to R4000 per ton can be received for this product. Heat is added to accelerate the process (150ºC). The only solid by-products are the mineral constituents of the bones and teeth of vertebrates. Even these can easily be crushed into a powder and used as a soil additive.

4.3.2. Incineration

Electricity can be generated through mass burn incineration by means of heat generated through combustion of waste. Although this process causes air pollution, modern plants meaningfully reduced emissions. This is a very effective way of waste treatment. The side effect of this process is the resulting harmful vapours. Proper operation and regular maintenance is therefore very important to control the quality of the air.

4.3.3. Gasification

Gasification is the process when destruction of biomass or organic matter (by burning at temperatures of higher than 850°C for at least 15 minutes) result in the production of ash and a combustible mixture of gases. The organic matter is heated in insufficient supply of air (Goyal et al., 2008). The resulting synthetic gas is used as fuel or as ingredient in chemical processes.

Dickenson (2006) recommended that gasification should to be considered for waste disposal. He stated that the process runs efficiently when optimal levels of operating temperatures are reached and thus emits greenhouse gasses well within the acceptable standard range for municipal wastes. Some functional failures and shortfalls were experienced in testing this technology.

4.3.4. Biogas

The anaerobic breakdown of organic material by bacteria can produce biogas. The devices that produce biogas are called anaerobic digesters. A gas mixture is formed. The yield and constitution of the different gasses may differ by modification. The yield of biogas production may often be low and not economical. This process can produce electricity. Similarly to figures published for a South African abattoir, at a rate of 150 slaughter units slaughtered per day, producing roughly 12tons of by products, a biogas plant may produce approximately 115kWh of electricity per day (Van Rooyen, 2013).

A study by Uduak et al. (2012) confirmed that the costs and benefits of addressing the poor waste disposal management practices at abattoirs by implementing a biogas plant using abattoir wastes as fuel, proved to be economically cost-beneficial.

4.3.5. Pyrolysis

Almost any organic matter can be used as fuel in the pyrolysis system. This may include abattoir and food processing waste, sewage sludge, municipal solid waste (MSW) and other organic waste. As a result of the pyrolysis process the output products include the following:

- useful liquid oil;
- gas mixture i.e. synthetic gas and
- solid products (char).

Each of the above has the potential to be used as fuels, either directly or after the upgrading of the output products, in different types of transport, power generation and combined heat and power generating.

Liquid oil can be used in internal combustion engines to generate electricity. The solid products or char produced is utilized for heating, soil fertilizer and co-firing in a coal plant. Pyrolysis gas can be useful in gas-fired boilers, turbines and spark ignition or dual-fuel engines.

4.3.6. Plasma Arc Gasification

Plasma arc refers to a specific method of gasification which is dependent on the amount of oxygen involved. Catalysts enhance the breakdown of high molecular weight compounds into smaller products. This process uses electric arc generated plasma for heat source for the pyrolysis, or in some cases gasification conversion.

4.3.7. Cost Benefit Analysis

A cost benefit analysis was done for a pyrolysis and biogas plant since it was derived from the questionnaires that these are the two technologies most sought after. Since both technologies are very expensive to establish the analysis showed that it would only be viable for abattoirs slaughtering more than 24000 slaughter units per annum. For the purpose of this analysis a number of 36000 slaughter units per annum were used whereby each slaughter unit used 25 kWh of electricity. The price on the biogas digester was set at R6,5 million and R12,5 million on the pyrolysis.

The pyrolysis showed a payback period of 6,86 years, while the biogas digester showed a payback period of 5,7 years. Although the breakeven point for the biogas digester is sooner than the one for the pyrolysis, a positive net present value (NPV) was calculated for the pyrolysis which is an indication that the project would add value to the business. This is in contrast with the biogas digester showing a negative NPV which is an indication that the project would not add value to the business.

Figures 4.1 and 4.2 show the cost benefit analysis of the pyrolysis and biogas digester plants respectively.

COST BENEFIT ANALYSIS FOR PYROLYSIS PLANT

DATA	
Slaughter Units / year	36000
Capital investment	R 12 592 000.00
Useful life (years)	15
n kWh used per slaughter unit	25
Average electricity cost (c/kWh)	155
Interest rate	5.25%
Payment period (years)	7
Installment per year	R 2 195 904.00
Nr of workers to operate	4
Average salary per worker	R 3 000.00
500KVA connection fee per month	R 12 000.00
Repairs and Maintanance per month	R 10 000.00
Bio-Diesel production (l/month)	10 000
Electricity generation	
Price for sale of Carbon credit	R 100.00
1 Carbon (1 ton CO2 emiss) credit of kWh	0.105%
Carbon Tax/1 ton CO2	R 48.00
Tons of CO2 emmissions per year	945
Diesel price per litre	R 12.40
Electricity Demand (KVA/day)	312.5
Pyrolysis Electricity Generation (KVA/day)	500
Possibly Sold back to ESKOM grid (KVA/day)	187.5

Annual Time line	0	2014	2015	2016	2017	2018	2019	2020	2021
SLAUGHTER UNITS		36000	36000	36000	36000	36000	36000	36000	36000
ELECTRICITY CONSUMPTION (kWh)		900000	900000	900000	900000	900000	900000	900000	900000
INITIAL INVESTMENT COST	**R 12 592 000.00**								
TERMINAL VALUE									
EXPENDITURE									
500KVA CONNECTION FEE		R 144 000.00	R 158 400.00	R 174 240.00	R 191 664.00	R 210 830.40	R 231 913.44	R 255 104.78	R 280 615.26
REPAIRS AND MAINTENANCE		R 120 000.00	R 129 600.00	R 139 968.00	R 151 165.44	R 163 258.68	R 176 319.37	R 190 424.92	R 205 658.91
SALARIES		R 144 000.00	R 158 400.00	R 174 240.00	R 191 664.00	R 210 830.40	R 231 913.44	R 255 104.78	R 280 615.26
INTEREST		R 661 080.00	R 661 080.00	R 661 080.00	R 661 080.00	R 661 080.00	R 661 080.00	R 661 080.00	
DEPRECIATION		R 839 466.67	R 839 466.67	R 839 466.67	R 839 466.67	R 839 466.67	R 839 466.67	R 839 466.67	R 839 466.67
TOTAL EXPENDITURE		**R 1 908 546.67**	**R 1 946 946.67**	**R 1 988 994.67**	**R 2 035 040.11**	**R 2 085 466.14**	**R 2 140 692.92**	**R 2 201 181.15**	**R 1 606 356.10**
INCOME OR SAVINGS									
DIESEL		R 1 488 000.00	R 1 636 800.00	R 1 800 480.00	R 1 980 528.00	R 2 178 580.80	R 2 396 438.88	R 2 636 082.77	R 2 899 691.04
CARBON TAX SAVING		R -	R -	R 45 360.000	R 49 896.000	R 54 885.600	R 60 374.160	R 66 411.576	R 73 052.734
CARBON CREDIT SALES		R -	R 94 500.00	R 103 950.00	R 114 345.00	R 125 779.50	R 138 357.45	R 152 193.20	R 167 412.51
ELECTRICITY COST SAVINGS		R 1 395 000.00	R 1 534 500.00	R 1 687 950.00	R 1 856 745.00	R 2 042 419.50	R 2 246 661.45	R 2 471 327.60	R 2 718 460.35
SAVINGS ON WASTE MANAGEMENT		R 108 000.00	R 108 000.00	R 108 000.00	R 108 000.00	R 108 000.00	R 108 000.00	R 108 000.00	R 108 000.00
PBDIT		**R 2 991 000.00**	**R 3 373 800.00**	**R 3 745 740.00**	**R 4 109 514.00**	**R 4 509 665.40**	**R 4 949 831.94**	**R 5 434 015.13**	**R 5 966 616.65**
CHANGE IN PBDIT		**R 1 082 453.33**	**R 1 426 853.33**	**R 1 756 745.33**	**R 2 074 473.89**	**R 2 424 199.26**	**R 2 809 139.02**	**R 3 232 833.98**	**R 4 360 260.54**
PBIT = (PBDIT - Depreciation)		**R 242 986.67**	**R 587 386.67**	**R 917 278.67**	**R 1 235 007.23**	**R 1 584 732.59**	**R 1 969 672.36**	**R 2 393 367.31**	**R 3 520 793.88**
Tax (30%)		R 72 896.00	R 176 216.00	R 275 183.60	R 370 502.17	R 475 419.78	R 590 901.71	R 718 010.19	R 1 056 238.16
NPAT		**R 170 090.67**	**R 411 170.67**	**R 642 095.07**	**R 864 505.06**	**R 1 109 312.81**	**R 1 378 770.65**	**R 1 675 357.12**	**R 2 464 555.71**
Operational Cash Flow (OCF)	**R (12 592 000.00)**	**R 1 009 557.33**	**R 1 250 637.33**	**R 1 481 561.73**	**R 1 703 971.73**	**R 1 948 779.48**	**R 2 218 237.32**	**R 2 514 823.79**	**R 3 304 022.38**
CASHFLOW		-R 11 582 442.67	-R 10 331 805.33	-R 8 850 243.60	-R 7 146 271.87	-R 5 197 492.39	-R 2 979 255.08	-R 464 431.29	R 2 839 591.09
Discount Factor (15%)	1.0000	0.8696	0.7561	0.6575	0.5718	0.4972	0.4323	0.3759	0.3269
PV	R -12 592 000.00	R 877 911.06	R 945 606.89	R 974 126.84	R 974 331.03	R 968 933.16	R 958 943.99	R 945 322.26	R 1 080 084.92
NPV	**R 1 652 105.24**								
IRR	**17%**								
BREAKEVEN POINT (YEARS)	**6.86**								

Annual Time line	2022	2023	2024	2025	2026	2027	2028
SLAUGHTER UNITS	36000	36000	36000	36000	36000	36000	36000
ELECTRICITY CONSUMPTION (kWh)	900000	900000	900000	900000	900000	900000	900000
INITIAL INVESTMENT COST							
TERMINAL VALUE							**R 5 036 800.00**
EXPENDITURE							
500KVA CONNECTION FEE	R 308 676.79	R 339 544.47	R 373 498.91	R 410 848.81	R 451 933.69	R 497 127.05	R 546 839.76
REPAIRS AND MAINTENANCE	R 222 111.63	R 239 880.56	R 259 071.00	R 279 796.68	R 302 180.41	R 326 354.85	R 352 463.23
SALARIES	R 308 676.79	R 339 544.47	R 373 498.91	R 410 848.81	R 451 933.69	R 497 127.05	R 546 839.76
INTEREST							
DEPRECIATION	R 839 466.67	R 839 466.67	R 839 466.67	R 839 466.67	R 839 466.67	R 839 466.67	R 839 466.67
TOTAL EXPENDITURE	**R 1 678 931.87**	**R 1 758 436.16**	**R 1 845 535.49**	**R 1 940 960.96**	**R 2 045 514.45**	**R 2 160 075.62**	**R 2 285 609.42**
INCOME OR SAVINGS							
DIESEL	R 3 189 660.15	R 3 508 626.16	R 3 859 488.78	R 4 245 437.66	R 4 669 981.42	R 5 136 979.57	R 5 650 677.52
CARBON TAX SAVING	R 80 358.007	R 88 393.808	R 97 233.188	R 106 956.507	R 117 652.158	R 129 417.374	R 142 359.111
CARBON CREDIT SALES	R 184 153.77	R 202 569.14	R 222 826.06	R 245 108.66	R 269 619.53	R 296 581.48	R 326 239.63
ELECTRICITY COST SAVINGS	R 2 990 306.39	R 3 289 337.03	R 3 618 270.73	R 3 980 097.81	R 4 378 107.59	R 4 815 918.34	R 5 297 510.18
SAVINGS ON WASTE MANAGEMENT	R 108 000.00	R 108 000.00	R 108 000.00	R 108 000.00	R 108 000.00	R 108 000.00	R 108 000.00
PBDIT	**R 6 552 478.31**	**R 7 196 926.14**	**R 7 905 818.76**	**R 8 685 600.63**	**R 9 543 360.70**	**R 10 486 896.77**	**R 11 524 786.44**
CHANGE IN PBDIT	**R 4 873 546.44**	**R 5 438 489.99**	**R 6 060 283.26**	**R 6 744 639.68**	**R 7 497 846.24**	**R 8 326 821.14**	**R 9 239 177.02**
PBIT = (PBDIT - Depreciation)	**R 4 034 079.78**	**R 4 599 023.32**	**R 5 220 816.60**	**R 5 905 173.01**	**R 6 658 379.58**	**R 7 487 354.48**	**R 8 399 710.35**
Tax (30%)	R 1 210 223.93	R 1 379 707.00	R 1 566 244.98	R 1 771 551.90	R 1 997 513.87	R 2 246 206.34	R 2 519 913.11
NPAT	**R 2 823 855.84**	**R 3 219 316.32**	**R 3 654 571.62**	**R 4 133 621.11**	**R 4 660 865.70**	**R 5 241 148.13**	**R 5 879 797.25**
Operational Cash Flow (OCF)	**R 3 663 322.51**	**R 4 058 782.99**	**R 4 494 038.28**	**R 4 973 087.77**	**R 5 500 332.37**	**R 6 080 614.80**	**R 6 719 263.91**
CASHFLOW	R 6 502 913.60	R 10 561 696.59	R 15 055 734.87	R 20 028 822.65	R 25 529 155.02	R 31 609 769.82	R 38 329 033.73
Discount Factor (15%)	0.2843	0.2472	0.2149	0.1869	0.1625	0.1413	0.1229
PV	R 1 041 482.59	R 1 003 331.16	R 965 768.83	R 929 470.10	R 893 804.01	R 859 190.87	R 825 797.54

Figure 4.1. Cost benefit analysis of pyrolysis

COST BENEFIT ANALYSIS FOR BIOGAS PLANT

DATA		
Slaughter Units / year		36000
Capital investment	R	6 500 000.00
Useful life (years)		15
n kWh used per slaughter unit		25
Average electricity cost (c/kWh)		155
Interest rate		5.25%
Payment period (years)		7
Installment per year		R 1 133 528.00
Nr of workers to operate		4
Average salary per worker	R	3 000.00
500KVA connection fee per month	R	12 000.00
Repairs and Maintanance per month	R	10 000.00
Heat Production (kW)		150
Electricity generation (kW)		115
Price for sale of Carbon credit	R	100.00
1 Carbon (1 ton CO2 emiss) credit of kWh		0.105%
Carbon Tax/1 ton CO2	R	48.00
Tons of CO2 emmissions per year		945

Annual Time line	0	2014	2015	2016	2017	2018	2019	2020
SLAUGHTER UNITS		36000	36000	36000	36000	36000	36000	36000
ELECTRICITY CONSUMPTION (kWh)		900000	900000	900000	900000	900000	900000	900000
INITIAL INVESTMENT COST	**R 6 500 000.00**							
TERMINAL VALUE								
EXPENDITURE								
500KVA CONNECTION FEE		R 144 000.00	R 158 400.00	R 174 240.00	R 191 664.00	R 210 830.40	R 231 913.44	R 255 104.78
REPAIRS AND MAINTENANCE		R 120 000.00	R 129 600.00	R 139 968.00	R 151 165.44	R 163 258.68	R 176 319.37	R 190 424.92
SALARIES		R 144 000.00	R 158 400.00	R 174 240.00	R 191 664.00	R 210 830.40	R 231 913.44	R 255 104.78
INTEREST		R 341 250.00	R 341 250.00	R 341 250.00	R 341 250.00	R 341 250.00	R 341 250.00	R 341 250.00
DEPRECIATION		R 433 333.33	R 433 333.33	R 433 333.33	R 433 333.33	R 433 333.33	R 433 333.33	R 433 333.33
TOTAL EXPENDITURE		**R 1 182 583.33**	**R 1 220 983.33**	**R 1 263 031.33**	**R 1 309 076.77**	**R 1 359 502.81**	**R 1 414 729.58**	**R 1 475 217.82**
INCOME OR SAVINGS								
CARBON TAX SAVING		R -	R -	R 45 360.000	R 49 896.000	R 54 885.600	R 60 374.160	R 66 411.576
CARBON CREDIT SALES		R -	R 94 500.00	R 103 950.00	R 114 345.00	R 125 779.50	R 138 357.45	R 152 193.20
ELECTRICITY COST SAVINGS		R 1 395 000.00	R 1 534 500.00	R 1 687 950.00	R 1 856 745.00	R 2 042 419.50	R 2 246 661.45	R 2 471 327.60
SAVINGS ON WASTE MANAGEMENT		R 108 000.00	R 108 000.00	R 108 000.00	R 108 000.00	R 108 000.00	R 108 000.00	R 108 000.00
PBDIT		**R 1 503 000.00**	**R 1 737 000.00**	**R 1 945 260.00**	**R 2 128 986.00**	**R 2 331 084.60**	**R 2 553 393.06**	**R 2 797 932.37**
CHANGE IN PBDIT		**R 320 416.67**	**R 516 016.67**	**R 682 228.67**	**R 819 909.23**	**R 971 581.79**	**R 1 138 663.48**	**R 1 322 714.55**
PBIT = (PBDIT - Depreciation)		**R -112 916.67**	**R 82 683.33**	**R 248 895.33**	**R 386 575.89**	**R 538 248.46**	**R 705 330.14**	**R 889 381.21**
Tax (30%)		R -	R 24 805.00	R 74 668.60	R 115 972.77	R 161 474.54	R 211 599.04	R 266 814.36
NPAT		**R -112 916.67**	**R 57 878.33**	**R 174 226.73**	**R 270 603.13**	**R 376 773.92**	**R 493 731.10**	**R 622 566.85**
Operational Cash Flow (OCF)	**R (6 500 000.00)**	**R 320 416.67**	**R 491 211.67**	**R 607 560.07**	**R 703 936.46**	**R 810 107.25**	**R 927 064.43**	**R 1 055 900.18**
CASHFLOW		-R 6 179 583.33	-R 5 688 371.67	-R 5 080 811.60	-R 4 376 875.14	-R 3 566 767.89	-R 2 639 703.45	-R 1 583 803.27
Discount Factor (15%)	1.0000	0.8696	0.7561	0.6575	0.5718	0.4972	0.4323	0.3759
PV	R -6 500 000.00	R 278 634.33	R 371 405.14	R 399 470.74	R 402 510.87	R 402 785.33	R 400 769.95	R 396 912.88
NPV	**R -541 431.79**							
IRR	**14%**							
BREAKEVEN POINT (YEARS)	**5.90**							

Annual Time line	2021	2022	2023	2024	2025	2026	2027	2028
SLAUGHTER UNITS	36000	36000	36000	36000	36000	36000	36000	36000
ELECTRICITY CONSUMPTION (kWh)	900000	900000	900000	900000	900000	900000	900000	900000
INITIAL INVESTMENT COST								
TERMINAL VALUE								**R 2 600 000.00**
EXPENDITURE								
500KVA CONNECTION FEE	R 280 615.26	R 308 676.79	R 339 544.47	R 373 498.91	R 410 848.81	R 451 933.69	R 497 127.05	R 546 839.76
REPAIRS AND MAINTENANCE	R 205 658.91	R 222 111.63	R 239 880.56	R 259 071.00	R 279 796.68	R 302 180.41	R 326 354.85	R 352 463.23
SALARIES	R 280 615.26	R 308 676.79	R 339 544.47	R 373 498.91	R 410 848.81	R 451 933.69	R 497 127.05	R 546 839.76
INTEREST								
DEPRECIATION	R 433 333.33	R 433 333.33	R 433 333.33	R 433 333.33	R 433 333.33	R 433 333.33	R 433 333.33	R 433 333.33
TOTAL EXPENDITURE	**R 1 200 222.77**	**R 1 272 798.54**	**R 1 352 302.82**	**R 1 439 402.16**	**R 1 534 827.62**	**R 1 639 381.12**	**R 1 753 942.29**	**R 1 879 476.09**
INCOME OR SAVINGS								
CARBON TAX SAVING	R 73 052.734	R 80 358.007	R 88 393.808	R 97 233.188	R 106 956.507	R 117 652.158	R 129 417.374	R 142 359.111
CARBON CREDIT SALES	R 167 412.51	R 184 153.77	R 202 569.14	R 222 826.06	R 245 108.66	R 269 619.53	R 296 581.48	R 326 239.63
ELECTRICITY COST SAVINGS	R 2 718 460.35	R 2 990 306.39	R 3 289 337.03	R 3 618 270.73	R 3 980 097.81	R 4 378 107.59	R 4 815 918.34	R 5 297 510.18
SAVINGS ON WASTE MANAGEMENT	R 108 000.00	R 108 000.00	R 108 000.00	R 108 000.00	R 108 000.00	R 108 000.00	R 108 000.00	R 108 000.00
PBDIT	**R 3 066 925.60**	**R 3 362 818.16**	**R 3 688 299.98**	**R 4 046 329.98**	**R 4 440 162.97**	**R 4 873 379.27**	**R 5 349 917.20**	**R 5 874 108.92**
CHANGE IN PBDIT	**R 1 866 702.83**	**R 2 090 019.63**	**R 2 335 997.16**	**R 2 606 927.82**	**R 2 905 335.35**	**R 3 233 998.15**	**R 3 595 974.91**	**R 3 994 632.83**
PBIT = (PBDIT - Depreciation)	**R 1 433 369.50**	**R 1 656 686.29**	**R 1 902 663.82**	**R 2 173 594.48**	**R 2 472 002.02**	**R 2 800 664.82**	**R 3 162 641.58**	**R 3 561 299.50**
Tax (30%)	R 430 010.85	R 497 005.89	R 570 799.15	R 652 078.34	R 741 600.61	R 840 199.45	R 948 792.47	R 1 068 389.85
NPAT	**R 1 003 358.65**	**R 1 159 680.41**	**R 1 331 864.68**	**R 1 521 516.14**	**R 1 730 401.41**	**R 1 960 465.37**	**R 2 213 849.10**	**R 2 492 909.65**
Operational Cash Flow (OCF)	**R 1 436 691.98**	**R 1 593 013.74**	**R 1 765 198.01**	**R 1 954 849.47**	**R 2 163 734.75**	**R 2 393 798.71**	**R 2 647 182.44**	**R 2 926 242.98**
CASHFLOW	-R 147 111.29	R 1 445 902.45	R 3 211 100.46	R 5 165 949.93	R 7 329 684.68	R 9 723 483.38	R 12 370 665.82	R 15 296 908.80
Discount Factor (15%)	0.3269	0.2843	0.2472	0.2149	0.1869	0.1625	0.1413	0.1229
PV	R 469 654.61	R 452 893.81	R 436 356.95	R 420 097.15	R 404 402.02	R 388 992.29	R 374 046.88	R 359 635.26

Figure 4.2. Cost benefit analysis of biogas

CHAPTER 5
CONCLUSION

5.1. INTRODUCTION

For low-throughput abattoirs it is costly and not viable to establish any of the researched plants to generate energy from waste. It is thus advisable to still do everything possible to process waste and minimizing the amount of waste products going into the municipal sewerage system and landfills.

The environmental benefits from improved waste processing and management are the following:

- Decreased spoilage and increased efficiency reduces the expense of purchasing materials and chemicals;
- Decreased costs of waste treatment and disposal;
- Income generation from by-products;
- Reduced environmental impact associated with waste disposal and consumption of raw materials and other resources;
- Improved reputation and promotion of the image of being environmentally responsible and providing employee satisfaction;
- Providing a safer workplace through process improvement and less waste handling.

5.2. CONCLUSIONS AND SUGGESTIONS

The following suggestions are thus made for the waste management of low and high throughput abattoirs:

5.2.1. Manure

Since most of the participating red meat abattoirs either bury the stomach contents, dispose thereof at the municipal landfill site or the municipal sewage systems, little or no processing takes place.

Cattle manure and urine are both good sources of important nutrients (phosphorous, nitrogen and potassium). The organic matter component can provide nutrients beneficial to crops.

Manure may lose its quality and usefulness when stored uncovered. The process of composting (breaking down organic matter in dead plant material; crop residue and leaves by decay before returning them to the soil) can also be applied to old manure. It is recommended that effective hygiene and collection measures are applied during the processing and disposal of stomach content and manure. It is recommended that manure is collected dry from vehicles, lairages, slaughter areas and offal rooms. The process of vermiculture can also be applied. This is when processing of compost takes place by making use of worms.

5.2.2. Blood

Only some of the participating abattoirs process blood. Blood should be treated correctly, as it can pose a health hazard. The processing into blood meal creates another avenue of income by means of waste processing into a product. As mentioned by one of the abattoirs the cost of processing blood into blood meal is less than half of the income it generates.

Blood meal can be produced by means of rendering. The typical yield of blood meal from cattle is about 2.7 kg per slaughter unit. With careful collection and no added water, blood meal yields up to 3.1 kg per head can be collected. It is thus suggested that when slaughtered animals are hoisted for bleeding, blood must be collected in containers under the carcasses.

Coagulation of collected blood is normally performed in a continuous steam coagulator. The blood can then be used for drying. According to Clottey (1985) the estimated yield of blood meal in cattle ranges from 10 to 20 % of the weight of blood collected. Pigs can be fed with chemically preserved blood, and composted blood is used for grape and fruit trees. Blood meal is a food source for fish like barbells. Suitable hygienic collection of blood could result in the developing of blood products fit for human consumption.

5.2.3. Condemned meat

Condemned meat can be processed in the same way to blood by means of sterilization and production of carcass or bone meal. This product is a valuable component in some dog foods. This might generate additional income to the abattoir.

Composting of condemned meat can also prove to be a valuable alternative for handling this type of waste and to be used as fertilizer of pastures. Most Free State abattoirs do not utilize or process condemned meat. Condemned meat is often buried or burned. This proves to be a health hazard for animals, humans and nature. Another alternative is to use condemned meat for feeding of wild animals at zoos or lion farms.

Condemned meat can further be processed at a rendering plant whereby the waste tissue is processed into value added materials like lard and tallow.

5.2.4. Waste water

High volumes of waste water are generated at abattoirs. Participating abattoirs mostly dispose waste into municipal sewage systems. Waste water should be managed to prevent contamination of the premises. The installation of traps to collect residual solids like fat and coagulated blood is one method of preventing contamination when conventional sewage backs up.

Waste water can be processed. Suggestions with this regard are to either let the waste water be used as form of irrigation where it is allowed to flow onto pastures and gardens or it can be purified. Purification systems can be expensive but will reduce the organic load on the municipal sewage systems and has the advantage of reducing the amount of small insects and flies.

5.2.5. Horns and hooves

Horns and hooves can be sold or processed to have financial benefits. Several products like creams, use for parts of musical instruments, knife handles, glue and buttons could be a result of horn and/or hoof processing. Alternative uses could also include the selling of hooves for consumption by pets or production of brawn for human consumption

5.2.6. General

As most abattoir owners often do not pay for disposal of these wastes, they would not benefit financially from alternative waste management measures. It would, however, have a positive environmental result. The negating facts identified in the waste management model are mainly related to the costs of implementation.

As there is not sufficient enforcing of the legislation regarding landfills and waste disposal, abattoir owners are not forced to become compliant in finding alternative waste management methods.

5.2.7. Waste to energy

The results from the comparative study of the different waste treatment and waste-to-energy conversion technologies for abattoir waste showed to have different potentials. It has been found that biogas and plasma arc gasification technology shows the highest potential for energy generation with 950kWh/100t of organic waste and 816kWh/100t of municipal solid waste respectively. Compared to other technologies like the pyrolysis technology (500-571kWh/100t) and incineration process (450-544kWh/100t), biogas and plasma arc gasification showed higher energy generation potential.

Although, plasma arc gasification has a high potential for generating energy, it has the highest capital cost to install. It is therefore suggested, when implementing waste-to-energy generation technologies, factors like environmental regulations, installation costs and the handling of by-products, should be considered before identifying the most viable technology. Since there are a number of factors that influence the generation of the amount of energy, the values in this paper are based on theoretical ideals. This may provide indicative potential values that may differ from actual field measurement values.

The biogas plant requires the least amount for start-up capital and has a fairly high potential for electricity generation. Biogas plants can be sourced locally and established at a start-up cost of around R6 million. While the yield may vary due to different organic wastes' methane production capabilities, it is advisable to use biogas as a source of heating. Some of energy is lost when generating electricity with methane gas. Biogas technology would be very suitable for energy generation at abattoirs since the by-products at abattoirs are of organic nature. When the process of biogas production is taking place, organic slurry is produced that also has a commercial value as an organic compost and fertilizer.

Another option to consider would be a pyrolysis plant. Any type of waste can be used by the pyrolysis to obtain one of the by-products which may include gas for the generation of electricity, bio-oil and a solid called char, that can be utilized as fertilizer or for heating purposes. The pyrolysis cost from R12million in South Africa, and could be well implemented at any HT abattoir and municipal dump sites.

The cost benefit analysis for the pyrolysis plant exhibited a positive net present value, while the biogas digester did not. This showed that the pyrolysis may add value to the business on the long run. Since these technologies are very expensive, it may be only viable for abattoirs with a very high throughput of slaughter units (more than 30000 slaughter units per annum)

Therefore, waste to energy systems offers the advantages of taking freely available, and sometimes problematic, organic waste to generate energy, reducing existing energy costs in an environment, and providing an additional revenue stream in the form of natural fertilizers.

There is potential energy, potential income and potential cost saving in waste.

5.2.8. Current waste management at abattoirs

It is concluded that abattoirs are reluctant to implement optimal waste management systems. Since South Africa is a water scarce country, water supplies are constantly contaminated by different industries. Agricultural and agricultural-processing industries, like abattoirs, consume a lot of water. Pollution control is getting stricter to reduce and eliminate discharge of polluting materials into the atmosphere, ground and, primarily, the discharge into water.

Lately, discussions on waste management, the use of waste of generate income or energy and legislations around waste management have become an important topic of discussion for the abattoir industry.

High throughput abattoirs are much more inclined to implement new waste management systems. Most systems are very expensive, but fortunately many realize the importance and future return on investment after implementing such a system. The same applies for low throughput abattoirs slaughtering high numbers of units and thus producing a lot of waste. Many abattoirs do implement some waste management techniques whereby they generate additional income or saving on disposal expenses. The implication of this, prove to be very advantageous for some of these abattoirs.

5.3. Final remarks

Livestock by-products have a lot of economic and nutritional significance for the livestock industry which needs to be made the most of. As the option for landfilling to be used for abattoir waste disposal is becoming limited and regulations for abattoir management are stricter, alternative treatment options need to be considered to reduce the amount of waste produced. The selection and combination of technologies should be carried out in such a way that recycling targets are maximized and the production of energy is optimized in such a way that a maximum return on investment is achieved. Whatever treatment solution is arrived at, the impact on the environment should always be considered and the technology risks carefully assessed.

Since very few abattoirs are informed about the newest technology that is available with regards to waste to energy, this study serves as an introduction to these new technologies. This study provides abattoirs with a viable method of getting rid of waste and in the same time using waste as means of generating energy to be used at the abattoir.

The second important aspect that this study shows is the design of a financial model to determine whether it is viable to erect this technology and how many wastes from slaughtered animals are necessary to generate sufficient energy.

In the medium and long term, the application of this study and its principles could be applied to municipalities, residential areas and other instances producing waste. Abattoirs can save a lot of money by generating their own power, have a means of getting rid of waste, building up carbon points as well as doing their part in slowing down, stopping or even reversing global warming.

5.4. Further investigation

A number of guidelines exist and some research has been undertaken, but it is still unclear to abattoir owners how they should address waste management while also complying with a changing environment. Further research is needed into new technologies to identify ways to address waste management.

List of references

[f]Ahmad, J. and Ansari, T.A. 2012. Biogas from Slaughterhouse Waste: Towards an Energy Self-Sufficient Industry with Economical Analysis in India. J Microbial Biochem Technol 2012, S12. http://dx.doi.org/10.4172/1948-5948.S12-001

Akinro, A.O., Ologunagb, I.B., Olotu Y. 2009. Environmental implications of unhygienic operation of a city abattoir in Akure, Western Nigeria. ARPN 108 Chukwu et al. Int. J. Biosci. 2011 Journal of Engineering and Applied Sciences 4, 311-315

Barth, T. and Kleinert, M. 2008. Motor fuels from biomass pyrolysis. Chemical Engineering & Technology 2008;31(5):773–81

Bello, Y.O. and Oyedemi, D.T.A. 2009. Impact of abattoir activities and management in residential neighbourhoods: A case study of Ogbomoso, Nigeria. Journal of Social Science 19, 121-127

Bradshaw, A.D., Southwood, R. and Warner, F. 1992. The Treatment and Handling of Wastes, The Royal Society, London: Chapman & Hall, pp. 183

Bridle Consulting for Meat & Livestock Australia Limited. 2011. Pilot testing pyrolysis systems and reviews of solid waste use on boilers. PUBLISHED BY Meat & Livestock Australia Limited

Brooks, C. 2013. Consequences of increased global meat consumption on the global environment -- trade in virtual water, energy & nutrients. Retrieved from https://woods.stanford.edu/environmental-venture-projects/consequences-increased-global-meat-consumption-global-environment on 17 July 2014

Burnley, S. 2001. The impact of the European landfill directive on waste management in the United Kingdom. Resources, Conservation and Recycling, 32(3-4) pp. 349–358

Chukwu, O., Adeoye, P.A. and Chidiebere, I. 2011. Abattoir wastes generation, management and the environment: a case of Minna, North Central Nigeria. International Journal of Biosciences (IJB), ISSN: 2220-6655 (Print) 2222-5234 (Online). Vol. 1, No. 6, p. 100-109, 2011

Clottey, J.A. 1985. Manual for the slaughter of small ruminants in developing countries. St. John A. FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS Rome, 1985. Retrieved from http://www.fao.org/docrep/003/x6552e/X6552E00.htm#TOC on 10 September 2014

COP17/CMP7, Durban, South Africa. 2011. Working together saving tomorrow today. Retrieved from http://www.cop17-cmp7durban.com/ on 25 August 2014

Department of Agriculture and Rural Development. 2009. Guideline manual for the management of abattoirs and other waste of animal origin. Retrieved from file:///C:/Users/J.W.%20Swanepoel/Downloads/Guideline%20Manual%20for%20the%20Management%20of%20Abatooirs%20(1).pdf on 3 August 2014

Department of Agriculture, Fisheries and Forestry. 2011. A Profile of the South African Beef Market Value Chain. Retrieved from http://www.daff.gov.za/docs/AMCP/BeefMVCP11-12.pdf on 25 August 2013

Department of Agriculture, Fisheries and Forestry. 2012. A profile of the South African beef market value Chain. Retrieved from http://www.nda.agric.za/docs/AMCP/Beef2012-13.pdf on 14 February 2014

Department of Agriculture, Forestry and Fisheries (DAFF). 2014. Veterinary public health abattoir lists: Red meat abattoirs. Retrieved from http://www.nda.agric.za/vetweb/VPH/AbattoirLists/Red%20Meat/Free%20State%20Read%20Meat%20Abattoirs.htm on 3April 2014

Department of National treasury of South Africa, May 2013, Carbon tax Policy Paper. Retrieved from http://www.treasury.gov.za/public%20comments/Carbon%20Tax%20Policy%20Paper%202013.pdf on 20 November 2013

Department of Environmental Affairs, South Africa. 2011. REPUBLIC OF SOUTH AFRICA NATIONAL CLIMATE CHANGE RESPONSE WHITE PAPER. Retrieved from https://www.environment.gov.za/sites/default/files/legislations/national_climatechange_response_whitepaper.pdf on 20 July 2014.

Department of the environment, Australian Government. 2013. Emissions Reduction Fund Green Paper. Retrieved from http://www.environment.gov.au/system/files/resources/66237232-3042-4cd8-99a3-040705fead3b/files/erf-green-paper_1.pdf on 6 November 2013

Department of Water Affairs and Forestry. South African Republic. 1998. Minimum requirements waste management guideline series. Minimum Requirements for Waste

Disposal by Landfill, 2nd edn., Vol. 2, Cape Town: Formeset Printers for Government Printer, pp. 3–2.

Department for Environment, Food & Rural Affairs, UK. 2010. Consultation launch on revised Waste Framework Directive. Retrieved from https://www.gov.uk/government/news/consultation-launch-on-revised-waste-framework-directive on 29 April 2014

Dickinson, T.E. 2006. Alternative Technology for the Disposal of Slaughterhouse Waste. Obtained from http://www.iafbc.ca/funding_available/programs/livestock/documents/LWTI-1_FinalReport_Gasification.pdf on 12 September 2014

Divac. 2014. Bovine slaughter process flow diagram. Retrieved from http://www.divac.co.za/Products22.htm on 21 April 2014 on 7 May 2014

Eberhard, A; Kolker, J. Leigland, J. 2014. Africa's Renewable Energy IPP Procurement Program: Success Factors and Lessons. Retrieved from http://www.gsb.uct.ac.za/files/PPIAFReport.pdf on 18 July 2014

Eskom. 2014. About demand response. Retrieved from http://www.eskom.co.za/sites/idm/Business/Pages/Backup%20V2014-07/Business%20How%20To%20Assist.aspx on 4 May 2014

European Union. 1999. Council Directive 1999/31/EC of 26 April 1999 on the landfill of waste. Official Journal of European Communities L182/1. Retrieved from http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:31999L0031&from=EN on 12 October 2014

Fakir, S. 2013. Climate action: no more time for debate. Retrieved from http://www.wwf.org.za/what_we_do/climate_change/?8920/climate-action-oped on 26 August 2014.

Food Safety Authority of Ireland, 2013. Harvesting Blood for Making Black Pudding. General Factsheet series issue no. 1, September 2013

Free State Government. 2014. The Free State. Retrieved from http://www.freestateonline.fs.gov.za/?page_id=744 on 26 April 2014

From The Ground Up Resource Consultants Inc. 2009. Slaughterhouse Waste and Specified Risk Material (SRM) Management Study. Retrieved from http://www.agf.gov.bc.ca/resmgmt/SRM_Program/Reports/Slaughterhouse_Waste_and_SRM_Mgmt_Study.pdf on 25 March 2014

[h]Frost, P & Gilkinson, S. 2010. Hillsborough Interim technical report. First 18 month performance summary for anaerobic digestion of dairy cow slurry. Agri Food and Bio sciences institute. Retrieved from http://www.afbini.gov.uk/afbi-ad-18-months-v05.pdf on 18 July 2014

Gauri, S.M. 2006. Treatment of wastewater from abattoirs before land application: a review. Bioresource Technology 97, 1119- 1135

Gregory, N.G., Wilkins, L.J. and Gregory, A.M.S. 1988. Studies on blood engorgement in beef carcasses. J Sci Food Agric 46: 43-51

Goyal, H.B., Seal, D. and Saxena, R.C. 2008. Bio-fuels from thermochemical conversion of renewable resources: a review. Renewable and Sustainable Energy Reviews 2008;12:504–17

Hartmann, H. and Ahring, B.K. 2006. Strategies for the anaerobic digestion of the organic fraction of municipal solid waste: an overview. Water Science and Technology, 53(8): 7-22

Jayathilakan, K., Sultana, K., Radhakrishna, K. and Bawa, A.S. 2012. Utilization of byproducts and waste materials from meat, poultry and fish processing industries: a review. J Food Sci Technol (May–June 2012) 49(3):278–293

Jewaskiewitz, S. 2008. Waste-to-energy. Are we ready for it in South Africa?

Waste management, Imiesa February 2008 p 69-77

Intergovernmental Panel on Climate Change, 2007. In: Houghton, J.T., et al. (Eds.), Climate Change 2001. Cambridge University Press, New York.

McKendry, P. 2002. Energy production from biomass (Part 1): overview of biomass. Bioresource Technol 2002;83:37–46.

[d]MERC Order (Case 65 of 2009). 2010. MERC Order for SBSPL for Determination of Tariff for the Power generated from Municipal Solid Waste; 2010. Retrieved from http://mercindia.org.in/pdf/Order%2058%2042/Order_65_of_2009_Sept_9_2010.pdf on 10 April 2014.

[c]Monojit Chakraborty, M., Sharma, C., Pandey, J. and Gupta, P.K. 2013. Assessment of energy generation potentials of MSW in Delhi under different technological options. Energy Conversion and Management 75 (2013) 249–255

[b]National Master Plan for Development of Waste-to-Energy in India. 2006. Technical Memorandum on Waste-to-Energy Technologies; Retrieved from http://ebookbrowse.com/national-master-plan-technical-memorandum-onstudy-of-government-infrastructure-pdf-d348576610 on 14 March 2014

Nixon, J.D., Wright, D.G., Dey, P.K., Ghosh, S.K. and Davies, P.A. 2013. A comparative assessment of waste incinerators in the UK. Waste Management 33 (2013) 2234–2244

OMOH, O.L.Y. and NEAYOR, B. 2010. Generation of Electricity from Abattoir Waste Water with the Aid of a Relatively Cheap Source of Catholyte. J. Appl. Sci. Environ. Manage. June, 2010. Vol. 14 (2) 21 – 27

Omole, D. O. and Ogbiye, A. S. 2013. An evaluation of slaughterhouse wastes in south-west Nigeria American Journal of Environmental Protection. 2013; 2(3): 85-89

Patkie, S., Subramaniam, J., Kumar, R. and Patil, D.A. 2000. Environment management issues in an abattoir: a case study. Indian Journal of Environmental Protection, 20, 821–828.

Patra, R.C., Swarup, D., Naresh, R., Kumar, P., Nandi, D., Shekhar, P., Roy, S. and Ali, S.L. 2007. Tail Hair as an Indicator of Environmental Exposure of Cows to Lead and Cadmium in Different Industrial Areas. Ecotoxicol. Environ. Safety, 66:127-131.

People's Republic of China (PRC). 2011. Report on the Implementation of the 2010 Plan for National Economic and Social Development and on the 2011 Draft Plan for National Economic and Social Development. Fourth Session of the 11th National 11th National People's Congress, 5 March 2011. Retrieved from http://news.xinhuanet.com/english2010/china/2011-03/17/c_13783842.htm on 27 April 2014

Pike Research. 2012. Waste to energy technology markets. Renewable power and heat generation from Municipal Solid Waste: market outlook, technology assessment and capacity and revenue forecasts. Retrieved from http://www.phoenixenergy.com.au/wp-content/uploads/2012/01/Pike-Research-Report.pdf on 6 June 2014.

Red Meat Abattoir Association (RMAA). 2011. By-Products Management – Red Meat Abattoirs.

Red Meat Research and Development. 2012. Overview of the red meat industry. Retrieved from http://www.rmrdsa.co.za/index.php?option=com_content&view=article&id=121&Itemid=67 on 9 November 2013

Riebeek, H. 2010. Global Warming. Retrieved from http://earthobservatory.nasa.gov/Features/GlobalWarming/page1.php on 18 January 2014

Roberts, H. and De Jager, L. 2008. Waste handling model and practices used at red meat abattoirs in the Free State province, South Africa. International Journal of Technology Management and Sustainable Development Volume 7 Number 2 © 2008 Intellect Ltd

Rodriguez-Martinez, J., Rodriguez-Garza, I., Pedraza-Flores, E.,Balagurusamy, N., Sosa-Santillan, G. and Garza-Garc, Y. 2002. "Kinetics of anaerobic treatment of slaughterhouse wastewater in batch and upflow anaerobic sludge blanket reactor", Bioresource Technology, Vol. 85, pp. 235-241, 2002

SAGCOT. 2013. SAGCOT Investment Partnership Program Opportunities for Investors in the Livestock Sector. Retrieved from http://www.sagcot.com/fileadmin/documents/SAGCOT-IPP_Livestock_Full_Presentation__Compatibility_Mode_.pdf on 14 May 2014

Saidur, R., Islam, M.R., Rahim, N.A. and Solangi, K.H. 2010. A review on global wind energy policy. Renewable and Sustainable Energy Reviews, vol. 14, pp. 1744-62

Salminen, E. and Rintala, J. 2002. Anaerobic digestion of organic solid poultry slaughterhouse waste – a review. Bioresource Technology, 83,13–26

[a]Saini, S., Rao, P. and Patil, Y. 2012. City based analysis of MSW to energy generation in India, calculation of state-wise potential and tariff comparison with EU. Procedia Soc Behav Sci 2012;37:407–16

South Africa (Republic). 1989. Environmental Conservation Act 73 of 1989 (ECA). Retrieved from http://www.ehrn.co.za/download/act_eca.pdf on 14 May 2014

South Africa (Republic). 1989. National Environmental Management Act 107 of 1998 (NEMA). Retrieved from https://www.environment.gov.za/sites/default/files/legislations/nema_amendment_act107.pdf on 14 May 2014

South Africa (Republic). 1989. National Water Act 36 of 1998 (NWA). Retrieved from http://www.energy.gov.za/files/policies/act_nationalwater36of1998.pdf on 14 May 2014

South Africa (Republic). 2000. Meat Safety Act (Act 40 of 2000). Pretoria: Government Printer. p. 3. (Replacing South Africa, 1992). Retrieved from http://rvav.co.za/wp-content/uploads/2014/02/08.-Price-and-or-Abattoir-Information-Application-2014.02.10.pdf on 14 May 2014

South African Institute of Race Relations. 2013. South Africa goes with the urbanisation flow. Retrieved from www.sairr.org.za on 12 January 2014

Spence, J.E. 2012. Renewable Energy in the Australian Red Meat Processing Industry & The Viability of Paunch as a Biofuel. Retrieved from https://eprints.usq.edu.au/23223/2/Spence_2012_whole.pdf on 1 February 2014

The Butcher Website - Abattoir regulatory structure. 2013. Retrieved from http://www.thebutcherweb.co.za/butchervol1no7industryinsight.html) on 26 August 2013

The Food and Agriculture Organization (FAO). 2014. The role of livestock in climate change. Retrieved from http://www.fao.org/agriculture/lead/themes0/climate/en/ on 7 May 2014

[g]Uduak, A., Salisu, I. and Ye-obong, U. 2012. Slaughterhouse wastes to biogas in akwa ibom state, nigeria: a cost-benefit analysis. Retrieved from http://spidersolutionsnigeria.com/wp-content/uploads/2012/12/Slaughterhouse-Wastes-to-Biogas.pdf on 1 September 2014

U.S. Department of Agriculture. 2001. Livestock slaughter 2000 summary. National Agricultural Statistics Service. Mt An 1-2-1 (01a), Washington, DC. (DCN 00183)

[i]Van Rooyen, C. 2013. Biogas uit afval dryf slagplaas. Landbouweekblad, 30 Augustus 2013

[e]Vladimír Lapčík1, V. and Lapčíková, M. 2012. Possibilities of energy recovery from municipal waste / možnosti energetického využití komunálního odpadu. Geoscience Engineering. Volume LVIII (2012), No.4 http://gse.vsb.cz p. 49-58, ISSN 1802-5420

Varela, F. 2006. Plugging the gap: A survey of world fuel resources and its impact on the development of wind energy, World Fuel Resources Ltd, United Kingdom

Vecchiatto, P. 2013. Electricity tariff rises have hurt economy, says energy minister. Retrieved from http://www.bdlive.co.za/business/energy/2013/10/28/electricity-tariff-rises-have-hurt-economy-says-energy-minister on 17 April 2014

Visser, G.A.V. 2002. Waste Management in South Africa – The Role of Government. International Waste Management Biennial Congress, Durban: November 2002, pp. 321–325

Weiers, W. and Fischer, R. 1978. The Disposal and Utilisation of Abattoir Waste in the European Communities. Published by Graham & Trotman for the Commission of the European Communities. ISBN 0 86010 0731

Yount, K. 2006. Populations and Sampling. Research Design and Statistical Analysis for Christian Ministry. 4th Ed.

APPENDICES

APPENDIX 1 – QUESTIONNAIRE

Abattoir Waste Disposal
Processor Questionnaire

<u>**General Information**</u>

1. Abattoir name: ***Click here to enter text.***
2. Contact Person: ***Click here to enter text.***
3. Appointed position: ***Click here to enter text.***
4. Phone Number: ***Click here to enter text.***
5. Address of Abattoir: ***Click here to enter text.***
   Click here to enter text.
   Click here to enter text.
   Click here to enter text.
6. Date of establishment: ***Click here to enter text.***
7. Name of owner/s: ***Click here to enter text.***
8. Under which category of abattoirs are you registered?

   ☐***High Throughput*** ☐***Low Throughput*** ☐***Rural***

9. Main type and number of animals slaughtered?

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Sheep/Goat	*nr*	*nr*	*nr*	*nr*	*nr*	*nr*	*nr*	*nr*	*nr*	*nr*	*nr*	*nr*	*nr*
Lamb	*nr*	*nr*	*nr*	*nr*	*nr*	*nr*	*nr*	*nr*	*nr*	*nr*	*nr*	*nr*	*nr*

Cow/Ox/Bull	***nr***	***nr***	***nr***	***nr***	***nr***	***nr***	***nr***	***nr***	***nr***	***nr***	***nr***	***nr***	***nr***
Calve	***nr***	***nr***	***nr***	***nr***	***nr***	***nr***	***nr***	***nr***	***nr***	***nr***	***nr***	***nr***	***nr***
Horse	***nr***	***nr***	***nr***	***nr***	***nr***	***nr***	***nr***	***nr***	***nr***	***nr***	***nr***	***nr***	***nr***
Pig(sausage)	***nr***	***nr***	***nr***	***nr***	***nr***	***nr***	***nr***	***nr***	***nr***	***nr***	***nr***	***nr***	***nr***
Pig (bacon)	***nr***	***nr***	***nr***	***nr***	***nr***	***nr***	***nr***	***nr***	***nr***	***nr***	***nr***	***nr***	***nr***
Pig (porker)	***nr***	***nr***	***nr***	***nr***	***nr***	***nr***	***nr***	***nr***	***nr***	***nr***	***nr***	***nr***	***nr***
Other	***nr***	***nr***	***nr***	***nr***	***nr***	***nr***	***nr***	***nr***	***nr***	***nr***	***nr***	***nr***	***nr***

10. What is your abattoir's capacity of slaughter units per year? ***Click here to enter text.***

11. How many days is the abattoir operating per year? ***Click here to enter text.***

12. How many people are employed at the abattoir? ***Click here to enter text.***

13. What area does the following occupy (m^2)?

    - Liarages ***Click here to enter text.***
    - Abattoir ***Click here to enter text.***
    - Space for further expansion ***Click here to enter text.***

14. Method of cleaning:

    - Liarages ***Click here to enter text.***
    - Slaughter area ***Click here to enter text.***

<u>Operations & Financials</u>

<u>Electricity</u>

15. What type of electricity does your abattoir use?

☐ ***Single phase electricity*** ☐ ***3-phase electricity***

16. What is the amount (kW) of electricity used annually? ***Click here to enter text.***

17. How much electricity does your abattoir use per slaughter unit? ***Click here to enter text.***

18. What is cost of annual electricity (R) usage? ***Click here to enter text.***

19. What is the current cost (R) of electricity per unit (KW)? ***Click here to enter text.***

20. Who is your abattoir's electricity supplier? ***Click here to enter text.***

Water

21. How is water supplied to your facility? ***Click here to enter text.***

22. How much water (kilolitres) does your abattoir use annually? ***Click here to enter text.***

23. How much water (kl) does your abattoir use per slaughter unit? ***Click here to enter text.***

24. What is the annual cost (R) of water used at your facility? ***Click here to enter text.***

25. What is the current cost (R) of water per unit (l)? ***Click here to enter text.***

26. How much waste water (l) does your abattoir produce per annum? ***Click here to enter text.***

27. How are the waste water treated?
Click here to enter text.

28. Are you levied for waste water by the local municipality?
☐ ***Yes*** ☐ ***No***

29. If yes, how much (R) per annum? ***Click here to enter text.***

Waste Products

Manure

30. What is the total amount of animal manure produced per slaughter unit (including liarages) (Kg)? ***Click here to enter text.***

31. Is the animal manure processed or disposed? ☐ ***Processed*** ☐ ***Disposed***

32. If disposed how? ***Click here to enter text.***

33. What is the cost of disposal of animal manure? ***Click here to enter text.***

34. If processed, describe the method of processing:
    Click here to enter text.

35. What is the end product after processing?
    Click here to enter text.

36. What is this product used for / purpose?
    Click here to enter text.

37. What is the cost of processing? ***Click here to enter text.***

38. Amount received for product? ***Click here to enter text.***

<u>Blood</u>

39. What is the total amount of blood produced per slaughter unit? ***Click here to enter text.***

40. Is the animal blood processed or disposed? ☐***Processed*** ☐***Disposed***

41. If disposed how? ***Click here to enter text.***

42. What is the cost of disposal of blood? ***Click here to enter text.***

43. If processed, describe the method of processing:,
    Click here to enter text.

44. What is the end product after processing?
    Click here to enter text.

45. What is this product used for / purpose?
    Click here to enter text.

46. What is the cost of processing? ***Click here to enter text.***

47. Amount received for product? ***Click here to enter text.***

Condemned Meat

48. What is the total amount of condemned carcases/meat produced per slaughter unit?
    Click here to enter text.

49. Are the condemned animal products processed or disposed? ☐***Processed*** ☐***Disposed***

50. If disposed how? ***Click here to enter text.***

51. What is the cost of disposal of condemned animal products? ***Click here to enter text.***

52. If processed, describe the method of processing:
    Click here to enter text.

53. What is the end product after processing?
    Click here to enter text.

54. What is this product used for / purpose?
    Click here to enter text.

55. What is the cost of processing? ***Click here to enter text.***

56. Amount received for product? ***Click here to enter text.***

Horns

57. What is the total amount of horns or hooves produced per slaughter unit?
    Click here to enter text.

58. Are horns processed or disposed? ☐ ***Processed*** ☐***Disposed***

59. If disposed how? ***Click here to enter text.***

60. What is the cost of disposal of horns or hooves? ***Click here to enter text.***

61. If processed, describe the method of processing:,
    Click here to enter text.

62. What is the end product after processing?
Click here to enter text.

63. What is this product used for / purpose?
Click here to enter text.

64. What is the cost of processing? ***Click here to enter text.***

65. Amount received for product? ***Click here to enter text.***

Other

66. What other waste products are disposed or processed?
Click here to enter text.

67. If disposed how? ***Click here to enter text.***

68. What is the cost of disposal of other waste products? ***Click here to enter text.***

69. If processed, describe the method of processing:
Click here to enter text.

70. What is the end product after processing?
Click here to enter text.

71. What is this product used for / purpose?
Click here to enter text.

72. What is the cost of processing? ***Click here to enter text.***

73. Amount received for product? ***Click here to enter text.***

Non Production Waste

74. What types and how much non production waste (boxes, plastic, etc.) do you produce?
Click here to enter text.

75. Are non-production waste processed or disposed? ☐***Processed*** ☐ ***Disposed***

76. If disposed how? ***Click here to enter text.***

77. What is the cost of disposal of non-production waste? ***Click here to enter text.***

78. If processed, describe the method of processing:
    Click here to enter text.

79. What is the end product after processing?
    Click here to enter text.

80. What is this product used for / purpose?
    Click here to enter text.

81. What is the cost of processing? ***Click here to enter text.***

82. Amount received for product? ***Click here to enter text.***

<u>Other</u>

83. Do you separate srm (specific risk materials)? ☐ ***Yes*** ☐ ***No***

84. If not, could you do so? ☐ ***Yes*** ☐ ***No***

85. Would you want to change your current waste disposal or handling method?
    Click here to enter text.

86. Please motivate why?
    Click here to enter text.

87. Do you expect production to increase or decrease in next 5 years? ☐ ***Yes*** ☐ ***No***

88. If so, by what %? ***Click here to enter text.***

89. Would you like to apply waste to energy conversion methods? ☐ ***Yes*** ☐ ***No***

90. Do you know of such methods that exist, and if so what kind of methods do you know of?
    Click here to enter text.

91. What type of waste to energy conversion methods would you like to apply to your abattoir and please motivate the reason?
    Click here to enter text.

92. Would you consider using the 5th quarter for energy production rather than selling the offal products as food?
Click here to enter text.

93. Please motivate the reason for the above answer?
Click here to enter text.

94. Have you investigated other methods of waste management or waste to energy conversion methods? ☐***Yes*** ☐ ***No***

95. What methods have you investigated?
Click here to enter text.

96. Please motivate the reason why or why not would you apply these methods?
Click here to enter text.

97. What information would you like to receive out of a study like this?
Click here to enter text.

98. Any other comments or remarks?
Click here to enter text.

Thank you very much for your participation!

To submit, please save and send this document to: swanepoeljw@gmail.com

UFS UV BUSINESS SCHOOL SAKESKOOL BE WORTH MORE WEES MEER WERD

be worth more

APPENDIX 2 – LETTER TO PARTICIPANTS

1 July 2014

To whom it may concern

USING WASTE TO GENERATE ENERGY AT AN ABATTOIR

Background

Abattoirs in South Africa struggle to rehabilitate waste due to a lack of resources, bad management and low prioritization. The ineffective management of animal waste products could cause substantial environmental damage. Uncontrolled spillage of waste products such as animal blood and waste water could cause health risks as well as environmental instability.

Thus the question: "Is there an alternative way to manage or disperse of abattoir waste, saving money and the environment? "

The second problem comprise of the fact that the main means of power generating in South Africa are getting very expensive. Electricity is the main expense at an abattoir. Therefore, alternative methods of generating power, in a sustainable, green and cost effective way, have to be explored.

As such, the following thermal and biological technology segments are examined:

- Incinerators and combustion applications
- Advanced thermal technologies
- Anaerobic digesters

T: +27(0)51 401 3163
F: +27(0)86 655 8044
E: oberholzereh@ufs.ac.za
http://bus.ufs.ac.za

Room 312
EMS Building, Block B
205 Nelson Mandela Drive
Bloemfontein 9301

PO Box 339 (IB17)
Bloemfontein 9300
South Africa

UNIVERSITY OF THE FREE STATE
UNIVERSITEIT VAN DIE VRYSTAAT
YUNIVESITHI YA FREISTATA

This purpose of this study is therefore to research the most efficient method to use abattoir waste to generate renewable power.

The objectives would therefore be the following:

- To establish a cost effective and sustainable alternative to manage and use abattoir waste to generate power.
- To compare the relevant waste to energy equipment with current sources of energy production.
- To research the amount of abattoir waste needed to produce the required amount of energy to make it viable.
- To develop a waste management system or model that could be applied to any abattoir or closed urban unit.

Importance and benefit of the study

This study will have many benefits that will accrue due to the relevance of its nature. Since very few abattoirs are informed about the newest technology that is available with regards to waste to energy, this study will firstly serve as an introduction to this new technologies. It will give abattoirs a viable method of getting rid of waste and in the same time using waste as means of generating energy to be used at the abattoir.

The second important aspect that this study will show is the design of a financial model to determine whether it is viable to erect this technology and how many waste from slaughtered animals are necessary to generate sufficient energy.

Your help in filling out the questionnaire and providing the researcher with the sufficient data would bring valuable information to the table. Personal information that you provide would be kept confidential, but other information would be used for statistical purposes.

I shall provide the final document to the participants of the study.

Thank you very much for your participation!

Kind regards

J.W. Swanepoel

(M. Sc. Agric & MBA)

0784577655

swanepoeljw@gmail.com