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Master of Town and Regional Planning

Evaluating the Viability of using Methane Gas Produced within Landfill processes to generate electricity: A Case Study of Mariannhill Landfill Site, eThekwini Municipality, South Africa.

By

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DECLARATION

I, Mr Sandile Zulu declare as follows:

The work on which this thesis is my original work (except where acknowledgements indicate otherwise) and that neither the whole work nor any part of it has been, is being, or is to be submitted for another degree in this or any other university.

Signed _____ Date_____

DEDICATION

Ntombifuthi Idah Zulu

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LIST OF ACRONYMS

BRT	:	Bus Rapid Transit
CDM	:	Clean Development Mechanism
CEMIG	:	Companhia Energetica de Minas Gerais
CER	:	Certified Emission Reduction
CFM	:	Cubic Feet Per Minute
CO2	:	Carbon Dioxide
CTRS	:	Centro de Tratamento de Residuos Solidos
DOE	:	Department of Energy
DSW	:	Durban Solid Waste
ER	:	Emissions Reductions
EU ETS	:	European Union Emission Trading Scheme
GASMIG	:	Companhia de Gas de Minas Gerais
GHG	:	Green House Gases
GIS	:	Geographic Information System
GNI	:	Gross National Income
GNP	:	Gross National Product
GWH	:	Gigawatt Hours
HWMS	:	Halton Waste Management Site
IEA	:	International Energy Agency
IPCC	:	Intergovernmental Panel on Climate Change
IPP	:	Independent Power Producer
IRENA	:	International Renewable Energy Agency
KWH	:	Kilowatt Hours

LFG	:	Landfill Gas
LFGE	:	Landfill Gas-to-Energy Project
LG2EP	:	Landfill Gas to Electricity Project
MSW	:	Municipal Solid Waste
MW	:	Megawatt
MWH	:	Megawatt Hours
NDP	:	National Development Plan
NERSA	:	National Energy Regulator of South Africa
NGP	:	New Growth Path
OHESI	:	Oakville Hydro Energy Services Incorporated
PCF	:	Prototype Carbon Fund
PDD	:	Project Design Document
PPA	:	Power Purchase Agreement
PRUNIT	:	Plant Rescue Unit
REFIT	:	Renewable Energy Feed-in Tariff
REPA	:	Renewable Energy Purchasing Agency
SBO	:	Single Buyer Office
TV	:	Television Set
UNFCCC	:	United Nations Framework Convention on Climate Change

ABSTRACT

With South Africa facing the urgent crisis of a shortage of energy; the drawbacks are deeply felt by the population who continuously face increasing electricity prices. In addition, Eskom is the hegemonic energy supplier of electricity in the Republic, mainly through the combustion of coal. A process that is not environmentally sustainable, and resembles an outdated method of generating energy. Thus, this calls for a change in basic assumptions within the production of energy. Moreover, alternative energy sources ought to be developed to diversify the energy sector. Considering this, the following thesis seeks to explore and validate the use of methane gas extraction to produce electricity from a renewable energy source perspective. The focus of this research is to evaluate the viability of using methane gas extraction within landfill sites to generate energy. This was achieved through the assessment of the Mariannhill Landfill Site, which has been generating electricity from capturing methane gas since 2006 (making this the ideal time to undertake such a study as the gas-to-electricity project at the Mariannhill Landfill Site has been operating for just over 10 years). The findings show that 90% of people feel that there are tangible benefits from the use of alternative energy (making specific reference to gas-to-electricity projects). In as much as it can be agreed on that alternative energy sources yield concrete benefits; the findings reveal that alternative energy sources within South Africa produce very little benefits. This is largely due to the bias governing policy (the Renewable Feed-in tariff, REFIT) that deals with the electrification of alternative energy sources. Alternative energy sources (making specific reference to methane gas capture) produce substantial amounts of energy, but cannot plug the energy back into the electricity grids (both the national and local grid) as the tedious policy forms a challenging barrier. This calls for an immediate address of this piece of legislation to realise the maximum benefits of alternative energy (especially methane gas capture).

CHAPTER ONE

INTRODUCTION

1.1 Title

Evaluating the viability of using methane gas produced within landfill processes to generate electricity: A Case study of Mariannhill Landfill Site, eThekwini Municipality, South Africa.

1.2 Introduction

South Africa faces many challenges towards its development. One critical challenge that the country faces is that of the energy shortage. With the country experiencing recent black outs (especially in the year 2014) - many businesses were negatively affected and thus, performed poorly and less productive during this time (Statistics South Africa, 2013). This poses major threats to the country's stability and development. Hence, serious intervention to reduce the load on Eskom would be extremely beneficial to the country's development.

This rising issue of climate change is another crucial issue that seems to be creeping up on both Africa as a continent and the country at large. The rising temperatures occurring through the global warming phenomenon are a serious concern for the country with regards to a number sectors (for example; the health sector and the wildlife and tourism sector). According to Harkiolakis (2013) many argue that this process is in fact a natural process, however, even if that is the case – the effects of global warming are still very harmful to mankind (for example; skin cancer from a result of excessive ultra violet rays from the sun) and thus need to be mitigated against. One very common way to mitigate against global warming is the use of air-conditioning within buildings – a process that requires an enormous amount of energy in terms of electricity.

These two vast challenges (the lack of energy to drive development and the issue of climate change) only point out to one solution – that being to explore alternative ways to produce energy. Furthermore, these alternative energy sources need to help reduce climate change and its effects. This suggests that these alternative methods need to form part of the clean energy (renewable energy) spectrum. Thus, this dissertation aims to explore solutions to address these problems accordingly. This dissertation seeks to discover the viability of using methane gas produced within landfill sites to produce energy. The Mariannhill Landfill Site has been chosen as the study area for this specific study. The conversion of methane gas adds enormous value

to the reduction of climate change. This is due to methane gas being one of the most potent Green House Gases (GHG) that contribute towards global warming.

Furthermore, the research project aims to find an alternative way to produce energy to fuel the cities in the country. This translates into the reduction of Eskom's load. And once again snowballs into the country moving forward in terms of its development and its journey towards becoming a first world country. In addition, with more energy becoming available to Eskom from alternative sources, a reduction of the price of energy can be expected. This will go a long way in ensuring more households are warm during winter and thus, do not suffer from the harsh effects of climate change.

1.3 Background

The topic for this study looks at the viability to generate energy from methane gas within landfill sites. The reason behind this is the fact that generating energy from methane gas within landfills has already been investigated and implemented (eThekwini Municipality, 2015). This suggests that it is already known that energy generation from methane gas is possible. Thus, this specific dissertation aims to find out how viable this process is. The researcher aims to find out if this process of generating energy from methane gas within landfill sites is a route that the government can take to effectively produce a significant amount of energy that will reduce the load on Eskom. Furthermore, one seeks to find out if this process can become standard practice in landfill sites across the country due to the costs incurred during the process being considerably lower than the benefitting outcomes.

The Mariannhill Landfill Site is among the first pioneer projects to generate energy from methane gas in the eThekwini region. According to eThekwini Municipality (2015) the energy generation plant at the Mariannhill and Bisasar Landfill Sites were built between 2003 and 2010 (whereby Mariannhill Landfill Site went live in December 2006) under the Durban Landfill Gas to Electricity Project (LG2EP). With the Mariannhill energy plant having been operational since 2006, one can evaluate its progress over the last 10 years. The fact that this energy generation project has been in operation for a decade, suggests that the constraints and the benefits of this kind of energy production are well understood by the relevant personnel working at the Mariannhill Landfill Site Energy Plant. Thus, this evaluation should give a good indication with regards to the viability of energy generation through the conversion of methane

gas at the landfill site and give indication whether this process could possibly be commercialised or not.

Furthermore, the Mariannhill Landfill Site is best suited for this study based on two defining reasons. Firstly, the Mariannhill Landfill Site was the first project of its kind in the eThekwini region and secondly, the Mariannhill Landfill Site has a conservancy on the site. The significance of the conservancy on the site is very integral to this specific study in the sense that the study aims to find an alternative way to generate significant amounts of energy towards the national grid – however, at the same time, this energy must also be safe for humans and contribute towards clean energy (renewable energy). Thus, the conservancy shows that the Mariannhill Landfill Site is doing its bit in protecting the environment and on the same note protecting humans.

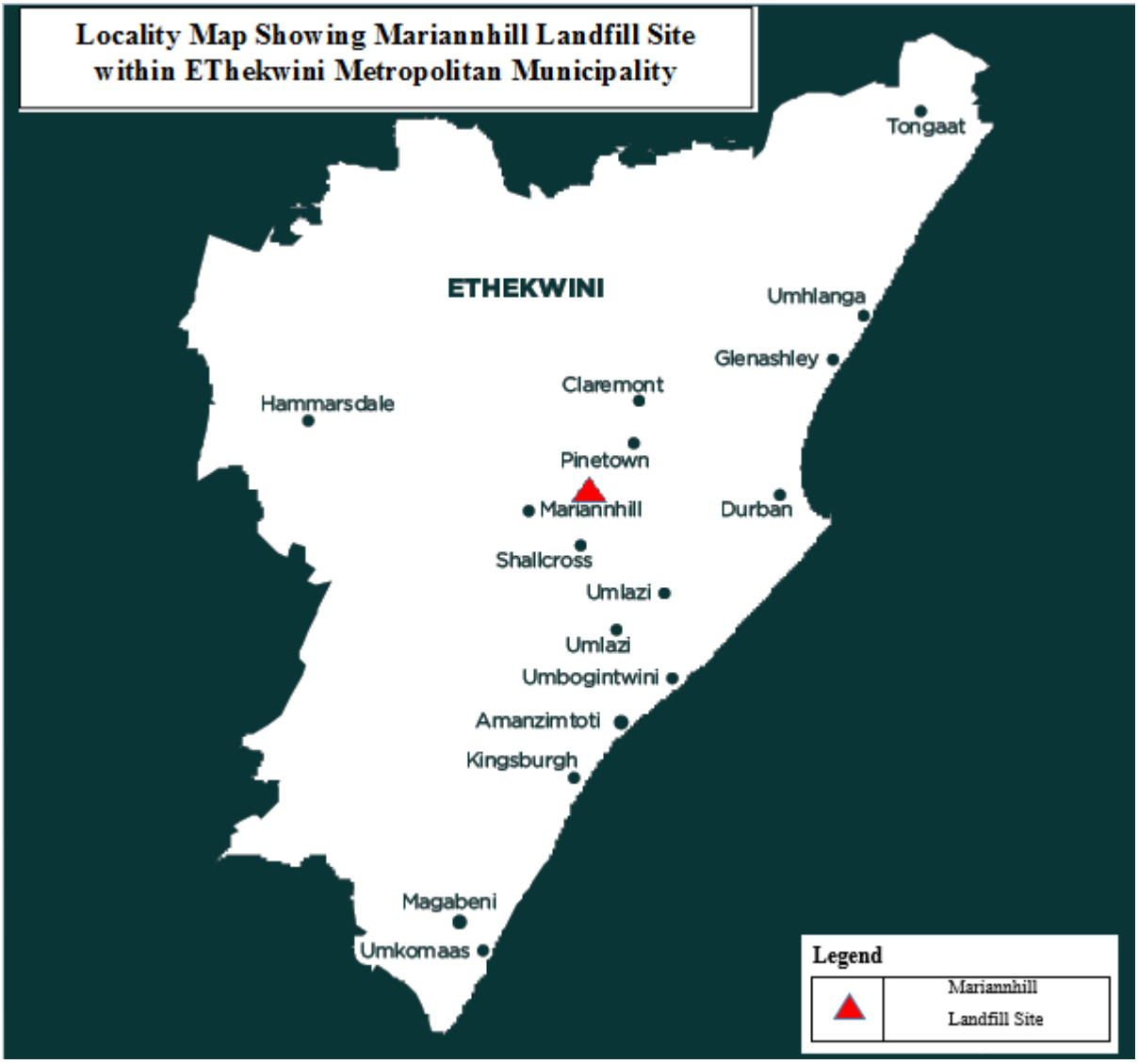
Figure 1.1 Mariannhill Landfill Site

Source: http://www.resource-india.net/CivilEngNov2007.pdf (accessed 10 February 2016 @ 21:45).

1.4 Description of the Case Study

The Mariannhill Landfill Site is situated roughly 21km west of Durban (South Africa) in the town of Pinetown.

Map 1.1 Locality Map Showing Mariannhill Landfill Site within EThekwini Metroplotan Municipality



Source: www.municipalities.co.za (accessed 21 March 2017 @ 23:44).

The Mariannhill Landfill Site consists of several sustainable projects that it runs; these projects include the Mariannhill Landfill Conservancy, the plant rescue unit (also known as PRUNIT), the Landfill Gas to Electricity Project and the following projects:

- *The Red Data Species*: This section deals with the protection of endangered species (specifically the Black-headed Dwarf Chameleon and the Hilltop Chameleon) and works together with the Kwa-Zulu Natal Ezemvelo Wildlife Organisation.
- *The Leachate Treatment Department:* this section deals with ensuring that the harmful chemicals that are derived from waste in the landfill do not leak into the surface and ground water and eventually poison animals and people.
- *The Rehabilitation (Carbon Sinks):* this section deals with restoring the environment to its natural state after it has been dug up and filled with waste. This section is responsible for the planting of trees, grass and other vegetation to ensure the land returns to its natural state.
- *The Re-use and Recycle Department:* this section deals with the recycling of rubbish or unwanted items within households (especially glass) to ensure that these items can be used again either for the same function or a different function.
- *The Biological Control Department:* this section deals with the killing of alien species to keep the environment safe from alien species. This section works very closely with the conservancy.

Landfill Conservancies (2010)

1.5 Problem Statement

South Africa is a developing country according to global standards and therefore, has a great deal of catching up to do in terms of development (National Development Plan, 2011). This suggests that the country needs to undergo huge development projects that will bring change to the country and thus make the lives of people living within South Africa easier, safer and better. According to the Government Communication and Information System (2015) the creation of jobs through faster economic growth and improving of infrastructure are among the main objectives stipulated within the NDP. Thus, one can see that the South African Government is taking crucial strides towards developing the country.

However, the country faces an electricity crisis (as mentioned above), which poses a huge challenge towards development (Inglesi, 2010). This is further backed up by Statistics South Africa (2013) with the statistics that confirm that the electricity available for purchase locally

in the country between 2010 and 2013 decreased from 239 474 GWh to 236 760 GWh. This shows that the country's energy availability dropped and this may have reacted negatively on development. Furthermore, this suggests that the energy sector in the country would be a good spot to invest a great deal of research to remedy the situation before the situation gets worse (Davids, 2012).

According to energy analyst Ted Blom (Inglesi, 2010) loss of capacity caused by planned and unplanned outages advised that Eskom's energy availability could drop by up to 60% of its total amount for a prolonged period. This suggests that the country is at risk of lengthy blackouts (Davids, 2012). Thus, halting and hindering development within South Africa. One can clearly see how significant the planning profession is in terms of planning for the city and merging urban development with energy production. From a spatial planning perspective, this makes it imperative to give focus to the planning of landfill sites that will generate enrgy from a methane gas extraction point of view. Thus, this suggests that spatial planning from a city and municipality planning level ought to strategically engage in the acquiring of land that is suitable for the use of landfill sites.

According to Davids (2012) energy and development clearly go together, thus, it is vital that planning professionals plan carefully for the future. However, the other side of the energy coin deals with the sustainable development debate. This suggests that energy and development are crucial to drive the country forward, however, these strides towards a first world country cannot be at the cost of human lives and the environment (Winkler, 2006). According to the Department of Environmental Affairs (2015) transition to a low-carbon economy remains a long-term goal for the country. This suggests that the government supports the notion of sustainable development. This suggests that landfill sites that produce energy ought to be envinronmentally friendly and not cause harm to human lives. Furthermore, this suggest that landfill sites should be located away from residential areas, and where they (landfill sites) are already located near residential areas, monitoring should take place to ensure that the nearby residents are affected in the least possible way.

However, according to the Department of Energy (2016) 90% of South Africa's energy is generated from coal-fired power stations. This not only questions the government's efforts towards driving sustainable development, however, this shows a high level of unsustainable development habits and non-renewable energy practices (Winkler, 2006). Furthermore, this suggests that alternative methods to generate energy should be explored, especially alternative

methods that contribute towards renewable energy. In conjunction to this, Winkler (2006) claims that the implementation of policies at municipal levels that promote a reduction in carbon emissions could help reduce carbon emissions. For example, industries (such as the oil and gas industry) that produce methane gas as a byproduct should be given incentive to sell their methane gas to landfill sites to generate energy in exchange for carbon points.

1.6 Aim

The aim of this research is to find out if energy production through the conversion of methane gas within landfill sites can become standard practice within landfill sites and significantly contribute to the National Grid.

1.7 Research Objectives

The study's objectives are to:

- Find out how much electricity the Mariannhill Landfill site contributes towards the National Grid.
- Identify the constraints that hinder electricity production from methane gas.
- Identify the benefits of electricity production from methane gas.
- Find out whether the process of generating electricity from methane gas is environmentally sustainable or not.
- Find out how energy production from methane gas within landfill sites affects people living around the landfill.

1.8 Research Questions

Main Research Question:

Is it possible to generate a significant and sustainable amount of energy from methane gas extraction within landfill processes at the Mariannhill Landfill Site, EThekwini Municipality?

Sub-questions:

- Can external energy sources assist Eskom with regards to reducing its load?
- What challenges are involved in the process of generating electricity from methane gas?

- How can man-kind and the City at large benefit from this process?
- How can this process be enhanced?
- Does this process contribute towards clean energy production?
- Does this process align with environmental sustainability?

1.9 Hypothesis

Generating electricity from methane gas within landfill sites is environmentally sustainable, does not harm or pose any threat to human beings and reduces the load on Eskom.

1.10 Rationale

The following study is of a great deal of significance towards the future development of Durban as a city and cities across South Africa. The study is focused on the generation of energy and thus, this gives impetus to the development of the city at large. According to News Twenty-four (2016) a private company proposed a new iconic tower building in the Durban area less than 200m from the Moses Mabhida Stadium - furthermore, a building that would become the tallest building in the southern hemisphere if approved. One can only ponder on the implications of such a building being erected with regards to the energy usage it would take up. This suggests that the city will be at huge energy shortage risks. On the other side of the coin, such a building would bring immense financial expansions to the city and push Durban up the International economic ladder.

The reason for the surfacing of this example of this iconic building is to show how development brings with it energy demands. Therefore, with the country already facing an energy predicament, it becomes evident that the energy production sector within the country ought to be given high priority. With this being said, this suggests that a great deal of monetary assets need to be invested in the energy sector. Furthermore, this places the energy sector at the pinnacle of research currently and at least for the next decade. Hence, the search to find out weather the production of energy through methane gas extraction within landfills is feaseable or not is well within the notion of further investment and research into the energy sector. This not only justifies the following study, however, this gives priority to this specific study.

One can easily realise from the above paragraph that economic development comes with great energy demands. Thus, for development to continue to thrive, such studies on energy

generation hold great value in shaping how cities unravel in the future. This study does not only seek to benefit humans and the city today, however, it seeks to benefit mankind and guide new city form for future generations accordingly.

1.11 Conclusion

The chapter has introduced the study in a clear and concise manner. The introduction and the problem statement coincide with each other as both these headings speak to macro development of the country and its linkage to the importance of energy. In addition, the background and the rationale for this study tie up well in bringing the study back to a micro level in looking at energy generation from a case study perspective at the Mariannhill Landfill Site. The research methodology gives clear indication on what route the researcher will take in addressing the problem in question. The chapter makes it very easy for the reader to anticipate what will follow in the upcoming chapters. The argument in question which is the viability to generate significant amounts of energy from landfill sites with regards to methane gas conversion has been the underlying factor in all the sub headings. And finally, the reader can get an indication of the impetus to explore alternative energy solutions.

CHAPTER TWO

RESEARCH METHODOLOGY

2.1 Introduction

According to Rajasekar *et al* (2006) research methodology is the systematic way to solve a problem. This suggests that research methodology is the steps the researcher takes to solve a problem and ultimately work towards gaining new knowledge. Furthermore, research methodology is the procedure that the researcher undertakes to describe, explain and predict phenomena related to the study (Rajasekar *et al*, 2006). This suggests that this is the plan that the researcher uses to guide their study. Research methodology is important as there may be research that may have already been conducted on the same problem, thus, employing a different research methodology can help people look at the problem differently and may also present slightly different findings (Rajasekar *et al*, 2006). This suggests that the research methodology gives a study its identity and therefore helps the researcher analyse the data collected in the field in a certain way.

Qualitative methods will be employed in the study. Qualitative research methods suggest that the subjects in the study describe their experience in accordance to the research (Currie, 2005). This suggests that qualitative data is subjective as it is based on the subjects' personal experience. Thus, qualitative methods will help explain phenomena in the project in a more descriptive manner (Roy et al, 2009). Which will ultimately help the researcher understand the problem in question better and eventually present more accurate findings.

2.2 Sources of Data (Primary and Secondary)

The researcher will use primary data and secondary data to solve the problems presented in the research problem. These two data sources will help the researcher analyse the findings that will be discussed in the paper. The following study will use the Mariannhill Landfill Site in the eThekwini Municipality in South Africa as a case study.

According to Currie (2005) primary data is data that is previously unknown; this data is collected by the researcher in the field during the data collection phase of a project. This suggests that primary data is raw data that is collected for analyses. This type of data helps the researcher understand the research problem better. Thus, suggesting that primary data can be subjective and can only be relevant in a specific area (Roy et al, 2009). For example, primary

data collected for two different rivers may be different even though the area has a common denominator of a river.

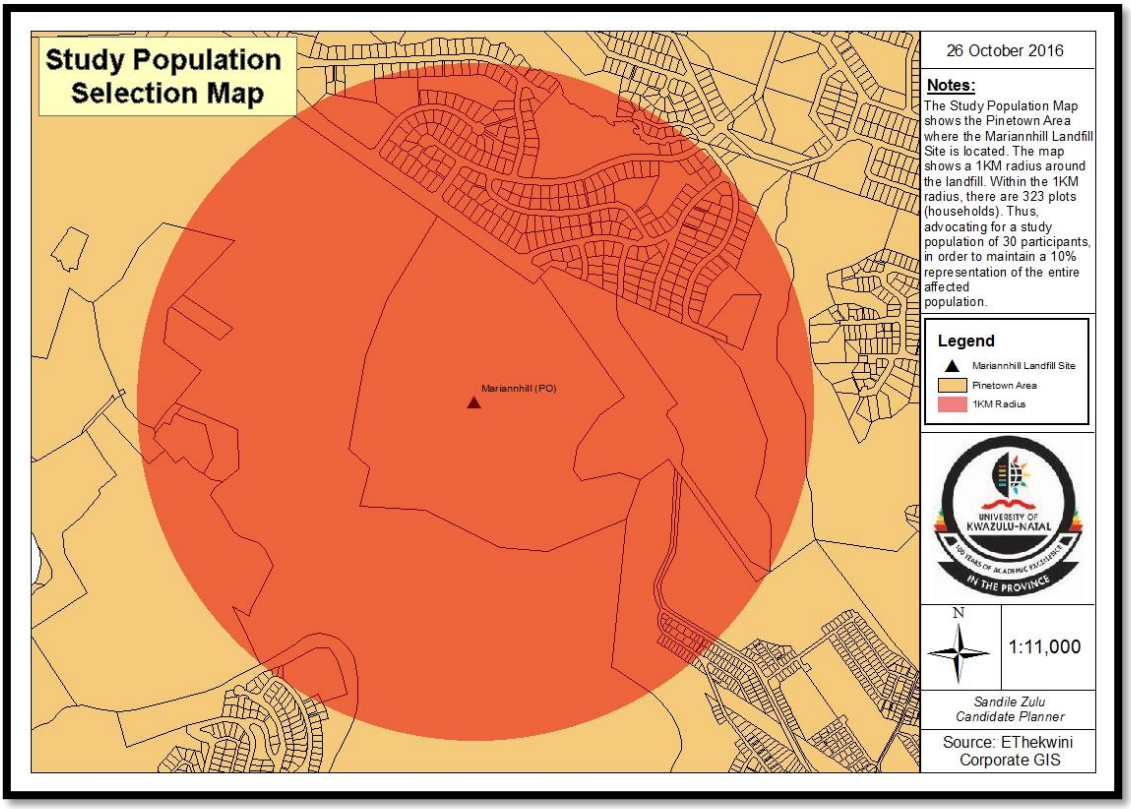
2.2.1 Primary data

The primary data section will make up of three different tools; namely, questionnaires, interviews and observations. The reason behind employing three different methods is to allow for the data to be cross-checked with one another so as to give more accurate results (Currie, 2005).

1. **Face-to-face Questionnaires with Participants**

The face-to-face questionnaires employed in the study belonged to the quota sampling method. According to Mack *et al* (2005) this method allows the researcher to identify people that he/she feels will be best suited to give the most accurate information towards the research. Thus, these face-to-face interviews were directed at adults over the age of 18 who reside within a 1km radius of the Mariannhill Landfill Site. In this way, the researcher could get the views of the people most affected by the electricity generation processes at the landfill site. With the aid of the GIS, the researcher could deduce that there are 323 households (plots) that fit this specific description (1km radius). Therefore, 30 households that fall within this description were randomly selected to participate in the face-to-face questionnaires. The reason behind choosing 30 people within the population gave the study a working sample size that is just under 10% (9, 3%). This is illustrated in map 2.1 below.

Map 2.1 Study Population Selection Map



Source: Author (2016)

2. Semi-structured Interview with Key Informant

A semi-structured interview involving the Project Executive for the Landfill Gas-to-Electricity Project for the EThekwini Municipality was conducted. This part formed the key informant side of the study. The term semi-structured interview suggests that the researcher had a few questions set to ask the interviewee, however, the interviewee is at liberty to respond freely and to an extent change the theme of the interview (Hox and Boeije, 2005). This suggests that more information and deeper explanations can be gathered from the interviewee as they will be responding freely (Currie, 2005). This interview took place on a one-on-one basis.

3. Observations

And lastly, the researcher made use of observations in and around the landfill site. These observations took place at three different time intervals (9am, 1pm and 4pm) and were conducted twice a week. The reason for the observations being held at these respective times

is to allow the researcher to get a holistic understanding of the phenomena at and around the landfill site (Hox and Boeije, 2005). Furthermore, these observation times cover the whole day evenly, hence, allowing the researcher to be able to get more insight on the movements of the trucks bringing in the waste into the landfill site, the landfill activities and the animal activity within and around the landfill site.

The first week saw the observations being conducted on Monday and Wednesday and week two observations were conducted on Tuesday and Thursday. These observations were conducted over a two-week period. The researcher timeously observed how things are done at the electricity generating plant and what goes on in the surrounding area. This allowed the researcher to be able to gather information that had been omitted in the interviews and the questionnaires. Furthermore, the observations also gave the researcher the opportunity to take pictures that were very useful for the project.

2.2.2 Secondary data

A significant part of the research was derived from the secondary data component. According to Johnson and Turner (2003) secondary data refers to information gathered from journals, books, newspapers and other sources of knowledge from the library (such as the internet). This suggests that secondary data deals with information that has already been analysed and therefore already has findings (Currie, 2005). This type of information is very vital in terms of supporting the research and also helping the researcher know which questions have already been answered in terms of the research objectives. Furthermore, secondary data formed much of the literature review in the next chapter, were the researcher went in depth in an attempt to understand similar phenomena around the world that connects with the research project.

2.3 Data Analysis

Once the data had been collected, the data was analyzed using Nvivo as a data analysis tool. The researcher employed a thematic analysis system to the data analysis, where the data was categorized into different themes (groups). This allowed the researcher to be able to easily group similar data together and at the same time this surfaced information that was similar very well. Nvivo also allowed the researcher to be able to create illustrations of the data as the thematic analysis system allowed for the data to be separated into different layers originating from their respective themes.

2.4 Objectives and Chosen Methods Matchup Table

Objective • *The study's objectives are to*	**Source of Data**	**Method**
Find out how much electricity the Mariannhill Landfill site contributes towards the National Grid.	Secondary data- Reports and Primary data	**Semi-structered Interview** (key Informant).
Identify the constraints that hinder electricity production from methane gas.	Primary data	**Semi-structered Interview** (Key Informant).
Identify the benefits of energy production from methane gas towards local development.	Primary data	**Semi-structered Interview** (Key Informant).
Find out whether the process of generating electricity from methane gas is environmentally sustainable or not.	Primary data	**Semi-structered Interview** (key Informant); **Face-to-face Questionnaires** (Sampled population around the Landfill Site).
Find out how energy production from methane gas within landfill sites affects people living around the landfill.	Primary data	**Face-to-face Questionnaires** (Sampled population around the Landfill Site).

2.5 Challenges Encountered in the Field

There were two main challenges that were encountered in this study. The first challenge and perhaps the major challenge was the fact that the locals around the Mariannhill Landfill Site were not available during the day as they were at work. This meant that the data collection phase could not be undertaken during the day. The remedial measure that was taken was to do the field work phase (the face-to-face questionnaires and semi-structured interviews) when the locals are back from work. Thus, the field work phase of the study was conducted on numerous days during the 5pm to 6:30pm time bracket. This posed problems of itself as this was the time that the locals were trying to settle in from work, prepare food, help their children with school

homework and do their household chores. However, the locals were friendly and willing to sacrifice a few minutes of their time to participate in the study.

Another huge challenge that was present during the study was the cost factor. It is very expensive to travel to the Mariannhill Park area from Durban (Howard College) three or four times in a week. The printing of the work is also expensive along with one's meals during the field work phase. In addition, the editor's charges were in the range of R4000. Even though there is a research fund that was granted onto the researcher, the funds have not yet been made available to the researcher. Thus, the study was funded solely on the researcher's own pocket. This is very frustrating as it leaves one in debt; as the researcher had to take a few loans to cover all these costs.

2.6 Conclusion

Clear guidance on how the researcher arrived at the conclusions made in the conclusions and recommendations chapter was discussed in this chapter. The chapter shows what material and research instruments the researcher used in realising the aim and objectives set out in the first chapter (namely, the introduction chapter). In addition, this chapter also includes a section that discusses the challenges encountered during the writing of the whole research. This has given the research a unique human element, as each thesis presents challenges of its' own.

CHAPTER THREE

LITERATURE REVIEW AND PRECEDENT CASE STUDIES

3.1 Introduction

Themelis and Ulloa (2007) argue that methane gas is a by-product of landfilling MSW and this methane gas is later emitted into the atmosphere. This suggests that landfill sites need to find innovative ways to dispose this methane gas in a safe manner that does not harm the atmosphere and in turn perpetuate global warming. In recent years, landfills across the globe have attempted to capture and utilise landfill biogas (which comprises mainly of methane gas) to generate energy (mainly electricity or heat) (Themelis and Ulloa, 2007). This suggests that landfills are attempting to use renewable ways to generate energy.

The following section will address several key aspects concerning methane gas extraction; the section will begin with a discussion explaining the process of generating energy from methane gas and then the section will move onto showing the First Order Decay Modelling method that will help deepen the understanding of the matter further. Furthermore, the paper will discuss the key barriers and proposed remedial measures concerning methane gas extraction for energy generation. The following part of this chapter will look at the precedents that will be drawn out from different examples across the globe. Concerning the international aspect, the study will zoom into both developing and developed countries showing both the successes and failures of methane gas extraction. All these past scenarios will give guidance to the study and pave a path that South Africa can learn from with regards to methane gas extraction.

The rear part of this section will look at the policy context behind energy generation with regards to landfill sites. This section will be broken up into two sub-sections; namely, international policy and South African policy. In this section, the paper will touch on policies that guide energy generation from methane gas from an international perspective and from a South African perspective. More detail will be stressed on the South African perspective, with the paper going deeper into the policy framework with the following headings; environmental, electrification and clean energy legislation.

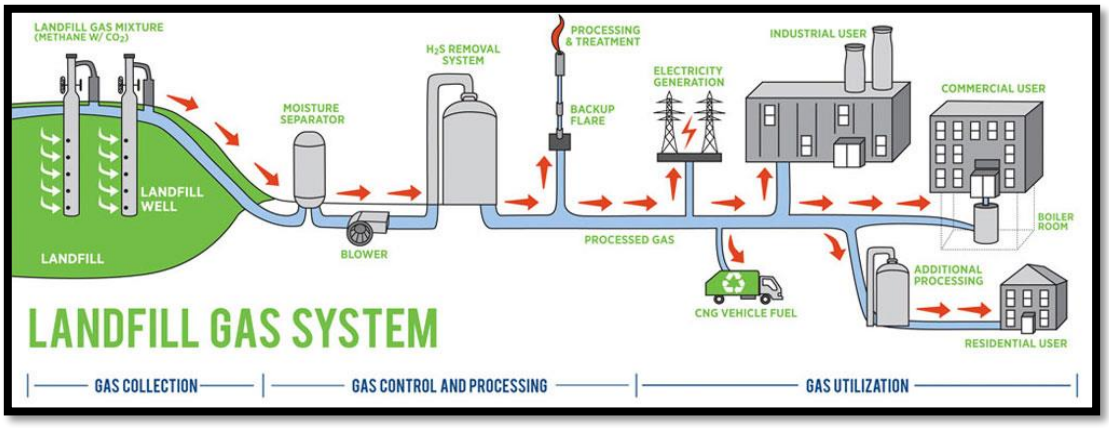
3.2 Process of Generating Energy from Methane Gas within Landfill Sites

The International Renewable Energy Agency (IRENA) (2012) claims that there are two principle waste-to-energy approaches; namely, incineration of waste and LFG capture to

produce energy. Incineration involves the process where waste is combusted (burned) to produce energy and this process is also known as 'thermal treating' (Igoni *et al*, 2008). This suggests that this process is associated with open dump sites and waste is merely burnt as a combustible fuel to produce energy as it changes form from organic material to ash. The downside with incineration are the environmental drawbacks that come with it (for example the smoke produced and the release of harmful particulates into the atmosphere) (Igoni *et al*, 2008). This suggests that this process produces harmful emissions into the atmosphere and thus, leads to excess environmental pollution. The reason behind this method is the fact that it is a simple and cost effective way of reducing waste cumulating in dumpsites, while generating energy (Spokas *et al*, 2006). This method could also lead to accidents associated with fires as this method employs open fires and wind could be a crucial hazard factor. The following paper will focus on landfill gas capture as a method of producing energy from waste.

According to Igoni (2008) landfill gas (which constitutes between 40-60% methane gas) can be captured by a system of vertical or horizontal wells drilled into the landfill site, connected to a blower which creates a partial vacuum to extract the landfill gas out before it escapes into the atmosphere. The wells are connected by pipes that bring the landfill gas to a central point. The landfill gas is then dried and cleaned before being used to drive a generator to create electricity (energy) or it can be purified further to be used as natural gas. This process is shown with the diagram labelled figure 3.1 below.

Figure 3.1 Diagram showing the Process for Energy Generation from Landfill Gas



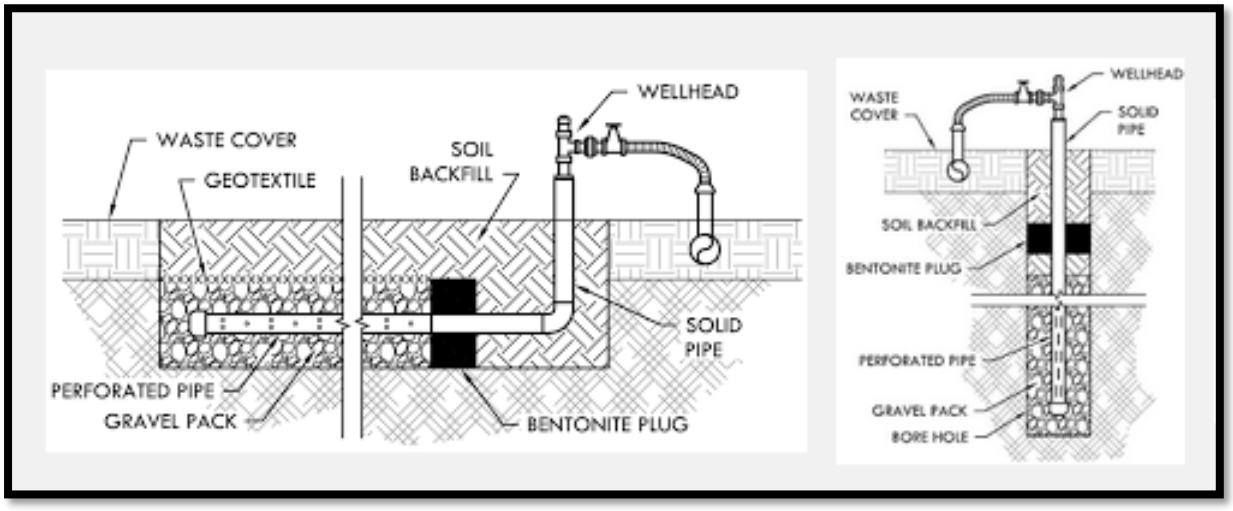
Source: Google Images (2016) (accessed on 17 June 2016 @ 21: 02).

Any excess gas should be combusted using an enclosed high temperature flare (Spokas *et al*, 2006). Many small CDM projects use only flaring, which does not produce useful energy but

reduces greenhouse gas emissions (Spokas *et al*, 2006). This suggests that the process of generating energy from landfill sites requires skilled professionals to undertake this process for maximum energy to be generated and at the same time ensuring that the waste to energy plant is as safe as it can possibly be for both the employees and the nearby locals.

The vertical and horizontal landfill gas extraction wells can be the success or downfall of LFGE projects; this is due to the fact that the terrain of the landfill site plays a crucial role in terms of how the landfill gas can be collected (IEA, 2008). This suggests that LFGE projects that are located on steep landfill terrain may be better suited to vertical landfill gas extraction wells, LFGE projects on more gentle land may be better suited to horizontal landfill gas extraction wells and some LFGE projects may be better suited to a combination of both vertical and horizontal landfill gas extraction wells. The following diagram (figure 3.2) shows the two-different landfill gas extraction wells (vertical and horizontal).

Figure 3.2 Horizontal LFG extraction well (left) and Vertical LFG extraction well (right)



Source: Google Images (2016) (accessed on 29 June 2016 @ 14: 20).

The horizontal landfill gas extraction well on the left shows how the pipe is drilled first vertically into the soil and then laid horizontally in a gravel pack (an area packed with gravel stones) (Townsend *et al*, 2005). The horizontal part of the pipe is laid under the layer of the waste so that the gas that has formed anaerobically from the waste decomposing is channeled by gravity downwards into the pipe (Townsend *et al*, 2005). In between the waste and the gravel pack lies a crucial gas permeable layer of geotextile material that stops pieces of waste from getting to the pipes and blocking them, this layer only allows the methane gas to pass through into the pipes (Townsend *et al*, 2005). The vertical extraction well operates in a similar

fashion to the horizontal wells. The pipes are laid in a vertical manner with vertical extraction wells. There also exists a gravel pack surrounding the pipe for protection (Yu *et al*, 2009). Furthermore, the pipes are also laid under the waste cover level (Yu *et al*, 2009). In addition, both vertical and horizontal pipes are back filled with soil (Townsend *et al*, 2005). Moreover, both types of pipes are connected to a wellhead above the ground that gives measurements on the amount of gas being extracted (Yu *et al*, 2009). These wellheads are then connected to the entire piping system that brings the methane gas to a central point (Yu *et al*, 2009).

Prior to the construction of a LFGE project within a landfill site, a feasibility study must be undertaken. If the feasibility study estimates suggest that sufficient landfill gas will be produced, a pump test should be carried out to confirm model estimates. This involves drilling wells in a restricted area, monitoring the gas flow for a period of time and extrapolating the results for the whole landfill site (Yip and Chua, 2008). It is difficult to estimate the amount of landfill gas emitted by a landfill as this depends on a number of factors, these factors include the following:

- The history of the MSW dumping (tonnes per day);
- The MSW composition (fast, medium and slow biodegradable content);
- The depth of the landfill site; and
- The climate, including average temperature and precipitation. (IPCC, 2006).

Hao *et al* (2008) argue that there are some risks when building and running a LFGE project, such as potential for exposure to high concentrations of methane at the wellheads during construction, or for accidents related to electricity generation and flaring equipment. This suggests that skilled professionals need to be employed to undertake the construction of such projects to minimise the risks. Furthermore, it is ideal to plan the LFGE project in the original design of the landfill by sealing the base of the landfill, filling the landfill cell by cell, and capping each cell as it is filled (Wanichpongpan and Gheewala, 2007). Thus, careful planning of landfill sites needs to occur to place a landfill site in the best possible position to generate electricity from landfill gas.

The financial viability of LFGE projects depends on many factors; namely the capital costs for the gas collection system, power generation equipment and/or gas pipelines or power lines, costs of operation and maintenance, the tariffs paid for electricity or natural gas generated, the eligibility for CDM carbon credits and any capital subsides available in the form of loans or grants (Hao *et al*, 2008). All these factors suggest that LFGE projects require strategic planning

and the cost factor is a stressing concern. Thus, it is important for a country to engage different departments to ensure the success of LFGE projects. However, when looking beyond the financial costs, the benefits (namely; energy generation, destroying of methane gas which results in a cleaner environment and reduction in greenhouse gases and a reduction in the risk of explosions as methane gas becomes explosive in large concentrations (Yip and Chua, 2008)) of LFGE projects may prove to strongly outweigh the costs in both the short and long-term from a planning perspective.

3.3 Modelling the Potential Energy Generating Capacity of a Landfill Site using the First Order Decay Model

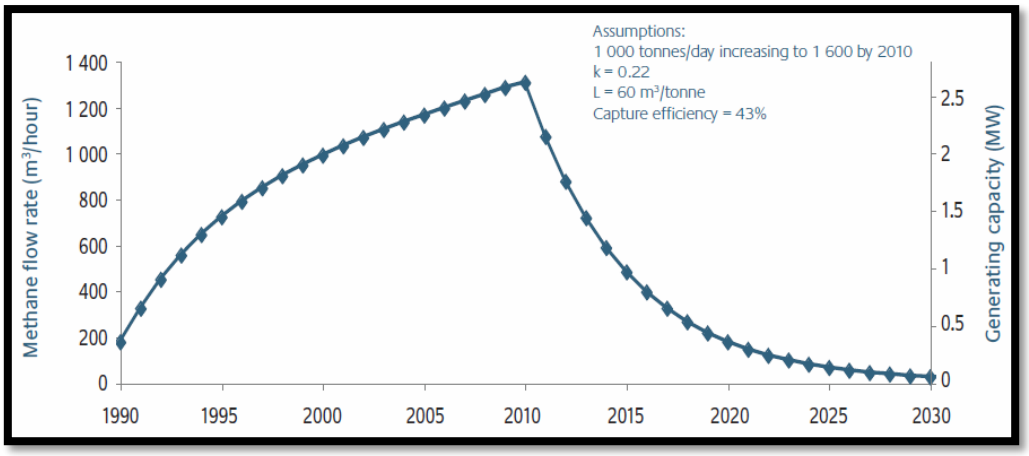
According to the Pingoud and Wagner (2006) LFG models use a first-order decay relationship and estimate emission paths according to that of figure 3.3 below. In this example, the following assumptions have been made:

- A landfill site opened in 1990;
- Receiving 1000 tonnes/day increasing to 1500 tonnes/day by 2010;
- Closing in 2010 after receiving 9.4 million tonnes;
- 43% of methane gas is assumed to be captured; and
- 500 cubic metres/ hour are required per MW (megawatt) of electricity generating capacity.

These assumptions yield a "L" value (the methane potential) of 60 cubic metres/ tonne and produce a "K rate" (speed of decomposition) of 0.22.

The graph below (figure 3.3) shows that methane flow and potential generating capacity swiftly increases until the landfill is closed and then quickly decreases (IEA, 2008). This shows a key issue with regards to LFGE projects as they should be flexible to cope with changing gas flow. Furthermore, the flaring system needs to have the capacity to be able to destroy excess methane, and the generating capacity should be modified with time as the gas flow increases and decreases (IEA, 2008). This suggests that modular generators could be moved to a new landfill site as the flow declines at the closed site.

Figure 3.3 Estimated Generating Capacity Based on a First Order Decay Model for a City Generating 1000 tonnes MSW per day.



Source: IEA (2008) (accessed on 17 June 2016 @ 22:04).

3.4 Key Barriers and Proposed Remedial Measures for LFGE Projects

According to Rajaram *et al* (2012) there are a number of barriers that are associated with LFGE projects; this section will discuss these barriers and also discuss remedial measures that can be taken to overcome these barriers. There are three main issues that raise concerns with regards to LFGE projects; these main issues include LFG recovery, LFG utilisation for power generation, LFG utilisation as fuel (Rajaram, 2012). These key issues will be tabulated (in table 3.1 below) to show the distinction and discussed below the table.

Table 3.1 Key Barriers and Proposed Remedial Measures for LFGE Projects

Key Issue	Major Barriers	Remedial Measures
LFG recovery	• Lack of mechanism of coordination and management.	• Set up coordination groups.
	• Lack of capital for setting up engineered landfill sites.	• Increase government input • User charge • Bilateral and multilateral fund • Commercial finance
	• Lack of successful experiences of LFGE projects.	Develop demonstration projects based on international experiences.
	• Lack of operation and maintenance experiences for engineered landfills	• Implement the demonstration projects • Prepare training materials • Build training centres • Conduct the relevant training

	• Lack of awareness of harmful impacts of emission of LFG.	• Propaganda by various media • Study tours to other countries/ cities • Print brochures
	• Lack of model for LFG generation potential.	Develop the software and models according to country specific conditions on the basis of international experiences
LFG utilisation for power generation	• Lack of definite and attractive policy of energy price.	Determine the energy price of LFG power generation.
	• Absence of standard Power Purchase Agreement (PPA).	Comprehend standard PPA.
	• Difficulty in grid connection.	• Adopt the energy grid-connected policy for renewable energy. • Mandatory Market Share. • Green energy price
	• Difficulty in determination of energy potential due to lack of LFG estimation model.	Develop suitable models of LFG generation and optimal energy capacity.
	• Lack of financial support from Government agencies.	Financial support from Government agencies.
LFG utilisation as fuel	• Lack of purification technology of LFG.	Develop the purification technology.
	• Lack of financial support from Government agencies.	Financial support from Government agencies.

Source: Rajaram *et al* (2012) (accessed on 21 June 2016 @ 12:54).

When looking at the first key issue; namely, landfill gas recovery, there are several barriers that have been mentioned and different countries may face different barriers depending on different factors such as the economic state of a country. The most pressing issue with regards to this key issue could perhaps be the coordination and management of LFGE projects, as this requires skilled professionals and this may be costly towards the energy departments within a country (Wang and Chen, 2010). The remedial measures stated show that negotiations with the relevant stakeholders is key in resolving these concerns in the attempts to drive LFGE projects and capitalise on the benefits associated with LFGE projects (McCormick and Kaberger, 2007).

The second key issue; namely, landfill gas utilisation for power generation, is a key issue that is heavily dependent on the organs of state that are responsible for the enactment of laws and policy with regards to energy and specifically clean energy development (McCormick and Kaberger, 2007). This suggests that governments need to implement legislation that drives both

clean energy projects of this nature and provide accessible ways for such projects to be able to translate the energy generated into the national grid. Key stakeholders in this regard would be the private sector. Hence, the government ought to create legislation that make it feasible for private developers to undertake LFGE projects. In addition, the government also needs to provide fiscal support for the development of LFGE projects (McCormick and Kaberger, 2007).

The final key issue: namely, landfill gas utilisation as fuel, looks at the technical side of LFGE projects through the purification technology. This suggests that government should implement higher education avenues to address this issue through bursaries that will train diligent people to acquire these technical skills and can fill this gap (Wang and Chen, 2010). Again, financial support from government agencies remains a crucial way to overcome this issue (McCormick and Kaberger, 2007).

From a spatial planning perspective within South Africa, one key barrier that lies ahead of LFGE projects is the cost factor (Ekhuruleni Metropolitan Municipality: Waste Management Services: Landfill - Annual Report 2010/2011). These projects are very expensive from a capital and operational point of view, thus, making it difficult for municipalities and metros to explore this alternative energy avenue. In simple terms, municipalities would rather focus their fiscal resources to water purification and provision projects, housing projects and infrastructure projects (for example, roads and storm water servitudes) (Ekhuruleni Metropolitan Municipality: Waste Management Services: Landfill - Annual Report 2010/2011). This suggests that municipalities and metros may have considered LFGE projects, for example; Ekhuruleni Municilaity have identified 4 landfill sites with the potential to generate energy from methane gas, of which 2 are already in operation; Simmer and Jack landfill site in Germiston (Frankson, 2015 in Infrastructure News 2015). This suggests that metros are able to match up to the costs that are involved with LFGE projects, even though it may still be difficult for smaller municipalities to engage in such alternative energy projects.

3.5 International Precedents

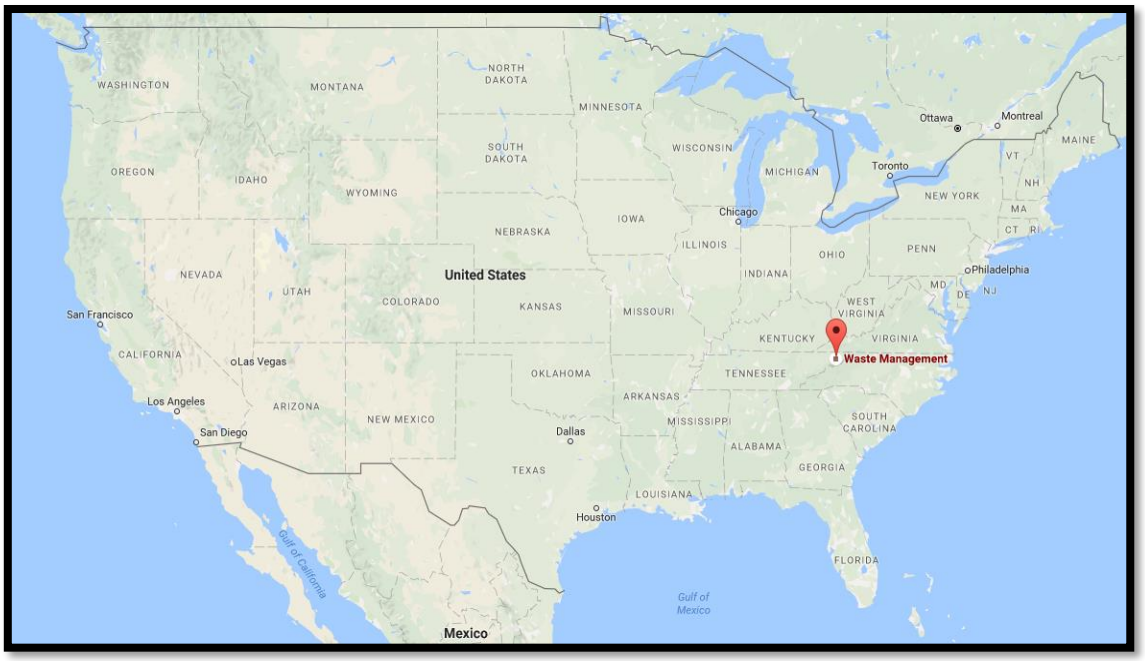
- Developed Countries

3.5.1 Setting the Standard with Iris Glen Landfill Gas to Energy Project in Johnson City, United States.

Map 3.1 Map showing the United States of America

Source: Google images (2016) (accessed on 06 October 2016 @ 21:29)

Map 3.2 Locality map showing Iris Glen Landfill Gas to Energy project



Source: Google maps (2016) (accessed on 06 October 2016 @ 21:30)

Map 3.1 shows a map the United States and Map 3.2 shows the where the Iris Glen Landfill Site is located within the United States. The Iris Glen Landfill site began operations in 1994

(17 October) and the LFGE project began its operation in 2007 (1st January) (Pindzola, 2008). This suggests that the project has been functional for a decade and this can give a good indication of whether the project has been a success or not. The LFGE project has a 25-year contract term that can be further renewed for 5 years (Pindzola, 2008). This suggests that the project is aimed at providing medium to long-term benefits to the city of Johnson. The Iris Glen Landfill Site was projected to have a 27-year life span (Pindzola, 2008). This suggests that the landfill site is due to close in the year 2021, thus, suggesting that the LFGE project at Iris Glen Landfill was implemented at the correct time as methane flow is still on the rise and is only expected to drop after the year 2021.

Iris Glen Landfill site delivers roughly 1300 cubic feet/minute (cfm) of landfill gas, which yields approximately 8.79 MWh of energy per month (Pindzola, 2008). This is a considerable amount of energy that is derived from this project and shows the benefits of converting methane gas (or LFG in the broader aspect). According to Pindzola (2008) the amount of energy generated at Iris Glen Landfill Gas to Energy Project is equivalent to the amount of energy it would take to power 8000 households in the United States. In terms of the carbon dioxide emission reductions, this is equivalent to planting 48 925 acres of forest or removing the emissions of 34 344 vehicles (Pindzola, 2008). These figures show the remarkable strides that Iris Glen Landfill Site has made in terms of LFGE projects. These figures can perhaps be used as the bench mark for LFGE projects and used to persuade organs of government to come up with policy that promotes the expansion of LFGE projects.

When looking at LFGE projects in the United States, Themelis and Ulloa (2007) claim that of the landfill sites in USA that capture biogas, approximately 2.6 million tonnes of methane gas is captured and 70% of this methane gas is utilised to generate heat and/or electricity. This suggests that electricity generation from methane gas is a highly profitable way to go about generating energy which resonates into a country's development. One can see that USA are clearly doing well in terms of renewable energy generation from a landfill perspective and South Africa can use these figures as target to reach.

Furthermore, when methane escapes into the atmosphere, it has a global warming potential that is estimated to be 23 times greater than that of the same volume of carbon dioxide (Themelis and Ulloa, 2007). This suggests that by converting methane gas into energy helps mitigate against climate change and this aspect far outweighs the financial benefits associated with LFGE projects. This is because the fiscal benefits associated with converting LFG into energy

are short-term benefits, no matter how long a LFGE project is in existence for, the financial gains are short-term spillovers when compared with the damage that is caused to the earth (environment) from MSW with regards to landfill sites. Thus, the ecological aspect that is covered by LFGE projects should be considered first and with superiority to the anticipated fiscal benefits.

3.5.2 Innovative Solutions to deal with Waste while Cleaning the Environment and Generating Electricity for the Halton Region, Canada.

Map 3.3 (below) shows a map of Canada and map 3.4 (below) shows where the Halton Waste Management Site is located within Canada. The Landfill Gas Collection and Utilisation Project between Halton Region and Oakville Hydro Energy Services Inc. (OHESI) began its operations in 2007 (July 11), where the landfill site collects LFG to produce electricity (Mohareb *et al*, 2008). The LFGE project has an energy capacity of approximately 2.1 MW (Mohareb *et al*, 2008). This suggests that this LFGE project is not very large in scale as it can only produce 2.1 MW of energy, however, this LFGE project still makes a huge contribution towards the environment as it reduces GHG emissions. This LFGE project provides enough energy to power 1500 households from its 2.1 MW capacity (Mohareb *et al*, 2008). This shows how this project benefits the Halton community both now and in the future generations to come. In addition, this suggests that less energy needs to be provided by the Canadian Energy Department towards the Halton area and the money that would have been used to do so can now be invested in other sectors of service delivery for the public.

Map 3.3 Map showing Canada

Source: Google images (2016) (accessed on 06 October 2016 @ 21:32)

The LFGE project found in the Halton Region can be perceived as the user of innovative technology with the implementation of the infrastructure for the project. According to Bonam (2009) phase 1 of the LFGE project which involves the collection of LFG, is where Halton Region installed over 3km of piping within buried waste at the Halton Waste Management Site (HWMS) to allow the gas to flow under vacuum from the landfill's interior to the site's first-ever enclosed flaring system. The 3km of piping suggests that even though this LFGE project can be regarded as a small one in terms of its energy capacity, the LFGE project has made use of advanced technology. Furthermore, this suggests that the project may have been expensive to implement, but still economically feasible to undergo with the long-term energy benefits over riding the implementation costs.

Map 3.4 Locality Map showing Halton Region Management Site

Source: Google maps (2016) (accessed on 06 October 2016 @ 21:30)

In addition, the gas collection and flaring process reduces odour at HWMS as combustion of the gas purifies it and leaves it virtually odourless (Mohareb *et al*, 2008). Thus, flaring can be seen as an innovative way to deal with odours associated with landfill sites. Furthermore, removing landfill gas from the landfill both reduces odours in and surrounding the landfill site and also cuts down the emission of ozone-depleting methane into the atmosphere, improving the environment (Bonam, 2009). This once again suggests that the environmental benefits from LFGE projects far outweigh the fiscal benefits; as the ozone layer is a far greater asset that man has to protect as the ozone layer protects man from the sun's harmful ultra violet rays (Frei *et al*, 1999).

Phase 2 of the LFGE project at HWMS, incorporated the gas utilisation system constructed and operated by OHESI to generate electricity from the LFG collected by Halton Region's system (Bonam, 2009). OHESI's landfill gas utilisation facility generates and transmits "green" energy to the power grid, derived directly from the Region's LFG supply (Bonam, 2009). This shows the cooperation between phase 1 and 2 with regards to the functioning of the LFGE project; phase 1 deals with the cleaning of the environment and phase 2 deals with the energy generation. With the energy derived from the LFGE project being transmitted directly into the power grid, one can see how valuable this project is in terms of the energy demand. In addition, this shows how innovative methods can be used to generate renewable energy.

The combustion of LFG at the current gas extraction rate of 750 scfm (standard cubic feet per minute) translates into an annual elimination of close to 80 000 tonnes of carbon dioxide equivalents, or over 4000 tonnes of methane, that would otherwise be released into the atmosphere (Mohareb *et al*, 2008). This suggests that the project contributes immensely towards the environment even though the energy generated at the project may be perceived as a low amount. Furthermore, the annual environmental benefits of this rate of elimination of methane emissions from HWMS are equivalent to any one of the following three initiatives; firstly, removing emissions that are equivalent to over 15 000 vehicles, secondly, planting 22239.48 acres of forest and thirdly, displacing the use of over 33 million litres of gasoline by vehicles (Mohareb *et al*, 2008). The following examples give clear indication of how valuable the LFGE project is at HWMS with regards to the environmental benefits alone. LFGE projects play a vital role today and also play an even more crucial role as they protect and cleans the environment for future generations.

3.5.3 Forty Seven Employees to lose their jobs as Harford County Waste-to-Energy Site closes in the United States

Map 3.5 (below) shows a map of the United States and map 3.6 (below) shows where the Harford County Disposal Centre is located in the United States. The waste-to-energy plant in Harford County began operating in 1988 at the Edgewood Area of Aberdeen Proving Ground (Karidis, 2016). In addition, the Harford County area receives approximately 130 000 tonnes of waste per year and with the closing of the plant, this waste will be sent to White Marsh County to their landfill site (Anderson, 2016). This suggests that a LFGE project can be undertaken or at least a feasibility study undertaken at the White Marsh landfill site as the site will be receiving a considerably greater amount of waste which in turn translates into a considerably higher level of LFG. If the feasibility study estimates that a LFGE project can be undertaken at White Marsh, this project could be much cheaper to facilitate as the machinery could be moved from Harford County to White Marsh.

Map 3.5 Map showing United States of America

Source: Google images (2016) (accessed on 06 October 2016 @ 21:48)

Map 3.6 Locality Map showing Harford County Disposal Centre

Source: Google maps (2016) (accessed on 06 October 2016 @ 21:59)

According to Karidis (2016) Harford County waste-to-energy plant has been in operation for 30 years with majority of the staff having worked at the plant since it began. This suggests that majority of the former staff at Harford County had devoted most of their lives and working careers to the waste-to-energy plant at Harford County and thus, suggests that they may not have jobs to fall back on. These are the harsh realities that are associated with LFGE projects and one can argue that the jobs that LFGE projects create are not sustainable (the jobs created are perhaps seasonal for an extended period of time). In addition, this suggests that the skilled professionals (such as the engineers) are able to find new LFGE projects where they can take their experience. However, the less skilled people (such as the cleaners and blower regulators) that work on LFGE projects find themselves in a situation of retrenchment as new LFGE projects are more likely to employ locals for this kind of work.

The plant was shut down on the 17th of March 2016 where the Harford County Board of Estimates approved a $311 538 (which is just over R4.5 million) contract with the Northeast Maryland Waste Disposal Authority to decommission and clean out the plant (Anderson, 2016). With the Harford County Board of Estimates making the call on closing the plant, one can see how a top-down approach is employed in the running of LFGE projects. This suggests that the employees did not have much say on the decision that was taken; even though the decision taken may have been the best decision at the time based on LFG levels. Anderson (2016) agrees with this notion with the assertion that the decision came about after the United

States Army refused to continue its relationship with Harford County and the regional waste authority beyond this year as they entered into a new $40 million deal with a private contractor (namely; Johnson Controls). The fact that the plant was on leased land from the United States Army (Anderson, 2016) shows that the decision taken was a political one that involved different stakeholders pulling in different directions. Thus, one can argue that the employees that have lost their jobs have not lost their jobs from the instability of LFGE projects, but rather the politics that are associated with LFGE projects.

This scenario is a crucial one in terms of LFGE projects and clean energy development for South Africa. While the government relies on the private sector to drive job creation through such initiatives, the government must always remain in a position of majority shareholding or in a position to overrule decisions. This is to ensure that the decisions taken regarding such projects do not affect the employees and the people involved in a negative manner. This is of utmost importance in developing countries like South Africa as the grievances of the people are often taken to the streets in the form of violent protests that could lead to loss of life (for example; the Marikana case where striking employees lost their lives in 2012) or damage to property. Thus, the South African government can capitalize on this experience with regards to the policy and legislation that it aims to enact. The policy and legislation should promote the expansion of clean energy development (especially LFGE projects) and simultaneously ensure that the government (including organs of state and local government) remain the core decision making entity.

- ***Developing Countries***

3.5.4 Turning a Liability into an Asset, converting Landfill Gas into Energy: A Case Study of India.

Map 3.7 (below) shows a map of India and map 3.8 (below) shows the Hyderabad Landfill Site's location within India. According to the IEA (2008) the capturing of methane gas for energy production in India benefits nearby industry with the provision of heat to power mechanical processes and this energy can also be purified and fed straight into local natural gas distribution systems. This suggests that these industries in India use less energy in the form of electricity to undertake the necessary processes that they need to undertake. Thus, the company that is responsible for electricity provision in India can reserve less electricity for industries and therefore this allows for more electricity to be able to be utilised for economic development.

Map 3.7 Map showing India

Source: Google images (2016) (accessed on 06 October 2016 @ 21:48)

Furthermore, this suggests that landfill sites will inform the geographic location of industries in the future. And this can benefit the city in a positive way as landfill sites are ideally located away from residential areas. Thus, having industries and landfill sites located away from residential areas protects people from the odours, noise and pollution that is associated with industries and landfills. However, this can put extra strain on transport infrastructure (especially roads) because industries require adequate amounts of labour force to operate. Hence, having many people commuting to and from industries is not efficient and leads to the degrading of transport infrastructure at a faster rate. A solution to counter this phenomenon could be the utilisation of a bus shuttle that transports locals from their residential areas to the industries they work for. Nevertheless, one can see that this symbiotic relationship between landfill sites and industries can have positive spinoffs in terms of shaping city form for generations to come.

Map 3.8 Map showing Hyderabad Landfill Site

Source: Google maps (2016) (accessed on 06 October 2016 @ 22:24)

The IEA (2008) strongly argue that capturing methane gas can save people's lives in the sense that when methane levels reach dangerous levels, nearby establishments are at a high risk of fire caused by explosion. This suggests that methane levels within landfill sites ought to be regulated on fixed intervals to ensure the safety of people working in the landfill sites, people residing near landfill sites and the property within and near landfill sites. According to the IEA (2008) at the Hyderabad Landfill Site in India there has been evidence of fires caused by explosions due to high methane levels. This clearly shows the importance of regulating methane gas levels within landfill sites as this phenomenon can lead to loss of life if left unattended. On the same note of loss of life, capturing methane gas within landfill sites helps to reduce the risk of contamination of local water supplies via leachate runoff (IEA, 2008). This suggests that excessive levels of methane gas can pollute underground water; causing further problems relating to water provision. Minnesota Department of Health (2016) argue that drinking contaminated water from methane gas has no known health hazards thus far, however, methane can also cause problems with the operation of the well pumps and water systems. This suggests that government departments responsible for the provision of water

become compelled to use greater fiscal resources to remedy this problem and supply their people with safe water. Thus, converting methane gas into energy can help save money at the same time while providing an alternative energy source.

The IEA (2008) agree with Themelis and Ulloa (2007) on the notion of methane gas contributing to global warming and further argue that methane gas is a greenhouse gas (GHG) that also adds to the climate change problem. This suggests that the process of converting methane gas for energy production serves as an environmental service that aids in the reduction of global warming in the greater fight against climate change. The IEA (2008) claim that even though methane gas only contributes a tiny portion (around 3% of the total anthropogenic GHG emissions) towards global warming, this is nonetheless a small portion mankind must work towards reducing. One can clearly see the importance of capturing methane gas from a safety perspective and an environmental perspective; and once again South Africa can take notes from this.

According to the IEA (2008) an important factor determining the viability of gas-to-electricity projects is the manner in which municipal solid waste (MSW) is collected, sorted and processed. This suggests that there is a systematic way to manage MSW to be able to reap the benefits of converting methane gas into electricity. Zhu *et al* (2007) argue that in India's rural areas, majority of solid waste is recycled, with most of the biodegradable material used as food for animals or fertiliser for farms. However, the opposite is evident in urban areas; where a large majority of MSW is dumped on non-managed dumps. Between 50-90% of the 42 million tonnes of urban waste produced in India annually is collected and dumped into uncontrolled open landfill sites without sorting and the remainder is left to decompose in streets, drains or illegal dump sites (Zhu *et al*, 2007). With a large portion of India's urban waste not landing up in regulated landfill sites that sort and process the waste accordingly, their potential to generate electricity from methane gas is considerably dented. This also perpetuates the climate change phenomenon and shows how not to manage waste within a country.

India experience a warm and wet climate and with the high portion of food scraps, the rate of decomposition in India is faster than landfill sites in developed countries (such as the United States and Australia) (Singh *et al*, 2011). The rates of methane flow can be expected to peak shortly after a landfill is closed and afterwards rapidly decrease (Singh *et al*, 2011). Therefore, due to the high rate of MSW decomposition, only large landfill sites will be able to produce methane at a high level over a long period to be able to support energy generation

(Unnikrishnan and Singh, 2010). This suggests that India has a high potential to generate electricity from methane gas if their planning of landfill sites and management of MSW is aligned with one another and strict monitoring protocol is followed. In addition, it will work in India's favour to have fewer landfill sites that are huge in size to be able to capitalise on their climate that promotes the fast generation of methane gas. Thus, this suggests that the environmental policy in India ought to become cognisant of their potential with regards to this kind of energy generation as this kills two birds with one stone; the mitigation of climate change and the generation of energy.

To address the problems associated with MSW and be able to reap the benefits of methane gas with regards to energy generation, in 2000 the Ministry of Environment and Forestry notified a set of laws under the Environmental Protection Act of 1986, governing MSW collection, transport, processing and disposal (Dechezlepretre *et al*, 2009). The rules require a major restructuring of waste collection and processing; the rules require that all organic waste be sorted and processed separately (Singh *et al*, 2011). This shows that the government of India made considerable efforts to address the problems associated with MSW and place India in a position to reap the benefits of energy generation from methane gas conversion. However, to date, few municipalities in India have made significant progress in implementing the new law (Unnikrishnan and Singh, 2010). This strongly suggests that for law to be followed in a country, there needs to be agencies that enforce the law, penalising those that go against the law. Thus, South Africa can learn from this experience; as it clearly shows that law without enforcement and monitoring is useless and does very little to remedy problems that the law is aimed at addressing.

LFGE projects cannot be considered in isolation as they need to tie up with national and provincial energy policies; this includes grid access, tariffs and incentives (Unnikrishnan and Singh, 2010). This shows that LFGE projects need to be guided by energy legislation as this is the end goal for the implementation of LFGE projects. In India, the primary energy consumption is 0.36 tonnes of oil equivalent (toe) per year for an average habitant, this is considerably lower that the global average that sits at 1.75 toe (Unnikrishnan and Singh, 2010). This suggests that the population in India does not use a large amount of energy and this can be linked to the nature of development in India as it is a developing country (3rd world country). However, with India's economy continuing to grow and the average wealth also rising, it is inevitable that the per capita energy consumption and the thus the total energy consumption will increase (Singh *et al*, 2011). This suggests that India should make considerable strides to

meet this expected energy demand. Thus, policy in accordance with energy ought to cater for this expected energy hike. India derives a large portion of its energy from coal and combustible renewables and waste (Singh *et al*, 2011). This strongly shows the benefits of developing renewable energy in terms of environmental factors and energy security. Thus, this shows that generating energy from methane gas within landfill sites is a viable option that brings with it progressive and sustainable ways to provide energy.

There are several government stakeholders relevant for LFGE projects in India; these stakeholders include local municipalities, the Ministries for Environment and Forests, New and Renewable Energy and Urban Development (Unnikrishnan and Singh, 2010). This suggests that LFGE projects are interlinked and should be approached in such a manner. Furthermore, in India local municipalities have the overall responsibility for the MSW management; they implement and enforce laws created by the Ministry for Environment and Forests within their authority (Unnikrishnan and Singh, 2010). This suggests that local municipalities play a very vital role in terms of renewable energy development as they are the watchdogs that ensure that the legislation is followed accordingly. The Ministry for Environment and Forests governs the Central Pollution Board which is responsible for sustainable waste management. The Ministry of New and Renewable Energy covers both renewable energy and new fossil fuel technologies. And the Ministry of Urban Development is the nodal Ministry overseeing urban development in India. And the Ministry's Central Public Health and Environment Engineering Organisation guides the municipalities on technical aspects of solid waste management (Unnikrishnan and Singh, 2010). One can see that all these different departments have a crucial role that they play in terms of ensuring that India capitalises on their potential to generate energy from landfill sites. This further suggests that the enforcement of the laws enacted by these government institutions is crucial in the growth of renewable energy developments of this nature. Thus, South Africa can learn from this experience as it proves that legislation without enforcement is rather feeble.

A significant financial incentive for LFGE projects is the possibility of receiving Certified Emission Reductions (CERs) certificates from the CDM (Dechezlepretre *et al*, 2009). This suggests that companies running clean energy projects can receive financial rewards in the form of tax reductions and earn carbon credits for not polluting the environment. These carbon credits can be sold to other companies or on carbon credit markets. Thus, one can see the long-term power behind such renewable energy projects in terms of financial gains. In India, the Deonar landfill site on the west coast near the city of Mumbai, capture and combust around

7000 cubic metres of LFG per day and this in turn saves around 18 000 tonnes of carbon dioxide equivalent per year, which is worth roughly 180 000 USD per year as CERs (assuming 50% methane content) (Singh *et al*, 2011). This shows clearly the impetus for LFGE projects in India; not only do projects of this nature yield steep fiscal benefits, they also protect the environment through the reduction of greenhouse gas emissions.

3.5.5 The Turning Point for Waste to Energy Generation in Belo Horizonte, Brazil.

Map 3.9 (below) shows a map of Brazil and map 3.10 (below) show a map of the Belo Horizonte Waste Management Site. The city of Belo Horizonte is the 3rd largest city in Brazil and produces 3580 tonnes of MSW and 28 tonnes of hospital waste each day (IRENA, 2012). This value is considerably high and suggests that a considerable amount of energy can be generated from a LFGE project at the Centro de Tratamento de Residuos Solidos (CTRS) landfill site in Belo Horizonte. Waste management in Belo Horizonte falls under the authority of the Municipal Department of Urban Cleaning (Boyd *et al*, 2009). This suggests that this department oversees making laws that deal with MSW, thus, suggests that this department is quite large in size as Belo Horizonte is the 3rd largest city in Brazil.

The operation of the first LFGE project at the CTRS landfill site began in 1989 and the landfill site itself began its operations in 1972 (Boyd *et al*, 2009). This shows that the LFGE project began 17 years after the landfill site began operating. This suggesting that methane flow was at a reasonably high level and on the rise, hence, suggests that the timing of the project was good. The LFG collected at the LFGE project at CTRS was used as clean fuel for the Superintendencia de Limpeza Urban (SLU) municipal vehicle fleet and the local electric utility, as well as the nearby Hotel (Boyd *et al*, 2009). This suggests that the LFGE project was generating considerable amounts of energy and the energy benefits made fair ground in reducing the energy demand on the energy provider in Belo Horizonte, Brazil.

Map 3.9 Map showing Brazil

Source: Google images (2016) (accessed on 06 October 2016 @ 22:45)

According to the Dechezlepretre *et al* (2009) the implementation, operation and distribution of recovered methane was conducted by Companhia de Gas de Minas Gerais (GASMIG), which is a subsidiary company of the state energy utility Companhia Energetica de Minas Gerais (CEMIG). This suggests that this company was working together with Brazil's energy department to carry out this LFGE project. Hence, showing that for such projects to be successful, they need to be approached in an inter-sectorial manner, engaging both the state and the private sector.

Map 3.10 Locality Map showing Belo Horizonte

Source: Google maps (2016) (accessed on 06 October 2016 @ 23:24)

However, SLU brought the LFGE project to a halt in 1995 when they ordered the closure of the LFGE project and removed the machinery. The closure was based on the observations that the volume of LFG produced in the collecting basins had decreased (Seres *et al*, 2009). This suggest that the energy that was being produced was no longer sufficient to make the LFGE project feasible. The closing of the LFGE project at CTRS now can be seen to have surfaced with negative implications. For example, when the LFGE project closed, the staff that worked there suddenly found themselves jobless. With so many people losing their jobs, this social crisis impacts negatively on families as parents find it harder to feed their families. This shows the risks and shortfalls associated with LFGE projects as this suggests that they provide unsustainable jobs. Furthermore, Seres *et al* (2009) claims that plastic garbage was non-biodegradable and resulted in a reduced decomposition rate of the organic material at CTRS. This also suggests that incorrect waste sorting measures were taken at CTRS and thus compromised the LFGE project. Hence, this shows that there are harsh lessons to be learnt from improper waste sorting methods in terms of LFGE projects.

The implementation of new technologies rescued Belo Horizonte when experts realised the potential to capture LFG once again in 2007 (Boyd *et al*, 2009). The local government launched

a tender for a specialised company to implement a LFGE project at CTRS again. One requirement was that it be linked with the certification and marketing of carbon credits under the CDM (Dechezlepretre *et al*, 2009). This suggests that the Brazilian Local Government had managed to raise the financial capital needed to undertake a LFGE project and was in a position to engage the private sector on a venture to make this LFGE project a success. An Italian company (Asja Ambiente Italia) which won the tender bid, was issued a 15-year contract (from 2008-2023) and the plant was operational by 2010 (Dechezlepretre *et al*, 2009). According to the Seres *et al* (2009) the project was given the authorisation to install and operate an energy plant of maximum 5MW (megawatts) capacity, which equates to a maximum annual energy generation of 43 800 MWh (megawatt hours).

This shows that the amount of energy that CTRS was generating in the second LFGE project was far greater than the initial LFGE project. Hence, showing the massive benefits the LFGE projects can bring if implemented and gone about in a professional manner. The skilled personnel that implanted the new technology the second time at CTRS can be seen as the game changers for waste to energy development in Belo Horizonte. Thus, the lesson that South Africa can take from this scenario is that LFGE projects cannot be approached in a manner that resembles short-cuts, skilled professionals must be involved and the relevant stakeholders in the form of the state and the private sector need to work collectively to ensure that the benefits of LFGE projects are maximised.

According to IRENA (2012) in 2011, the plant had a gross electricity production of 30 400 MWh, whereby the plant only consumed 2900 MWh for maintenance and operation. Thus, leaving approximately 28 000 MWh of electricity to be fed into the electricity grid; which translated to the electricity consumption of approximately 30 000 - 35 000 people (IRENA, 2012). These figures speak volumes; it is evident that the benefits of waste to energy are tangible benefits that aid in the more efficient running of the city. With more energy being available to people within the city, the local government can use more money to promote development in an attempt to uplift the city. In addition, this kind of economic development that is required to grow the city requires energy (electricity), thus, LFGE projects can also help to provide this crucial energy. Furthermore, additional source of income for the municipality covering Belo Horizonte is derived from the sale of approximately 1.3 million CERs over a 10-year crediting period under the CDM (IRENA, 2012). Thus, showing once again the financial weight that LFGE projects bring with them for both short and long-term spillovers.

Reduction of GHG emissions is a crucial aspect that all governments aim to address with the development that they undertake. GHG emissions from CTRS landfill site have substantially reduced since 2009 after the construction of the LFGE project and CTRS used to be the largest source of GHG emissions in Belo Horizonte (IRENA, 2012). This clearly shows that the implementation of the LFGE project impacted directly on the amount of GHG emissions in a positive manner as it resulted in the cleansing of the atmosphere from GHGs. This will be illustrated below with a table that shows the reduction in GHG emissions in Belo Horizonte.

Table 3.2 Reduction of GHG emissions in Belo Horizonte since 2010

Year	Methane destroyed/ combusted through project in tCH_4/y (UNFCCC tool)	CO_2 Emission Reductions in tCO_2e/y	Net quantity of electricity exported MWh/y
2010	15,079	237,473	27,510
2011	12,285	194,588	27,510
2012	10,224	162,409	25,250
2013	8,672	137,586	20,983
2014	7,480	118,506	17,704
2015	6,543	103,515	15,127
2016	5,790	91,475	13,057

Source: http://cdm.unfcc.int/Projects/DB/SGS-UKL1267696608.78/view accessed 21 June 2016 @ 4:45.

The table shows how methane gas and carbon dioxide (CO_2) have continued to drop since 2010 when the LFGE project went live at the CTRS Landfill Site. The table also shows the electricity that has been generated of the period 2010 – 2016. It is peculiar to note that all three of these variables (methane gas, CO_2 and electricity generated) have a direct relationship on each other; this means that as the one decreases (for example – methane gas) the next variable also decreases (for example – CO_2), which in turn decreases the last variable (electricity).

The social aspects associated with the LFGE at CTRS prove to be in favour of the locals that reside in Belo Horizonte. The IRENA (2012) argue that since the project was officially open, there has been a reduction in the complaints from residents relating to bad odours and the risk of explosions and fires has dropped significantly. Furthermore, the project has resulted in a considerable amount of job creation; employing both highly-skilled personnel in the form of engineers and less-skilled personnel (IRENA, 2012). South Africa can learn from this experience, the New Growth Path that the government undertook in 2009 gives impetus to job

creation and realises that the private sector should play a pivotal role on this regard (The Economic Development Department, 2015).

3.5.6 Lessons South Africa can capitalise on

3.5.6.1 Introduction

The case studies presented in the international precedents play a crucial role in concertising the issue of LFGE projects within a South African context. There are many lessons that South Africa can take with concerning the issue around sustainable energy concerning waste-to-energy projects. The following section will discuss the lessons that South Africa can take forward in the venture towards development into clean energy in the form landfill gas capture.

3.5.6.2 Discussion

The first lesson that can be shared in the literature is that of accurate timing when it comes to the establishment of LFGE projects. The timing is very crucial as it determines the amount of methane gas that can be harvested and this inevitably determines the amount of energy that can be generated. According to Pindzola (2008) at the Iris Glen Landfill Site in the United States began its operations in 1994 and the LFGE project began in 2007. The Iris Glen Landfill Site is due to close in 2021, thus, the project will be able to serve its 25-year contract (Pindzola, 2008). The same situation was observed in Brazil in Belo Horizonte where the landfill site began its operations in 1972 and the LFGE project began in 1989 (Boyd *et al*, 2009). This suggests that the LFGE project began 17 years after the landfill was opened and thus, methane gas levels were on the rise. Both these examples show how the timing of the LFGE projects was accurate and thus, resulting in the success of the projects. South Africa can learn a great deal from these examples.

There are several benefits that are derived from LFGE projects; Iris Glen Landfill Site Gas-to-Energy Project generates 8.79 MWh of energy per month (Pindzola, 2008). This is equivalent to the amount of energy it would take to power 8000 households and equivalent to planting 48 925 acres of forest or the removal of the emissions of 34 344 vehicles when looking at the carbon dioxide emissions reduction aspect (Pindzola, 2008). Similarly, Halton Region in Canada generates enough energy to power 1500 households with its 2.1 MW contribution towards electricity (Mohareb, 2008). With South Africa being a developing country, energy is continuously in demand and this has resulted in black outs along with waves of load shedding (Statistic South Africa, 2013). Therefore, the figures presented by these examples go a long way in encouraging South Africa in the direction of LFGE projects.

In addition, a paramount benefit that is derived from LFGE projects is the reduction of risks of fires that are triggered by high levels of methane gas (IEA, 2008). This phenomenon was observed in India at the Hyderabad Landfill Site. Themalis and Ulloa (2007) argue that methane gas contributes to global warming as methane gas is a greenhouse gas. Therefore, through destroying this methane gas, the environment is being cleansed and at the same time this helps keep mankind safe from tragedies like fires and this also takes care of the environment for future generations. Hence, this shows how South Africa can reap complimentary benefits from developments into LFGE projects. Furthermore, LFGE projects open up an international avenue for capital flow where waste-to-energy plants earn CERs on the international market (Unnikrishnan and Singh, 2010). This suggests that LFGE projects earn points for destroying methane gas and these points are purchased by 1st world countries. However, even though there is a large amount of money that LFGE projects can earn through the sale of CERs, this situation presents a catch-22 situation where 1st world countries can industrialise further at the expense of 3rd world countries that venture into LFGE projects.

The management of a landfill site is very crucial when looking at the establishment of a waste-to-energy plant. Zhu *et al* (2007) argues that there is a systematic way to manage MSW to be able to reap the benefits of converting methane gas into energy. In India, there are several large landfill sites that have the potential to generate considerable amounts of energy, however, the landfills are poorly managed; the waste is not collected, sorted, processed, and disposed of properly (Zhu *et al*, 2007). This suggests that for South Africa to be able to benefit from LFGE projects, the landfill sites within the country should be well managed and adhere to strict standards.

In addition, South Africa experiences a unique climate that is very different from that of 1st world countries (such as America and Canada); South Africa has a very warm and wet climate as opposed to the dry and cold climates that 1st world countries experience (Statistics South Africa, 2015). This means that waste will decompose at a faster rate in South Africa. Therefore, with diverging climates, South Africa cannot just simply plug in a blanket solution with norms and standards from 1st world countries regarding waste-to-energy plants. International norms and standards concerning waste-to-energy projects are essential, however, they should be used as a guideline and not a narrow line that restricts 3rd world countries from using their own autonomy regarding LFGE projects.

Legislation is the backbone of all that occurs within a country. Singh (2011) claims that in India there were laws passed governing the collection, transportation, processing and disposal of MSW by the Ministry of Environment and Forestry under the Environmental Protection Act of 1986. However, with poor enforcement measures in place, very few municipalities in India made significant progress in implementing the new laws (Singh, 2011). This shows how government ought to beef up the enforcement part of legislation in order for legislation to become effective. This notion can resonate in South Africa; the most crucial part of legislation is the enforcement part. Thus, South Africa can take the lesson of law enforcement with in this example.

Waste-to-energy projects involve a wide array of sectors; namely the electricity (energy) sector, the climate change sector, and the clean energy sector. Thus, with these projects being of this nature, this suggests that they ought to be treated in a holistic manner, where they interlink several sectors. Unnikrishnan and Singh (2010) converges with the views of Dechezlepretre *et al* (2009) with the assertion that LFGE projects cannot be considered in isolation and policy (both national and provincial) ought to link grid access, tariffs and incentives. Dechezlepretre *et al* (2009) takes this notion further in promoting public-private-partnerships to grow LFGE projects. This is very crucial for the success of these projects; the state is responsible for creating the laws and the laws that the state enacts need to encourage private developers to invest in LFGE projects. South Africa already places emphasis on private-public-partnership through the New Growth Path (The Economic Development Department, 2016). However, further stimulus is still needed to develop further into LFGE projects.

However, LFGE projects are not always as sweet as they sound; the example about Harford County Waste-to-Energy Site reveals the harsh realities that can be associated with such projects. According to Anderson (2016) the Harford County Waste-to-energy plant shut down on the 17th of March 2016 abruptly after a promising 30 years of operations. Even though the decision was largely politically motivated (Karidis, 2016), the workers that serviced the plant were the ones that were left to face the injustices of retrenchment. A similar scenario was witnessed in Brazil at the Belo Horizonte Waste-to-Energy Plant, when the plant closed down in 1995, before resuming again in 2007 (Seres *et al*, 2009). This not only affects the workers; but this also impacts negatively on the families of the workers as their economic situation becomes largely instable with the bread winner facing economic paralysis. Thus, in a South African context where the current unemployment rate sits at 26.6% (Statistics South Africa, 2016) for a population of 52.98 million (Statistics South Africa, 2013), such retrenchment

tragedies would be catastrophic towards the country's unemployment rate along with the economy. This suggests that South Africa cannot afford such slip-ups as unemployment is already high.

3.6 National Precedents (within South Africa)

3.6.1 Further Gas to Electricity Project Expansion by Ekurhuleni Metropolitan Municipality

Map 3.11 Map showing Ekurhuleni Metropolitan Municipality within South Africa

Source: Google maps (2016) (accessed on 06 December 2016 @ 22:24)

Map 3.11 (above) shows the Ekurhuleni Metropolitan Municipality within South Africa. The Project Design Document (PDD) (2014) for the Ekurhuleni Landfill Gas Recovery Project in the Gauteng province has proposed LFGE projects at four different landfill sites within the Ekurhuleni Metropolitan Municipality; these different landfill sites include Weltevreden, Rooikraal, Rietfontein and Simmer and Jack landfill sites. This will be the second LFGE project in South Africa, the first being the Durban Landfill Gas to Electricity Project. According to the South African CDM Projects Portfolio (2016) the Ekurhuleni Landfill Gas Recovery Project was registered on 26 October 2010 having a 20-year life span, however, is

yet to begin its operations in the near future. The LFGE project will ensure GHG emissions reductions through the combusting of recovered methane within the landfills and as a result generate electricity from this transmission (PDD, 2014). This suggests that this LFGE project will use methane gas that would have otherwise escaped into the atmosphere and/or the earth to generate energy, thus, this suggests that the project has sustainable development benefits.

The PDD (2014) claims that the project will make telling contributions towards sustainable development; this will firstly be derived through the project generating foreign investment worth R1.98 million through the sale of CERs from the project registration date to April 2017. This suggests that the project will yield far greater yields throughout its lifespan in terms of foreign investment from CERs. The Ekurhuleni Landfill Gas Recovery Project will boost local employment through the creation of 10 new jobs for the installation, operation and maintenance of the LFG extraction facilities (PDD, 2014). This suggests that this LFGE project will do its bit to create employment as per the government's New Growth Path mandate (The Economic Development Department, 2015). Furthermore, the project will improve the local environment; it will result in reduced air pollution, reduced odour nuisances, improved health and safety conditions for the landfill workers and nearby residents and a reduction in the risk of fires and explosions at the four different landfill sites (PDD, 2014). This strongly promotes the project and suggests innovative ways of dealing with waste. In addition, one can see how this project has positive ripple effects on several factors that are associated with landfill sites. This also shows the importance of methane gas conversion to energy. One can see how this type of energy generation helps to diversify South Africa's energy production market and at the same time contributes positively towards climate change.

Another benefit that the project will yield is the technology transfer factor; LFG recovery is not common practice in South Africa, thus, the project presents opportunities for technology transfer (PDD, 2014). This suggests that this project will help grow LFG recovery into widespread practice within South Africa and thus, coincides with this paper as it also seeks to explore the viability of such energy generation within South Africa. With regards to technology transfer; the project will employ advanced LFG extraction technology in the form of using both vertical extraction wells and horizontal extraction wells amounting to 96 gas wells (Envitech Solutions, 2016). Furthermore, according to Envitech Solutions (2016) the project will install 10.5 km of piping and 4 high temperature flares. This strengthens the notion of technology transfers towards South Africa and opens new avenues in terms of LFGE projects. In addition, the PDD (2014) also claims the project was developed in accordance with the South African

environmental regulations and in accordance with the sustainable development criteria of the South African Designated National Authority. This suggests that the project upholds the legislation that guides projects in a sustainable development manner and as a result shows a high level of integrity towards South African policy. This shows a good relationship between policy and on-the-ground work.

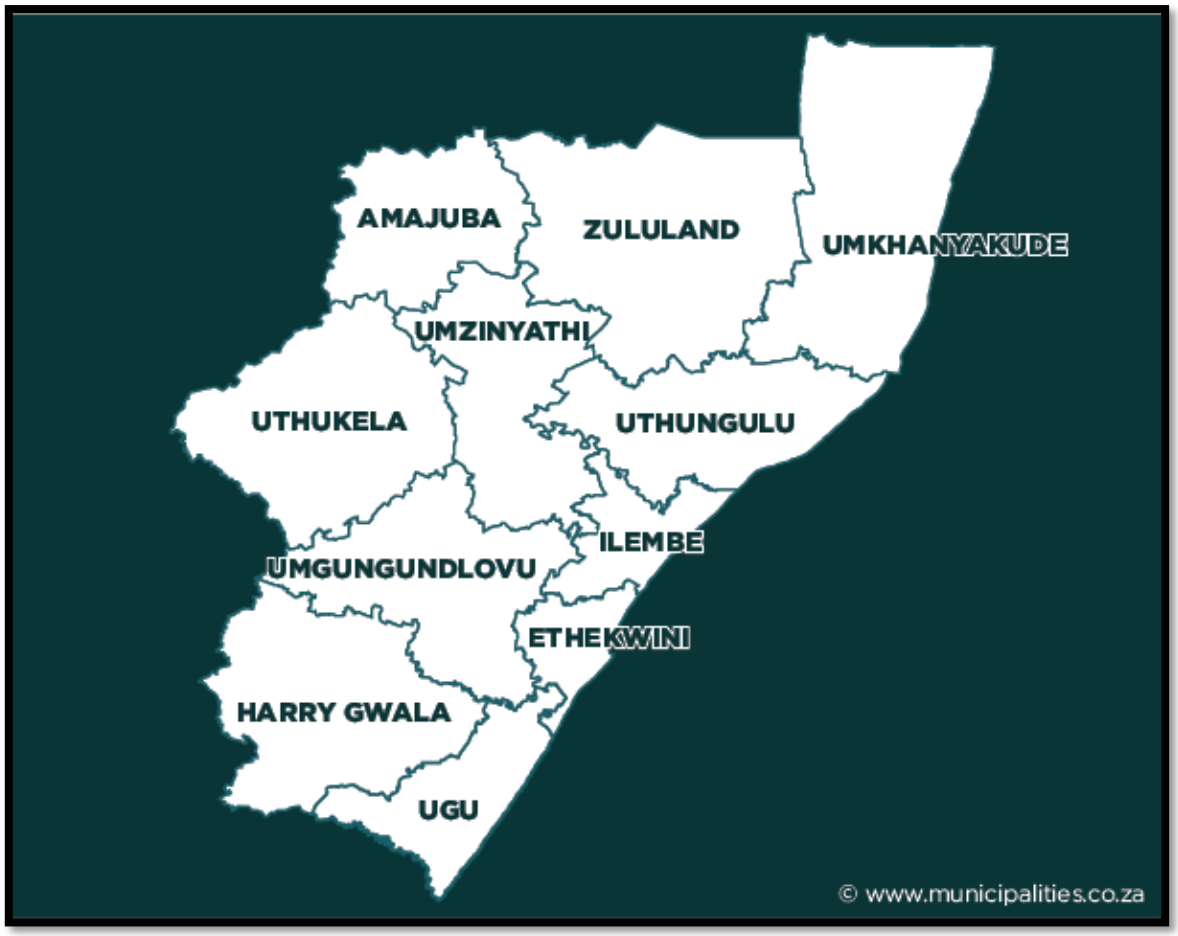
However, Gumbo (2013) disagrees with this notion with the assertion that African countries lack appropriate policies that support investments in renewable energy production and where there exist policies, there are stern inconsistencies in their application. This suggests that there needs to be strict intervention with regards to ensuring that projects abide by the set policies. This further suggests that the government in South Africa as well as other African countries need to work diligently on monitoring and evaluating the projects that they undergo to protect the environment and reduce any risks posed towards man. It is made clear that the successfulness of LFGE projects is dependent on many factors and the state has an integral role to play as the regulating body for projects of this nature.

3.7 Local Precedents (within eThekwini Municipality)

3.7.1 Africa's First Gas to electricity project launched by eThekwini Municipality in 2007

The eThekwini municipality in South Africa has embraced innovative technologies to convert MSW into energy since 2006 at three different landfill sites, namely; La Mercy, Mariannhill and Bisaser landfill site under the CDM (Gumbo, 2013). According to the Project Summary Document (2011) in the case of the Durban Landfill gas to electricity project, the fuel is burned in 20-cylinder spark ignition engines which in turn drive a generator to produce electricity which is fed into the local electricity network. This suggests that the project uses advanced technology. Map 3.12 below shows the eThekwini Municipality within the Kwa-Zulu Natal province.

Map 3.12 Map showing eThekwini Municipality within the Kwa-Zulu Natal Province



Source: Google maps (2016) (accessed on 06 December 2016 @ 22:24)

In as much as the Durban Landfill gas to electricity project has made use of advanced technology, on a macro level when looking at the entire continent, the technological infrastructure may still be a pressing issue that raises concern for projects of this nature. Gumbo (2013) argues that African countries lack the modern technology that is efficient and effective in converting waste into energy; particularly the equipment used to draw methane gas from landfills, as well as the engines that are used to cool and convert the methane gas into electricity. A solution could be to possibly export these machines that form part of modern technology from developed countries for the exchange of carbon credits. With this alternative solution being raised, it should be implemented in tandem with government policy; thus, government agencies within African countries need to enact legislation that will allow for innovative machinery to be imported into the country in exchange for carbon credits.

Furthermore, Gumbo (2013) claims that the few projects that have been implemented in the continent (especially the CDM in the eThekwini municipality) suffer serious shortages of qualified and well-trained personnel. This suggests that for these projects to be successful,

experienced people need to be employed. On this regard, the government could look at taking enthusiastic students abroad to learn from the success and failures of developed countries and return when they are qualified to work on landfill sites within the Republic.

The Mariannhill Landfill consists of a single 1MW engine however, there is capacity for a second engine) and takes in between 450 to 700 tonnes of MSW per day (Strachan *et al*, 2002). The project has 13 vertical wells and 6 horizontal wells. The Bisaser Landfill consists of six 1MW and one 0.5MW engines (Project Summary Document, 2011). Bisaser takes in between 3500 to 5000 tonnes of MSW per day and has 77 vertical wells along with 77 horizontal wells (Strachan *et al*, 2002). La Mercy Landfill has 25 horizontal wells, but was soon abandoned as the landfill site failed to produce adequate amounts of LFG even with pump tests indicating that the landfill site would produce enough LFG (Strachan *et al*, 2002). All these specifications of the project show the level of innovation of the technology used to ensure the success of the project. However, it can be argued that the Durban Landfill gas to electricity project was a steep learning curve for the municipality. This is due to the fact the project had a total capital cost of R114m and an annual operating cost of R12m to date (Project Summary Document, 2011). This suggest that the project was very costly to implement and is also quite expensive to run. Thus, the project can only remain sustainable if the economic, social and environmental benefits outweigh these cost barriers by a significant margin.

When looking at the energy benefits that the project brings with, Gumbo (2013) claims that the project (including all three landfill sites) generates approximately 7.5 MW of electricity, which provides power to roughly 3500 households in the eThekwini municipality. This translates into R91 million through the sale of electricity (Strachan *et al*, 2002) and clearly confirms that energy generation from methane gas does indeed reduce the load on Eskom with regards to providing electricity. However, Strachan *et al* (2002) argue that following several investigations into the utilisation of landfill gas by Durban Solid Waste (DSW), no project has been deemed to be financially viable. This ideology is based on the price of electrical power for an overall unit being R0.12 per KWh (in 2002) and it was strongly argued that the unit selling price could not be anything less than R0.25 per KWh with regards to electrical generation from landfill gas (Strachan, 2002). This suggests that the price of electricity generated from landfill gas would be set at a 100% increase for the locals and this could make life very difficult for the locals. Thus, this also suggests that LFGE projects require the backbone of government subsidy to become viable.

The major game changer with regards to LFGE projects is the stern benefit of Emissions Reductions (ER) credits making the utilisation of landfill gas viable. The project agreement for the Durban Landfill gas to electricity project was set at a sale of 3.8 million tonnes emissions reductions at the rate of $3.95 per ton over the maximum period of 21 years (Stretch *et al*, 2001). This figure indicates huge capital returns even though it was set way back around the year 2000 and shows the power behind the trade of ER. Furthermore, it was agreed that $0.20 per ton must be used towards a social benefit where eThekwini Municipality identified suitable community projects that meet eThekwini Municipality's sustainable criteria. This suggests that the project also had social spill overs and thus, all these different benefits collectively made the landfill gas project viable. According to Gumbo (2013) the Durban Landfill gas to electricity project has generated R48 million through the selling of certified carbon credits and it can be estimated that this project will generate over R400 million within their lifespan. The trade of ER is the focal point with regards to LFGE projects. Furthermore, the anticipated revenue from the project is R205 million which comprises of ER sales amounting to R114 million and R91 million from the sale electricity to the grid (Strachan *et al*, 2002). This would realise a net profit to the City of R55 million over the expected agreement period of 12 years. And the project may produce ongoing significant profits through the sale of CERs to other buyers on the world market (Strachan *et al*, 2002).

These economic benefits do outweigh the financial cost that were encountered in the implementation phase of the project along with the costs to run the project. Thus, prior to looking at the social benefits (such as job creation) and the environmental benefits (such as the reduction of GHGs) it can be said that even though the project was costly to implement and to run, it continues to be a success as the benefits far outweigh the costs endured. These huge fiscal benefits that arise from gas to electricity projects could be used as spillovers into the host country's development budget.

3.8 Policy Framework

3.8.1 Introduction

Policy is formed as the directive for decision making; whereby it provides guidelines and a framework for all stakeholders within a predefined sector or sectors (Hayek, 2012). This suggests that policy is a command that orders stakeholders operating within a specific sector or sectors to follow certain rules, attached to specific roles and responsibilities, as they go about

their operations. Thus, suggesting that policy should be accompanied with enforcement measures to punish those that do not follow the relevant policies. In addition, this gives the indication that policy is proactive; it should be implemented to solve challenges that arise rather than to be implemented to react to current challenges. The following section will list the different policies that restrict and guide LFGE projects. The section will break the policy framework into two sections; namely, international policy framework and South African policy framework. Furthermore, the section will go deeper into policy by zooming into one key relevant piece of legislation that is aligned to this specific study for both the international policy framework and the South African policy framework. In zooming into the specific policy, the following sub-headings will be used; aim, Relevance to study and policy criticism.

3.8.2 International Policy Framework

The following international policies guide LFGE projects:

- United Nations Framework Convention on Climate Change (UNFCCC)
- Kyoto Protocol 1997
- European Union Emission Trading Scheme (EU ETS)
- Clean Development Mechanism (under the Kyoto Protocol)

3.8.3 Key relevant International Policy

Clean Development Mechanism (CDM)

3.8.4 Purpose of Clean Development Mechanism (CDM)

According to the UNFCCC (2014) the CDM allows a country with an emission-reduction or emission-limitation commitment under the Kyoto Protocol to implement an emission-reduction project in developing countries. Furthermore, these projects can earn saleable Certified Emission Reduction (CER) credits; each equivalent to one tonne of CO2 which can be counted towards meeting the Kyoto targets (UNFCCC, 2014). Sutter and Parreno (2007) agrees with this view with the claim that CDM was designed with two objectives; to contribute to local sustainable development in the host country and to assist countries to achieve their emission reduction targets in a cost-efficient manner.

3.8.5 Application of Clean Development Mechanism in South Africa

The CDM policy is the most important piece of international policy that influences LFGE projects in developing countries (Gumbo, 2013). According to Gumbo (2013) the sale of CERs provides the steep funding that is required to initiate and run LFGE projects. This is coordinated

with the case of the eThekwini Landfill Gas-to-Electricity Project which incorporates the Mariannhill, Bisasar and La Mercy Landfill Sites; where the anticipated sale of CERs motivated for the go ahead for the project (Durban CDM Project Design Document (PDD), 2015). This suggests that during the feasibility-study-phase of the project, the anticipated sale of CERs was not profitable enough, the project would have not been established. This is because such projects are very expensive to start and run, thus, if the returns were not profitable enough, eThekwini Municipality would have battled to get the funding required.

The eThekwini Landfill Gas-to-Electricity Project indicated a total project cost of R150 million (which is split between a capital expenditure of R64 million and operating costs of R86 million) throughout the project's lifespan (Strachan *et al*, 2002). According to Couth *et al* (2011) the agreement with the World Bank's Prototype Carbon Fund (PCF) involved the sale of a massive total of 3.8 million CERs valued at $15.0 million US Dollars (approximately 100 million SA Rands) over 14 years' lifespan of the project. In addition, the anticipated revenue from the project is R205 million (which is split between R114 million from the sale of CERs and R91 million from the sale of electricity to the grid) (Strachan *et al*, 2002). These figures show how powerful the sale of CERs is financially and how easy it is to motivate for such a project if the returns are estimated to be so steep. Basically, going into such a project would translate into a very good/ profitable business deal. One can clearly see that CDM is the make or break point of LFGE projects. Thus, this policy is the most relevant to the study and to South Africa at large.

3.8.6 Criticism of Clean Development Mechanism

According to the UNFCCC (2014), CDM stimulates sustainable development and emission reductions, while giving industrialised countries some flexibility in how they meet their emission reduction or limitation targets. This shows a great deal of hypocrisy from a developed world perspective. It can be agreed upon that CDM stimulates sustainable development; however, creating sustainable development in developing countries, while allowing developed countries to industrialise further does very little for sustainable development on a global level. This catch-22 situation shows how developed countries are not committed to sustainable development. Additionally, with having the power to enact international policy, developed countries have created a policy that works in their favour in terms of industrialisation. The policy is merely sweetened to appear like it was enacted to develop developing countries and promote sustainable development. Moreover, America not signing the Kyoto Protocol and becoming a part of the world agreement committed to emissions reductions is just another sign

that shows how developed countries are uncommitted to sustainable development (Hovi *et al*, 2010).

3.8.7 South African Policy Framework

There are several policies and acts within South Africa that guide LFGE projects. The following South African policies guide LFGE projects:

- National Environmental Management Act, 1998 (Act No. 107 of 1998)
- National Environmental Management: Waste Act, 2008 (Act No.59 of 2008) National Norms and Standards for the Assessment of Waste for Landfill Disposal
- National Environmental Management: Waste Act No. 59 of 2008
- EIA Guideline for Renewable Energy Projects
- National Environmental Management Act: Air Quality Act, 2004 (Act No. 39 of 2004). Draft Declaration of Small boilers as controlled emitters
- Whitepaper on Renewable Energy
- Renewable Energy Feed-in Tariff (REFIT)

3.8.7.1 Key relevant International Policy

Renewable Energy Feed-in Tariff (REFIT)

3.8.7.2 Purpose of the Renewable Energy Feed-in Tariff

According to the Department of Energy (2016) REFIT is the guiding authority that regulates electricity tariffs in South Africa from electricity generated from renewable energy projects. This suggests that REFIT determines the price of electricity that is generated from renewable energy projects. Furthermore, Pegels (2010) argues that REFIT requires that the Renewable Energy Purchasing Agency (REPA), in this case the Single Buyer Office (SBO) of the national electricity utility Eskom, to purchase renewable energy from qualifying generators at pre-determined prices. In addition, these predetermined prices act as an incentive to renewable energy developers and private investors by reducing financial risk and providing market certainty (Pegels, 2010). This suggests that Eskom purchases the energy generated from renewable energy sources and sells this energy back to the public by plugging it back into the national grid. According to the National Energy Regulator of South Africa (NERSA) (2009), the key objectives of the REFIT are to:

- Create an enabling environment for renewable electricity power generation in South Africa;

- Establish a guaranteed price for electricity generated from renewables for a fixed period that provides a stable income stream and an adequate return on investment;
- Create a dynamic mechanism that reflects market, economic and political developments;
- Provide access to the grid and an obligation to purchase power generated;
- Establish an equal playing field with conventional electricity generation; and
- Create a critical mass of renewable energy investment and support the establishment of a self-sustaining market.

3.8.7.3 Application of the Renewable Energy Feed-in Tariff (REFIT) in South Africa

REFIT shows a high relevance to the study. Apart from the sale of CERs, energy generation is the utmost driver of the establishment of LFGE projects. Thus, with the study placing such high value on the potential to generate energy in the form of electricity, REFIT becomes the pillar in terms of policy framework. This notion is coordinated with NERSA (2009) with the first objective of REFIT; namely, to create an enabling environment for renewable electricity power generation in South Africa. This will go a long way in diversifying South Africa's energy sector. Moreover, this results in the cleansing of the environment as less coal will be burnt. Once more, this is infinitely what this study aims to encourage.

Furthermore, the second objective of REFIT; namely, to establish a guaranteed price for electricity generated from renewables for a fixed period that provides a stable income stream and an adequate return on investment (NERSA, 2009) – suggests that renewable energy projects sell the energy they generate at a fixed rate for the lifespan of the LFGE project. Thus, making it easy to quantify how much the project will make from electricity sales. This aligns with the claim made by Strachan *et al* (2002) as they could determine how much the eThekwini Landfill Gas-to-Electricity Project will generate with regards to electricity sales.

The forth objective of REFIT; namely, to provide access to the grid and an obligation to purchase power generated (NERSA, 2009) is a crucial aspect of this study, as this is where the generated electricity is plugged back into the grid. According to the Durban CDM PDD (2015) the electricity that is generated at the eThekwini Landfill Gas-to-Electricity Project was anticipated to be plugged back into the national grid initially at the feasibility phase of the project, however, this process was later found to be very onerous. Thus, the solution taken was to plug the electricity back into the municipal grid rather. Therefore, this piece of legislation becomes highly relevant to the study as the REFIT policy was only launched in 2009 (NERSA,

2009) and the eThekwini Landfill Gas-to-Electricity Project was in the loop from as soon as 2001 and got off the ground in 2006 (Durban CDM PDD, 2015).

3.8.7.4 Criticism of the Renewable Energy Feed-in Tariff (REFIT)

According to Pegels (2010) with Eskom's predominance in the electricity sector remaining untouched, independent power producers (IPPs) will find it challenging to enter the market and supply significant amounts of clean energy. This suggests that if Eskom is the hegemonic energy generator in South Africa, they will continue to dictate the price of electricity. The mere fact that Eskom purchases the energy generated from renewable projects to plug back into the national grid presents a situation where there is a 'middle man'; and with a 'middle man' the amount of money that was meant to be saved for the price of electricity ends up in the 'middle man's' back pocket. Rather, Eskom should assist renewable projects plug the electricity they have generated back into the national grid, to reap the maximum benefits of clean energy. Thus, one can argue that this policy allows Eskom to continue to bully consumers with regards to electricity prices.

Furthermore, the purchasing of electricity by Eskom from renewable energy projects does not translate into Eskom using less coal to generate electricity. The fact that Eskom purchases this renewable energy suggests that they should make that money back, thus, suggesting that the going the cheaper route to generate electricity (burning of coal) becomes a more viable and favoured option to make up the costs that were used to purchase electricity from renewable projects. Therefore, the attempt to reduce GHG and explore more renewable ways to generate electricity becomes rather feeble, as the same amount if not more of coal will be burnt to generate electricity.

3.9 Chapter Conclusion

The above chapter has provided in depth discussions pertaining to energy production from methane gas; with the process on generating energy from methane gas being explained in the initial parts of the section, it has made the reading of the entire chapter much easier and more meaningful. The precedents discussed in the chapter give examples that bring the notion of energy generation from methane gas home. These examples go a long way in adding the flesh to the skeleton body that explains the process of generating energy from methane gas. Thus, the synergy between the process of energy production in the initial part of the chapter and the precedents gives the reader a number of standpoints that they can choose to view energy

generation from methane gas. The national precedents only present one case study, this is due to the fact the eThekwini Municipality Landfill Gas-to-Electricity Project is a pioneer case in South Africa. Thus, other areas within the country are yet to establish gas-to-electricity projects of their own. The policy framework section has listed the international and South African legislation guiding gas-to-electricity projects. Furthermore, the section has gone even further to discuss in depth the most stressing pieces of international and South African legislation that shows utmost relevance to the study. The shortcomings in policy framework have been outlined in the key barriers and proposed remedial measures sub-section and have also surfaced in the precedents, therefore, this shows how the policy framework provided in the chapter ought to be strengthened with the power to enforce laws in order for LFGE projects to become a success.

CHAPTER FOUR

CONCEPTUAL FRAMEWORK AND THEORETICAL FRAMEWORK

4.0 Conceptual Framework

4.1 Introduction

The conceptual framework for this study will focus on the main concepts that will shed light to the topic and how the researcher will go about unravelling the findings that will surface at the hands of the primary data collected. The problem statement in the project will emphasise four main ideas that will work together to drive the study. These concepts are landfill site, economic development, renewable energy, and sustainable development.

4.2 Main drivers of the study

4.2.1 Landfill Site

According to Ngoc and Schnitzer (2009) a landfill site is used to dispose and treat municipal solid waste. This suggests that waste from households, industry, agriculture, and hazardous waste gets discarded in landfill sites to be treated. Landfill sites are the cheapest way to deal with solid waste and the most common way to treat solid waste (Ngoc and Schnitzer, 2009). This suggests that using landfill sites to deal with waste is a method that has been around for many generations, which intern suggests that this method is well established and well understood. Furthermore, Conserve Energy Future (2016) agree with this notion of a landfill site and support this argument with the claim that landfill sites focus on burying the waste in the land. In addition, there are processes that landfill sites undergo to eliminate odours and dangers of waste before it is placed in the ground. This argument clearly suggests that landfill sites treat waste and protect the environment from contamination of waste. This in turn protects animals and mankind from diseases and illnesses that are associated with poor waste management.

4.2.2 Economic Development

According to Nafziger (2012) economic growth refers to increases in a country's production or income per capita where production is calculated by gross national product (GNP) or gross national income (GNI). Furthermore, both (GNP and GNI) are derived from gross domestic product calculations (Nafziger, 2012). This suggests that economic development is purely measured on figures that denote how much a country produces with regards to goods and

services rather than the personal development of individuals. This suggests that health care is positive in economic development with regards to a high number of people falling ill and having to pay steep hospital bills. This miss conception may be one that is closely related to developing countries that are associated with poor health care.

However, Nafziger (2012) diverges from this notion with the assertion that economic development refers to economic growth accompanied by changes in output distribution and economic structure. Furthermore, he claims that these changes may include an enhancement in the physical well-being of the poorer half of the population; a decline in agriculture's share of GNP and an equivalent increase in the GNP share of industry and services; an increase in the education and skills of the labour force; and substantial technical advances derived within the country (Nafziger, 2012). This suggests that economic development does in fact trickle down to the individuals of a nation and it is through economic development that citizens of a nation can lead a better life.

4.2.3 Renewable Energy

The United States (US) Department of Energy (DOE) (2001) claim that renewable energy uses energy sources that are repetitively replenished by nature (for example; the sun, the wind, water, plants, and the Earth's heat). This suggests that these energy sources are sustainable as they replace themselves without man having to intervene. On this regard, energy production derived from methane gas produced within landfill sites can be renewable energy (Pehnt, 2006). The waste that is produced by man that eventually ends up in landfill sites can be in a constant state of replenishment (Pehnt, 2006). In addition, with the rise in material consumerism among man (Logemann, 2007) – this suggests that there will always be waste generated to produce energy within landfill sites. Furthermore, the US DOE (2001) agree with this notion with the contention that renewable energy technologies turn these fuels (the sun, the wind, water, plants, and the Earth's heat) into usable forms of energy. These usable forms of energy may include electricity, heat, mechanical power, and chemicals (Pehnt, 2006).

4.2.4 Sustainable Development

According to Kates *et al*. (2005) the concept of sustainable development was born out of the Brundtland commission in 1987 and refers to the ability to make development sustainable in such a way that ensures that the needs of present generations are met without compromising the ability for future generations to meet their own needs. This suggests that changes to the environment in a venture to promote development need to occur in a gradual way that does not

harm the environment enough to make the needs of future generations unreachable. For example, dumping industrial waste in rivers eventually kills off the life in the river with regards to living organisms and thus, future generations will not be able to reap the maximum benefits from that river. In addition, this poisoning of the river may be harmful to those living downstream and around it. Hence, this illegal action of dumping waste in the river is unsustainable.

4.3 Theoretical Framework

4.3.1 Introduction

The study will look at cementing its status with theories that will drive the project. The theories that will be employed in the study include Neo-liberalism and the Modernisation Theory. This section aims to unpack these theories, show their strengths and weaknesses, and also show how they link to this specific study. These theories will then be used to analyse and interpret phenomenon in the study. This will filter back into the notion of how these theories apply to South Africa.

4.3.2 Neo-liberalism

4.3.2.1 Early traces of Neo-liberalism

The word liberal took on a specifically political meaning after the establishment of liberal parliamentary conferences in Sweden and Spain, and later throughout Europe, in the beginning of the nineteenth century (Gray 1995 in Thorsen, 2010). When these developing political parties devised the term liberal, they wanted to signal their favourable assessment of the emerging democratic systems in Britain and especially the United States, as opposed to their traditional opponents, who wanted to return to pre-revolutionary forms of government (Sartori 1987 in Thorsen, 2010). This not only suggests that the ideology of Neo-liberalism originated in the Western North, but this also suggests that the term neo-liberalism was born out of political motives. Thus, one can argue that neo-liberalism was established by the Western North as a tool to rule and control governments from other countries through politics. Furthermore, this argument is coordinated with the assertion made by Mudge (2008), where he argues that the rise of professional political parties that did not agree with the 'old' ideological divides was during the inception phase of neo-liberalism.

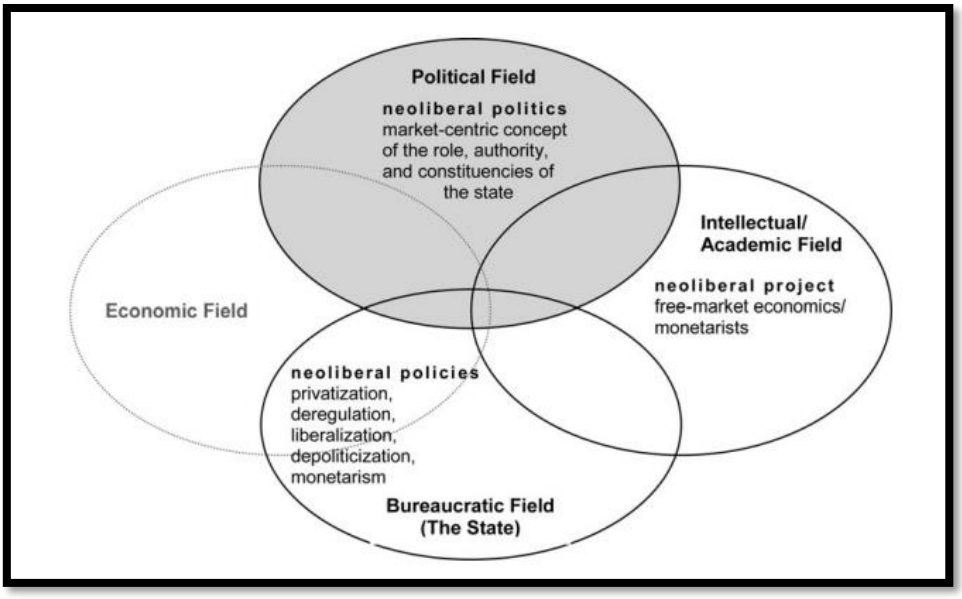
According to Thorsen and Lie (2009) neoliberalism is the political ideology which resulted from a few efforts at reviving classical liberalism in the period immediately before and during

World War II (which started in 1939 up until 1945), by political theorists such as Wilhelm Röpke and Friedrich von Hayek. This suggests that neo-liberalism was re-introduced now. This would make sense as the time before the second World War was very politically influenced. This view aligns with the view demonstrated by Mudge (2008) with the assertion that neo-liberalism was born from a previous hegemonic age in which politics were bounded by wefarist statis and Keynesian systems of thought which was dominant in Western Europe, giving rise to some of the most extensive welfare institutions the world has ever met.

4.3.2.2 Features of Neo-liberalism

According to Brenner and Theodore (2002) the term Neo-liberalism works in tandem with the capitalist system and advocates for the relaxing of trade tariffs between different countries and currencies. This is in sync with the claim made by Thorsen and Lie (2009) which states that neo-liberalism is based on the Latin premise "laissez-faire" which advocates for the relaxation of trade barriers between states and the market is focal point for trade. This suggests that neo-liberalism tries to allow countries to trade with each other on a frictionless plane. Furthermore, Mudge (2008) adds to this notion of neo-liberalism with the claim that neo-liberalism is defined as the ideological system that holds the 'market' sacred. Moreover, Fourcade and Healy (2007) in Mudge (2008) argues that neo-liberalism is rooted in an ethical project, expressed in the language of economics, that praises the 'moral benefits of market society' and identifies 'markets as a necessary condition for freedom in other aspects of life'. All these authors share similar sentiments on what neo-liberalism is based on.

Figure 4.1 Neo-liberalism's Three Faces



Source: Mudge (2008: 707). Downloaded from http://ser.oxfordjournals.org/ at UNIVERSITY KWAZULU-NATAL on October 19, 2016 @ 00: 42

Regarding figure 4.1 (above), Mudge (2008) argues that neo-liberalism's intellectual face is distinguished by (a) its Anglo-American anchored trans-nationality; (b) its historical growth within the institutions of welfare capitalism and the Cold War divide and (c) a complete emphasis on the market as the source and mediator of human freedoms. This suggests that the intellectual face of neo-liberalism originates from an American perspective. Furthermore, it was founded on institutions of welfare capitalism (for example the World Bank and the International Monetary Fund) along with the Cold War divide. In addition, the last premise of the intellectual face of neo-liberalism places paramount emphasis on the market as the controlling force for freedom that people experience. This coincides with the view of Thorsen and Lie (2009).

The bureaucratic face of neo-liberalism is the strongest of the three faces (still referring to figure 4.1), it is expressed in state policy as liberalisation, deregulation, privatisation, depoliticisation and monetarism (Mudge, 2008). Bond (2014) coincides with Mudge (2008) in his claim that neo-liberalism brings with it the deregulation of state control over major industries, privatisation of public services and the enhancement of international capital mobility. Furthermore, Mudge (2008) argues that all the above mention aspects of the bureaucratic face are targeted at promoting freed competition by getting the state out of the business of ownership and getting politicians out of the business of controlled-economy-style economic management. This suggests a vicious way of doing business that chokes small business, while well-established and economically resourceful businesses flourish at the expense of people. Moreover, neoliberal policies aim to violate institutions that had formerly been protected from the forces of private market competition (for example education and health care) (Mudge, 2008). This suggests that services that were previously provided by the state (such as education and health care) now become private entities and this results in the people not being protected by the state umbrella with regards to the raining prices charged by private sector.

The political face illustrated in figure 4.1 (above) shows that this aspect of neo-liberalism is a new market centric politics where struggles over political authority that share a particular ideological centre are underpinned by an unquestioned 'common sense'. This suggests that the rules implemented by the political face of neo-liberalism should be taken as the rule of thumb

and those operating within this sphere must obey without questioning. Mudge (2008) goes further to state that the political face expands deeper to dictate to the state to release market forces wherever possible and limit the reach of political decision-making. This suggests that the state must leave business to the private sector and should not intervene. All these three faces of neo-liberalism create a fourth face (as shown in figure 4.1), namely, the economic field.

4.3.2.3 Weaknesses of Neo-liberalism

Therefore, a criticism towards neo-liberalism is notion of allowing stronger countries with more powerful economies to trade with weaker countries that have less powerful economies (Bond, 2014). This suggests that first world countries can trade with third world countries. This may perhaps demonstrate an unfair trade relationship on the one hand, and on the other hand provides a platform for weaker countries to thrive to become more like first world countries. However, a race between a professional athlete and a toddler can only go one way (mudge, 2008).

With the state losing its control over major industries; the industries get to dominate through monetary power. This means that these hegemonic industries do not have to adhere to state set legislation, this becomes extremely problematic (especially in terms of labour legislation) as this allows industries and businesses to treat people like numbers as opposed to human beings (Bond, 2014). Furthermore, with many of the public services being handed over to the private sector, people must bear the steep prices set by the profit driven private sector (Bond, 2014). Thus, neo-liberalism cannot render development for developing countries (Thorsen and Lie, 2009).

Furthermore, Kaya (2006) argues that from a planning perspective, the private sector in Turkey has become increasingly interested in the operations of landfill sites because of the incentives available. This has resulted in the private sector engaging in the collection of waste and operation of landfill sites on the basis of a concession given by the municipality and approved by the Minister of Interior (Kaya, 2006). This suggests that the private sector is capitalizing on the opportunity presented by landfill sites in Turkey. This is still yet to occur in South Africa (eThekwini Municipality. 2011). With the involvement of municipalities through incentives that the private sector can capitalize on, one could be of the view that private sector involvement from a planning context could possibly increase and follow suit to Turkey. In addition, Kaya (2006) asserts that some companies in Turkey are focusing on the rehabilitation of old landfill sites due to their potential for energy recovery from landfill gas.

According to Bond (2014) a huge criticism towards neo-liberalism could be the deregulation of state power and allowing the so-called market to control the economic field. The state is in office as regulator of transactions within a country. Thus, with the side-lining of the state, all the set legislation becomes useless (Bond, 2014). For example, in a country like South Africa were the most supreme legislation is the constitution, neo-liberalism would mean that the principles in the constitution become futile. Thus, neo-liberalism undermines governments of countries. This also gives the impression that it becomes worthless voting for a powerless leader who submits to economically resourceful business men/ women (Bond, 2014).

4.3.2.4 Application of Neo-liberalism in South Africa

The connection between this theory and the study is very robust. The vast involvement of the private sector in providing public services such as health care through hospitals is strongly dependent on the amount of energy available. In this example, the significance of hospitals being very dependent on energy reflects how critical the issue of energy is with regards to the private sector being able to drive development within a country. The National Development Plan (2011) confirms this notion as the NDP offers a high level of importance to the private sector with regards to driving development.

Furthermore, when looking at economic expansion under neo-liberalism and its role in promoting development, the Durban Landfill gas to electricity project proves to be a good example. The funding to put this project into existance did not come from the government (EThekwini Municipality), however, the initial funding was made avaibale by the World Bank's Prototype Carbon Fund Income (Project Summary Document, 2011). This shows how the private sector has a huge role to play in driving development and this coincides with the features of Neo-liberalism. Thus, this adds great incentive to explore alternative ways to generate energy and speaks to the importance of this study.

4.3.3 Modernisation Theory

4.3.3.1 Early traces of the Modernisation Theory

According to Eisenstadt (1966) modernisation is the process of conversion towards those types of social, economic and political systems that have developed in western Europe and North America from the seventeenth to the nineteenth century, and have then spread to other European countries and in the nineteenth and twentieth centuries to the South American, Asian, and African continents. Modernising societies have developed from a great variety of different traditional, premodern societies. In western Europe, they developed from feudal or absolutist

states with strong urban centres, in eastern Europe from more oppressive states and less urbanised societies. In the United States and the first Dominions (for example Canada and Australia) they developed through processes of colonisation and immigration, some of which were rooted in robust religious motivations and organised in groups of religious settlers, while others were based mostly on large-scale immigration oriented mostly to economic opportunity (such as the Industrial Revolution) and greater equality of status (Eisenstadt, 1966).

This view is coordinated with the view of Apter (1965) where he claims that in most Asian and African societies the process of modernisation began from within colonial frameworks, some based on previous more centralised monarchical societies and elaborate literary-religious traditions, others (especially in Africa) mostly on tribal structures and traditions. This suggests that modernisation was based on religious beliefs that originated in the western world. Thus, this shows that modernisation is a western ideology that is imposed on the rest of the world, to make countries conform to a system that serves the western world.

4.3.3.2 Features of the Modernisation Theory

According to the Political Science Notes (2014) there are 9 key characteristics that belong to the modernisation theory, these include the following:

1. Application of technology and mechanisation
2. Industrialisation
3. Urbanisation
4. Rise in national and per capital Income
5. Increase in Literacy
6. Political participation
7. Development of Mass-Media techniques
8. Social Mobility
9. Cultivation of national identity

The first characteristic of modernisation; namely, the application of technology and mechanisation, suggests that people move away from their traditional ways of life (for example, agriculture and travelling) to more modernised ways of living. This notion converges with Gilman (2003) as he argues that modernisation theory stresses the notion of countries moving

from a traditional state to a more modern one. This involves the progression of third world countries towards becoming a first world state through the adaptation of new technologies which are found in the first world (Gilman, 2003). This suggests that traditional countries must change and/or upgrade their customary ways of life to conform to a more modern way of life. For example, when looking at how South Africa generates majority of its energy; coal-fired power stations are the dominant (over 90%) and traditional way that South Africa uses to generate its energy (Statistics South Africa, 2011). Thus, with conforming to the modernisation theory, alternative ways to generate energy that involve new technology such as renewable energy (clean energy) ought to be explored in a similar fashion to that of first world countries such as the United States.

The second characteristic; namely, industrialisation, is probably the backbone of modernisation. According to Engerman (2003) industrialisation means the establishment and further development of industries. Such industries may include mills, mining, processing firms and steel firms (Engerman, 2003). Urbanisation and social mobility are the third and eighth characteristic of modernisation. Both, urbanisation and social mobility involves the movement of people from the rural areas to urban centres in search of better opportunities (Gilman, 2003). Industrialisation and Urbanisation complement each other; with industrialisation occurring in urban centres, people are drawn towards these urban centres by the job opportunities that they present (Engerman, 2003). In addition, social mobility also links in with people having the freedom to rally for a leader that they feel will deliver services.

The fourth characteristic of modernisation; namely, the rise in national and per capital income, suggests that countries ought to industrialise further as agriculture alone cannot increase a country's capital income (Gliman, 2003). This also suggests that industrial growth will increase the amount of exports from a country, and this has the potential to generate huge capital for a country (Engerman, 2003). This coincides with the fifth characteristic of modernisation; namely, the increase in literacy. This is because with a country having more educated people, then more people can work to serve the economy (especially in the industrial sector) (Gilman, 2003). Therefore, the country will have a greater capital income with more people participating in the economy (Gilman, 2003).

According to Engerman (2003) political participation is the sixth characteristic of the modernisation theory, which advocates for democracy within countries. This suggests that countries should not be run by a dictator (Engerman, 2003). Furthermore, all citizens within a

country should be able to voice their opinions, attain equal opportunities and should be able to have a vote that is not pressured by any external forces.

The development of Mass-Media techniques is the seventh characteristic of the modernisation theory, suggests that countries should develop facilities that complement media (such as newspapers, broadcasting, postal facilities, movies, road, rail and air services, electricity, and T.V.) (Gilman, 2003). This helps in keeping people informed and enlightened of what is happening around the world and what new developments have come out. Thus, this keeps a country constantly in a modern state (Gilman, 2003).

Cultivation of national identity is the last characteristic of the modernisation theory, this suggests that when a country modernises, they attain a certain identity (Engerman, 2003) . For example, China has industrialised that fastest in the last century and seen as a country that is advanced in the assembling of products (Engerman, 2003).

4.3.3.3 Weaknesses of the Modernisation Theory

According to the Political Science Notes (2014) a rise in national and per capital income is one of the characteristics of the modernisation theory. This characteristic is very problematic when viewed from a third world perspective. For example, the building of hospitals be a positive boost to the economy as the hospitals employ staff members. Sick patients having to pay hospital bills contributes to the economy under modernisation, however, this does very little to add to development. Hence, in African countries where diseases and illnesses are rife, the per capital income of a country can easily give a figure that does not align with what is happening on the ground.

Expansions concerning industrialisation is another characteristic that is problematic. With modernisation pushing countries into industrialisation, this creates a situation where developing countries become more dependent on developed countries. Developing countries lack vital infrastructure (such as transport infrastructure – roads and rail) that is imperative for industrialisation. Therefore, developing countries would have to attain such infrastructure from developed countries. Moreover, the companies that are responsible for industrialisation originate from developed countries. This suggests that developing countries are ripped off their resources at the hand of modernisation. Thus, one gets the picture that modernisation was only developed to keep developed countries ahead as they gain easy access to the resources of developing countries.

4.3.3.4 Application of the Modernisation Theory in South Africa

According to Gilman (2003) the modernisation theory claims that modern states are wealthier and more powerful and therefore, their people are freer to enjoy a high standard of living. Furthermore, he asserts that facets such as the upgrading of transport and the building of world class buildings are just examples of how people in first world countries enjoy a high standard of living. This part of the modernisation theory alone adds focus to this study in the sense that the upgrading of transport systems requires large amounts of energy. South Africa is already underway with projects that aim to improve transport systems (for example, the Reya Vaya bus rapid transit (BRT) system in the Gauteng Province and the Gautrain that is a train that connects Pretoria and Johannesburg are already in operation with more projects underway across the country) (News Twenty-Four, 2016). In essence, the common denominator between these two technological advancements lies in the premise that any form of development brings with it energy demands. Thus, making it highly imperative to find new ways that can work towards generating additional energy.

4.3.4 Rostow's Model – the Stages of Economic Development

4.3.4.1 Early traces of Rostow's Model

According to Hilsenrath (1993) Rostow's model of economic growth was first published in the 1960's during the peak period of the cold war and was viewed as explicitly political as it opposed the notion of communism. This suggests that Rostow's model was challenging to communist governments, additionally, it is peculiar to note that Rostow was American. The fact that Rostow developed his model on economic development during the times of the cold war suggests that he was trying to gain influential stake into global politics. Furthermore, this also suggests that Rostow was in a way lobbying for America; it can be argued that the development of his model was in some way persuading governments (especially communist governments) from other countries to buy into this American theory and in doing so benefit America (Hilsenrath, 1993). In addition, Okwuosa (2016) claims that Rostow is regarded as one of the key thinkers in the 20th century in Development Studies and he was also an Economist and government official. The fact that Rostow was also a government official drives the notion of his theory lobbying other governments.

Allaway (2008) agrees with this view with the claim that Rostow developed his model in 1960. Furthermore, Allaway (2008) argues that Rostow's model was based on mainly 15 European countries. This is in line with Hilsenrath (1993) as he claims that Rostow's model was based solely on European countries in a western society that were already fairly industrialised and

urbanised. This suggests a heavy bias in the model and shows that the model only caters for a European perspective.

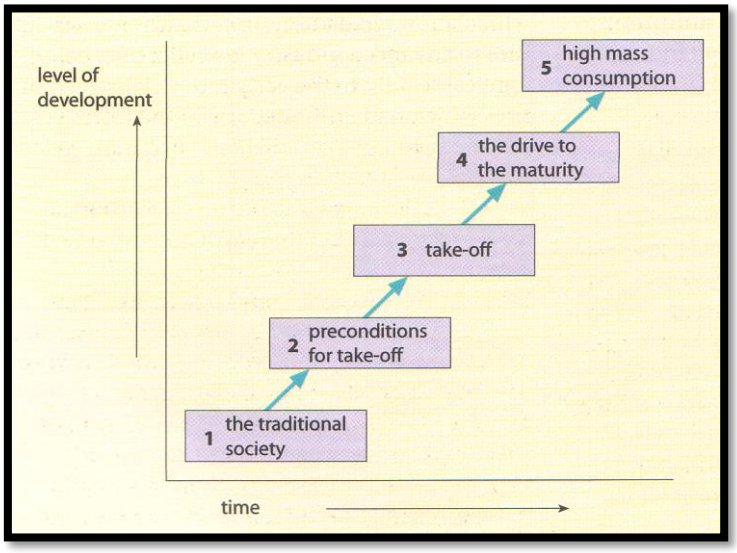
Okwuosa (2016) claims that prior to Rostow, development approaches had assumed that "modernisation" was characterised by the Western world (which comprised of more powerful and wealthier countries at the time), which could advance from the initial stage of under-development. This confirms the assertion made by Gilman (2003) pertaining to modernisation producing wealthier countries. This suggests that other countries ought to bench-mark themselves according to the Western world. In addition, Okwuosa (2016) claims that countries ought to aspire to become a "modern" society that is based on capitalism and a liberal democracy; and this is what Rostow based his model – the Stages of Economic Development on. This suggests that Rostow's model is rooted in the modernisation theory.

4.3.4.2 Features of Rostow's Model

According to Que (2011) Rostow's model on the Stages of Economic Development consist of five stages that countries must pass in order to become developed. Theses stages include:

1. Traditional society
2. Pre-conditions for take-off
3. Take-off
4. Drive to maturity
5. Age of high mass consumption.

Figure 4.2 Rostow's Model - The Stages of Economic Development



Source: Google images (2016) accessed on 20 October 2016 @ 15: 29

With specific reference to figure 4.2, Allaway (2008) claims that the traditional society is made up of a subsistence type of society where agricultural goods are consumed rather than traded (even there is some elements of barter trade). Que (2011) agrees with this notion and takes it further to note that agriculture is the dominant activity in a traditional society. This suggests that the agriculture involved here is not capital dependent and uses more home-based tools that are not very expensive.

The next stage illustrated on the diagram in figure 4.2 is the pre-conditions for take-off. Que (2011) claims that this stage is also known as the transitional stage. According to Allaway (2008) this stage is characterised of surpluses in agriculture that arise from advancements in transport infrastructure. Furthermore, agriculture becomes commercialised and mechanised with technological improvements (Allaway, 2008). This stage is also the stage where levels of capital grow, investment and saving begin to grow, bringing with it entrepreneurs (Allaway, 2008). This suggests that this is the stage where societies begin to abandon their traditional ways of subsistence.

The third stage in the diagram shown on figure 4.2 is the take-off stage. This stage is characterised by the society leaving agriculture and going into manufacturing; this creates a boost in industrialisation and brings with it rural-urban migration (Allaway, 2008). This view converges with Que (2011) who claims that this stage involves the switching from the agricultural sector to the industrial sector. Furthermore, Que (2011) argues that growth is concentrated in a few nodes in the country during this stage. This suggests that there is steep competition to access these booming areas. This is also the stage where new political and social institutions that advocate for industrialisation are born (Allaway, 2008). In addition, Hilsenrath (1993) claims that this stage brings with it transportation infrastructure advancements; resulting in the building of airports, roads and railways.

The drive to maturity stage is the fourth stage on the diagram labelled figure 4.2. Que (2011) argues that this stage is characterised by technological innovations that create investment opportunities. Allaway (2008) takes this notion further as he states that growth becomes diverse as technological innovations support it. This suggests that economic development begins to spread throughout the country in this stage. Furthermore, this also suggests that this stage involves the expansion of industries and transportation infrastructure that was established in the previous stage (namely; take-off).

The final stage on the diagram on figure 4.2 is the stage of high mass consumption. In this stage, the service sector becomes very dominant (Que, 2011). Allaway (2008) in agreeing with Que (2011) claims that this stage involves rapid expansion of the tertiary industry (this is the part of a country's economy that is concerned with the provision of services). Furthermore, he asserts that industry shifts to the production of durable consumer goods (Allaway, 2008). This suggests that the country at this stage is heavily involved in the exporting of goods. Thus, producing a positive balance of payments as the country exports more than it imports, hence, making considerable contributions to their economy. Moreover, Que (2011) argues that this results in the upper class being able to live a luxurious lifestyle.

4.3.4.3 Limitations to Rostow's Model

The fact that Rostow's model on economic development is based purely on the experience of European countries in a Western Society that were already industrialised and urbanised (Hilsenrath, 1993) to a certain extent is quite problematic. This assumption made by this theory of a uniform world is one that does not exist. Thus, the theory is flawed with regards to making this assumption. Furthermore, one can easily see how such a Western based theory could not work in an African context; instead it could create further problems if adopted in the African context.

Furthermore, another criticism to Rostow's model on economic development is the fact that it makes the presumption that all countries start with the same basic foundations; for example, the same natural resources, climates, population size and structure (Hilsenrath, 1993). One can easily see that no two countries share the same foundation, thus, this theory has shot itself in the foot. Therefore, it becomes very difficult now in the 21st century to simply take this Western theory and plug it into places like Latin America, Asia or Africa. Allaway (2008) agrees with this criticism, and further adds that Rostow's theory suggests that all countries have the potential to break the cycle of poverty and develop through these proposed 5 linear stages. Moreover, Que (2011) argues that this model only works in Western countries. All these authors converge at the focal point that denotes that this theory lacks substance when applied to regions outside of Western countries.

According to Que (2011) Rostow's model on economic development only shows the economic growth of a country. This is another grey area of the theory. With regards to development, economic growth is not the only aspect that indicates development. In fact, using economic growth to gage development represents an incomplete picture; other aspects that accompany

development have been omitted (for example, the literacy level, employment level and population per square metre are aspects that give a clearer picture in terms of a country's level of development).

4.3.4.4 Application of Rostow's Model in an Africa context

The presumption made by Rostow's model of economic development that all countries start with the same basic foundations (specifically referring to climate) (Hilsenrath, 1993) is one aspect that makes this theory relevant to this study. To elaborate, the climate experienced in Western countries is a cold and dry climate and Africa experiences a warm and wet climate. Thus, when looking at the development of waste-to-electricity projects within the scope of landfill gas extraction, LFGE projects in the West will render slightly different results to LFGE projects in Africa. This difference is derived from the time taken for waste to decompose; western landfills will decompose at a much slower rate than African countries. However, the legislation on LFGE projects is set in the West. This is problematic as the Western set legislation does not make considerations for climates outside of theirs. Therefore, this study aims to show this shortfall in LFGE projects policy framework and provide possible solutions.

4.4 Chapter Conclusion

This chapter has discussed the conceptual and theoretical framework of the study. The section covering the conceptual framework deals with concepts that drive the study and in addition make the reader understand the project better. Moreover, the theoretical framework section secures theory into the project. The three theories chosen have been well explained and most importantly their linkage to the study has been outlined. Both the conceptual and theoretical framework covered here give guidance to the study with concise well discussed content. Thus, this gives a solid platform for the following chapter that explores the literature review along with the precedent case studies.

CHAPTER FIVE

DATA PRESENTATION AND ANALYSIS

5.1 Introduction

Data presentation and analysis are the backbone of any study; this is where the secondary data in the form of known knowledge is married with the primary data that is collected in the field. The following study has employed the thematic data analysis method. According to Braun and Clarke (2006) thematic data analysis involves the organising of data into patterns (themes) and thus, resulting in the data set being described in a more detailed manner. This suggests that themes can be identified from the questionnaires based on the objectives that accompany study. Furthermore, the data that was collected in this study was analysed on Nvivo. Nvivo is a qualitative data analysis software program (Bazeley and Jackson, 2013) that can be used to make data analysis easier and faster. The following chapter will present the findings from the primary data which was collected in the field for the project. In addition, this chapter will integrate the literature discussed in the literature review, the research objectives of the study and the findings from the primary data collection.

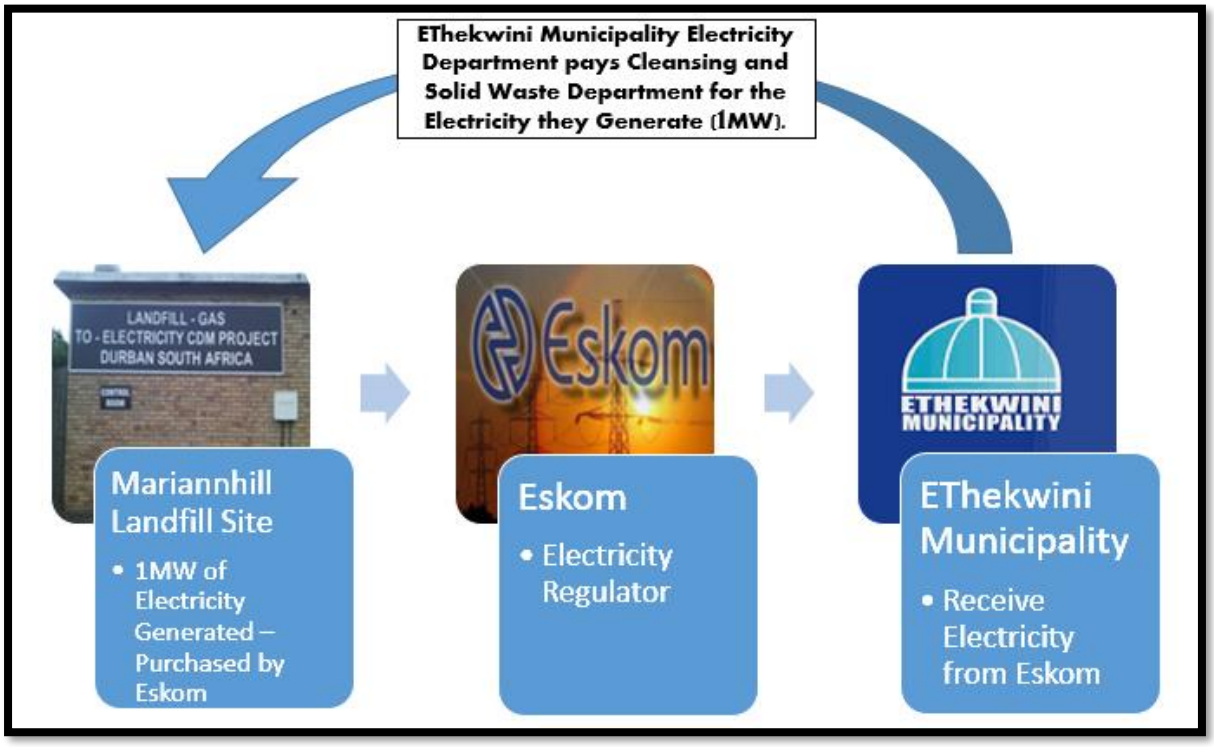
5.2 Electricity generated by Mariannhill Landfill Site towards National Grid

Mariannhill Landfill Site is one of the crucial components of the eThekwini Municipality Landfill Gas-to-Electricity Project which incorporates three landfills (namely, Bisasar, La Mercy and Mariannhill Landfill Site). One of the objectives of this study was to find out how much electricity this landfill (Mariannhill Landfill Site) contributes towards to national grid. More specifically, the amount of electricity this landfill generates and how much gets put back into the national grid. Dechezlepretre *et al* (2009) argues that electricity generation gives majority of the impetus towards the implementation of waste-to-energy projects; hence, this is the first objective the study set on finding. This information was collected during the field work phase of the study. One key informant that took part in the study had the following to say:

> So, at Mariannhill we currently still generating 1 mega-watt of electricity. Now we have the gas and we have got the electricity, now we need to plug it back into the grid. In those days (around 2001) when we looked at the purchase agreement with Eskom, we found it to be very onerous and the city took the decision that the Department of Cleansing and Solid Waste would sign an agreement with our electricity department

who would then purchase the electricity generated. So, we do not generate electricity into the national grid (the 33KV lines), we generate into the municipal grid (the 11 KV lines). What the municipality saves by bringing in the electricity from the national grid on Eskom is what the electricity department pays the Cleansing and Solid Waste Department for that gas. Whatever electricity we generate, Eskom does not have to supply us, so we reducing the demand for Eskom.

Figure 5.1 Developed Landfill Gas Electrification Model



Source: Author (2016)

Figure 5.1 shows a diagram that illustrates how the generated electricity from the Mariannhill Landfill Site is plugged back into the electricity grid. According to the Key Informant, Mariannhill Landfill Site consists of a 1MW engine at the electricity generating plant. Furthermore, the amount of electricity generated (electricity output) varies from month to month dependent on the capacity at which the engine is run at. In addition, the electricity output at Mariannhill Landfill Site ranges from 600-900 KWh on a monthly basis. The generated electricity at the Landfill Gas-to-Electricity at Mariannhill Landfill Site is purchased by Eskom (National Energy Regulator of South Africa (NERSA) Consultation Paper (2009), as opposed to being fed straight back into the electricity grid (be it the national or the local grid). Eskom then distributes this electricity into the local municipality (eThekwini Municipality to be specific). And lastly, eThekwini Municipality (the Electricity Department) pays the

Mariannhill Landfill Site which is under the Cleansing and Solid Waste Department for electricity they generate. This is in line with section 3.1 of the Renewable Energy Feed-in Tariff (REFIT) policy which elaborates on the Purchase Obligation of the legislation. The Purchase Obligation states that the Renewable Energy Purchasing Agency (REPA) (which is housed in Eskom's Single Buyer Office) will be obliged to purchase the energy delivered by the renewable energy projects licensed by the NERSA under REFIT phase 1 and 2 (NERSA Consultation Paper, 2009). In simple terms, REFIT states that the energy that is generated by renewable projects cannot be sold to any other energy entity but Eskom. This clearly shows how Eskom is the middle-man in this transaction.

Furthermore, this diagram (figure 5.1) is coordinated with Pegels (2010) concerning the Renewable Energy Feed-in Tariff (REFIT) policy, where Eskom purchases the generated electricity from renewable energy projects and makes it available to the public by plugging it back into the grid.

Picture 5.1 National Grid Lines (33KV) along Mariannhill Landfill Site

Source: Author (2016)

It is very interesting to note that the generated electricity at the Mariannhill Landfill Site does not get plugged back into the national grid because the national grid connection lines (the 33KV lines) run adjacent to the Mariannhill Landfill Site. With the national grid lines being so close to the landfill, it becomes rather redundant for Eskom to first purchase the electricity and then

plug it into the local grid. This shows how policy (making specific reference to the Renewable Energy Feed-in Tariff (REFIT) section 3.1) should not be cast and stone; there should be some flexibility within policy to avoid over complicating simple situations. It would be much easier and cheaper to connect the landfill gas-to-electricity plant at the Mariannhill Landfill Site to the national grid lines as they are already right there. This could also help create temporary employment and impact positively on local development, as locals would be employed to connect the electricity lines. In addition, local electricity companies could receive the tender for this job as the main contractor or as a sub-contractor. This notion is supported by Gumbo (2013) who asserts that African countries lack appropriate policies that support investments in renewable energy production. Picture 5.1 above shows the nation grid lines along the Mariannhill Landfill boundary.

5.3 Challenges and constraints that hinder electricity production from methane gas at the gas-to-electricity plant at Mariannhill Landfill Site

According to the respondents, there can be a number of challenges that can hinder electricity production within the scope of landfill gas-to-electricity projects. These challenges are not generic; they differ from plant to plant depending on both the surrounding area and the plant itself. The challenges experienced at the Mariannhill Landfill Site were categorised into three categories; namely, 1. the cost factor; 2. the surrounding industrial and residential area and 3. the technical aspect. The first category (the cost factor) surfaced the following response:

> The cost is probably the first hindrance. You should ask yourself why other municipalities (specifically Metros) haven't followed suit. I mean we started the project in 2008 and currently we still operating. Your biggest hindrance is cost. Who's going to pay for it? So, it's a funding thing, so now ultimately if a municipality wants to undergo such a project it becomes difficult.

Picture 5.2 below shows the gas-to-electricity plant at the Mariannhill Landfill Site. This is the pioneer gas-to-electricity project in South Africa that could withstand that cost factor barrier. The remarks made by one key informant are key in fuelling the change in thinking concerning landfills and landfill gas extraction. The key informant makes the assertion that law does not regulate gas-to-electricity projects. This suggests that the government ought to enact legislation that makes it compulsory for all, or at least the major landfills within local municipalities to establish gas-to-electricity plants. This will go a long way in improving the environment, reducing greenhouse gas emissions and producing excess electricity. In as much as the cost

factor for such projects is a tough obstacle to get around; government needs to come to the table and vigorously engage with the private sector in a probe to expand gas-to-electricity projects. If the government could attain funding to build a new coal-fired power plant called Medupi which costs nothing less than at least R105 billion (Eskom, 2016); then surely the government can attain funding to expand gas-to-electricity projects. It's just a matter of priorities; it boils down to a choice between the environment (renewable energy projects) or profits (non-renewable energy projects – coal). The above assertion does not in anyway attempt to compare renewable energy projects with non-renewable energy projects as there are a range of factors that place these two types of projects at opposite ends. This assertion merely expresses how the government can do better in sucuring some form of funding for renewable energy projects as it has already been deduced that they are quite costly to implement.

Picture 5.2 The Gas-to-Electricity Plant at Mariannhill Landfill Site

Source: Author (2016)

Furthermore, the remarks made on the second category (the surrounding industrial and residential area) were as follows:

> One of the problems we found was that Mariannhill being an industrial area, slightly residential, after peak periods (11 to 12 o clock at night when there is no requirement

(with the factories being all closed and the residents asleep), the electricity demand goes down and therefore, it becomes a problem for us to push the electricity further into the network and resulting in some trips. So, we had some electrical problems at Mariannhill.

The electrical problems experienced at the Mariannhill Landfill Site suggest how the challenges vary from area to area. Therefore, as mentioned above, policy (making specific reference to the Renewable Energy Feed-in Tariff (REFIT) legislation) ought to be flexible enough to allow for such challenges to be addressed neatly. According to the Key Informanmt, Mariannhill waste-to-electricity plant could have avoided the electrical trips experienced in the area with direct connection to the national grid lines. Picture 5.3 below shows a picture of the surrounding area around the Mariannhill Landfill Site. One can clearly see that this area is a residential area, even though one cannot deduce where the industrial area lies in relation to the Mariannhill landfill Site.

Picture 5.3 Residential Area Surrounding Mariannhill Landfill Site

Source: Author (2016)

And the remarks made on the third category (the technical aspect) were as follows:

The other constraint is technical knowledge; it's a very technical project and there is not that many people out there that have the relevant skills (especially in

Municipalities). Now if the municipality wants to sell off the project, then they remove the risk from the municipality. But then they have to provide long term agreements. So again, your second hindrance in that regard is the supply chain management in long term private public partnerships. It's an onerous process. This is one thing that has delayed bigger metros from committing and going along this route. In terms of the technical side; regional landfill sites, well operated, the dump scenario you won't get gas.

The following remark is coordinated with Gumbo (2013) who makes the assertion that the reason why very few projects have been implemented in Africa is the fact that Africa suffers serious shortages of qualified and well-trained personnel. According to the Institution of Engineering and Technology (2016) secondary data shows that gas-to-electricity projects require the following skills and technical aspects:

• **Research, planning and development** – for example; data analysts, planners, software developers, GIS technicians, environmental analysts, ecologists, aerodynamics specialists, technical experts, scientists, mechanical, civil and electrical engineers.

• **Design and manufacture** – for example; procurement and selection of kit, technical designers, mechanical and electrical engineers, electrical and grid connection design, geophysicists, technical experts.

• **Construction and installation** – for example; project managers, contract managers, site management, cabling, civil engineers, construction.

• **Operations and maintenance** – for example; grid connection, electricity generation, physical inspection and maintenance, technician, disaster management.

• **Support services** – for example; business development, communication and public relations, human resources, finance, legal support, administration, facilities management.

However, even with this assertion being true within the African context, the Landfill gas-to-electricity project at the Mariannhill Landfill Site has made use of innovative and advanced technology. This was observed during the observations of the study where several vertical gas extraction wells were identified. Picture 5.4 above shows 4 images of the vertical extraction wells (gas pipes); the first image shows the concrete marking of the gas pipe; the following images show the concrete structure that surrounds the gas pipes. The two diagonal images even show the gravel pack that engulfs the piping, along with the actual pipes.

Picture 5.4 The Vertical Extraction Wells (Gas Pipes)

Source: Author (2016)

5.4 The Benefits of Electricity Production from Methane Gas

According to the respondents, there are tangible benefits that can be derived from electricity production. These benefits have been dichotomised into two pools, namely, benefits of energy production from methane gas towards area local development and benefits towards man-kind and the city at large. This is what the respondents had to say about the first pool (area local development) of benefits:

> One area that you could be looking at is generation of electricity to a community or an island mode where you generate the electricity and don't plug it back into the Eskom grid or the national grid, you supply the electricity to the people around the landfill site. All contracts that get put out we use local community labour and we empower through that way. Unfortunately, as much as I'd love to say we power up the community in terms of electricity, we don't – it goes back into the grid. Other than labour intensive work that you employ through the local communities and the ward, it's minimal.

The remark made by the respondent above shows that there is very minimal benefit that the such projects bring onto local development. The mere fact that the generated electricity does

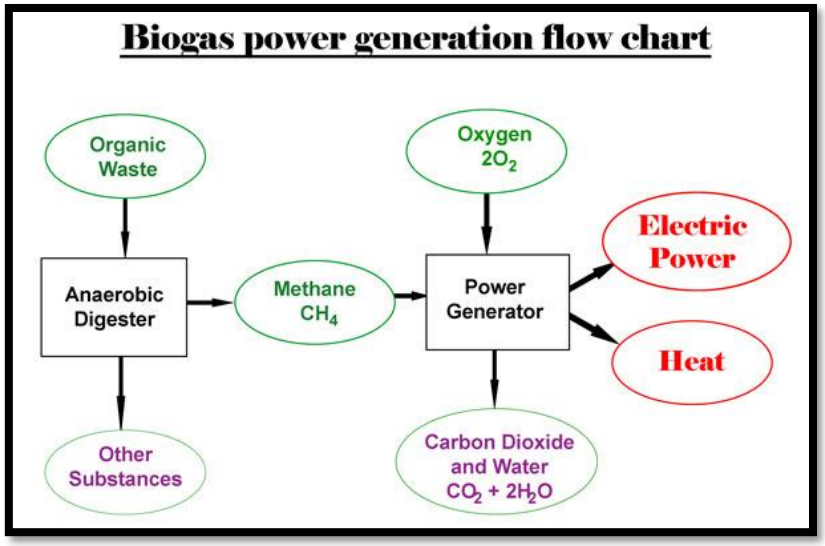
not feed directly into the local houses suggests that there is very little benefit for the locals. Furthermore, the way the electricity is distributed after being generated at the Mariannhill Landfill Site is divergent to the views of (Mohareb *et al*, 2008) where the electricity generated at the Halton Region Waste-to-Electricity Plant in Canada is plugged directly into the local household, powering 1500 households.

The next pool (benefits derived by man-kind and the city at large) surfaced the following remarks by one key informant:

> One of the problems that people have living near a landfill is the odour. So, by actively extracting the gas you reducing the odour. We've proved that, we had a lot less complaints from the surrounding community once the project started. So, that's one of the benefits for sure. The methane that would have been vented into the environment (I mean it's a known fact that methane destroys the environment) is being destroyed and that helps reduce the effects of global warming. Thus, mankind is getting a vital environmental service from the running of such projects. If you look at CDM and you look at first world countries and third world countries; we will get CDM because we are destroying the methane gas here in African (South Africa) and first world countries will be able to buy the CERs. Now the biggest debate from the NGOs and environmentalists are that the first world countries (for example America) should be doing that in their own country and we should still be doing here. So, by allowing them to buy our carbon credits, it allows them to industrialise even more. So, it's a catch 22 scenarios. But it's the right thing to do; it will destroy the methane gas.

The above response links in well with Themalis and Ulloa (2007) where they argue that the capturing of methane gas for energy generation contributes towards cleansing the environment; not only do LFGE projects help reduce the odour around landfills, destroying the methane gas also helps address global warming and climate change. Furthermore, Strachan et al (2002) makes the claim that the anticipated income from the project is R205 million which includes both the sale of ER estimated at R114 million and R91 million from the sale of electricity to the grid. These figures show the steep benefits that come with such projects. However, it is unclear where and how this money is and continues to be distributed.

Figure 5.2 Biogas Power Generation Flow Chart



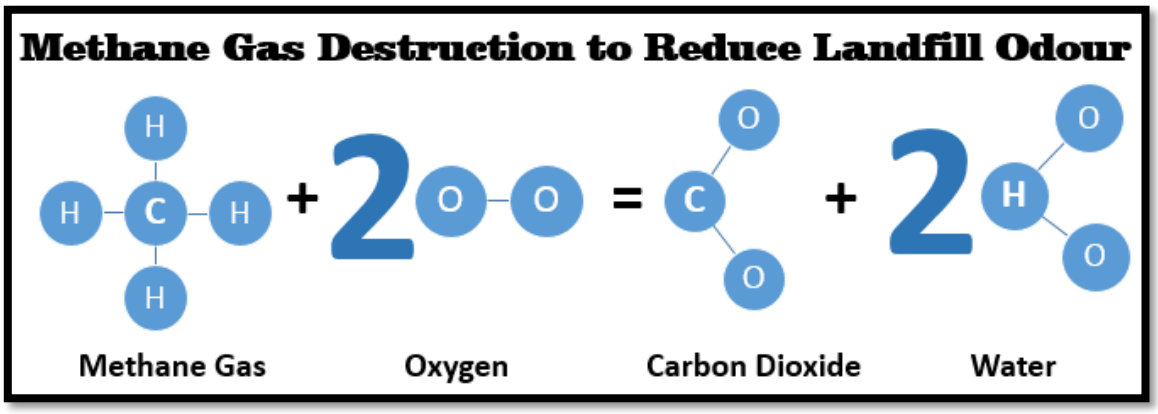
Source: Hunyo (2015)

The diagram above (figure 5.2) shows the biogas power generation flow chart. In this diagram, it is clear how organic waste decomposes through anaerobic digestion to produce methane gas as a by-product (accompanied by other substances). This process takes place within landfills and the result of this process is the venting off of a bad odour. The gas-to-electricity plant then collect this methane gas and mix it with oxygen within the mechanical engine of the power generation plant. The spin-offs of this process include the generation of energy (both electricity and heat) along with the release on carbon dioxide water (Hunyo, 2015). This is how the odour is destroyed within landfill sites that extract and combust methane gas. Furthermore, the below diagram (figure 5.3) shows the chemical bond process that occurs with the termination of odour within landfill sites that destroy methane gas.

Figure 5.3 shows how methane gas as a molecule is made of one carbon atom bonded with 4 hydrogen atoms. When methane is combined with oxygen (which is made up of 2 oxygen atoms) within the power generation engine, the carbon atom loses its hydrogen atoms and attaches to 2 oxygen atoms to produce carbon dioxide and the left-over hydrogen atoms form bonds with the left-over oxygen bonds to produce water (Hunyo, 2015). This is how the odour is destroyed within landfills that practice methane gas extraction. One can see how beneficial waste-to-electricity projects are. In as much as they may do very little for local development; the environmental service that man-kind attains from such projects cannot be quantified - this reduces greenhouse gases today, which saves the environment for future generations. However, the catch 22 situations that surfaces in the response suggests that first world countries push the

development of gas-to-electricity projects to be able to continue to industrialise further. This shows the schizophrenic nature of first world countries.

Figure 5.3 Diagram Showing how Odour is Destroyed through Methane Gas Extraction



Source: Author (2016)

5.5 Environmentally Sustainability of Methane Gas Electricity Generation

With waste-to-electricity plants falling under the renewable energy sector; it becomes clear that these projects are environmentally sustainable to at least some degree. However, this does not mean that the level of environmental sustainability should not be questioned. Hence, one of the objectives in the study sets out to determine whether the process of generating electricity from methane gas is sustainable or not. One of the respondents had the following to add:

> …environmentally it's the right thing to do, it's whether you can pay back the project that's the challenge.
>
> Our health and safety is very strict, its and area that we place a lot of emphasis on. Methane between 5 and 15 % becomes very explosive, so you got to be very cautious with methane gas. In terms of safety; methane is a very heavy gas so it settles in confined spaces. So, you must be very careful when dealing with methane gas in confined spaces. A landfill that is on fire is extremely difficult to put out.

The above response is coordinated with Bonam (2009) who argues that destroying the methane gas protects the ozone layer from being depleted by methane gas. This suggests that the process of generating energy from methane gas is environmentally sustainable as the ozone layer protects man-kind from the sun's harmful ultra violet rays. The environmental sustainability aspect associated with such projects far out weights the profit that can be made; because the ozone layer cannot be purchased nor does it have a replacement.

Furthermore, with assessing the environmental sustainability of waste-to-electricity projects, it is crucial to ask the question of whether this process can inflict any harm on humans. This is because the project may be environmentally sustainable, however, it may be dangerous or risky to undergo (and these dangers may cause fatalities from time to time). One respondent gave the following remark when asked if this process could inflict any harm of humans:

> Other than the safety issues; no. I think it's a massive benefit to electricity generation and the environment and the people in the surrounding communities. So, I don't believe it can be harmful to humans, unless you get an unplanned disaster of some sort; maybe the engine blows up or a fire starts or something.

The above responses, one can easily see that the process of methane gas extraction for electricity generation is environmentally sustainable. Furthermore, this links in with the claim made by the IEA (2008) in this process being one that does not claim human lives. The fact that there are such avenues to generate electricity that are not being explored to their full potential suggests that there are political forces that are restricting the expansion of these projects. Perhaps there is a lack of awareness that is suffocating the expansion of gas-to-electricity projects in South Africa.

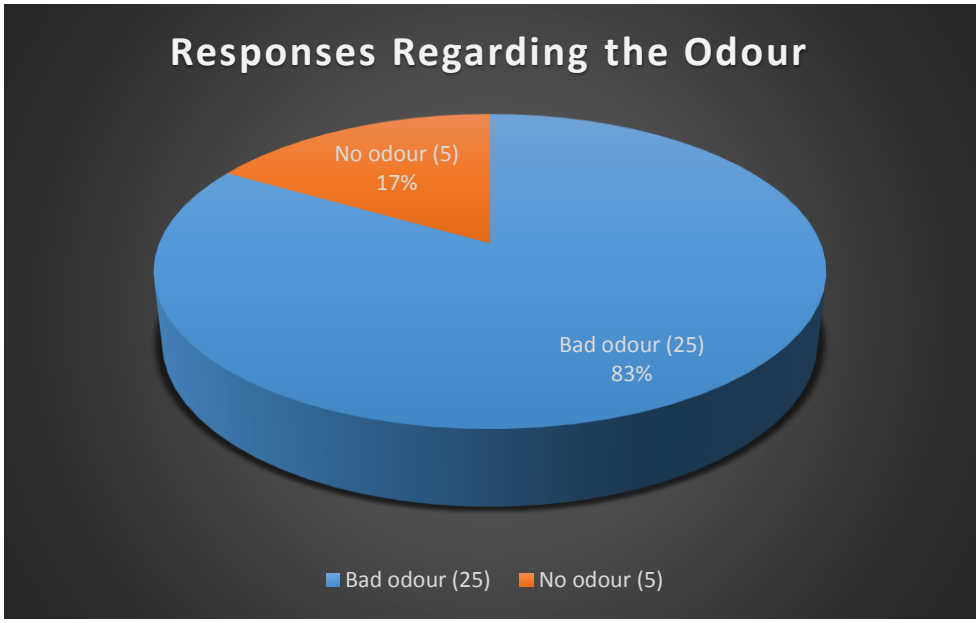
5.6 Attitude of the community on the odour they experience

According to the respondents, the odour that is experienced coming from the Mariannhill Landfill Site is the most daunting thing that the locals nearby have to deal with on a daily basis. Many respondents responded strongly about the odour; making negative remarks.

The pie chart below (figure 5.4) shows the responses that were reflected by the respondents (30 in total) that took part in the study. A large portion of the respondents (25 respondents to be exact) felt that the odour that originates from the Mariannhill Landfill Site is rather disturbing and gives off a pungent smell. This shows the feelings of 83% of the respondents. These figures show that most of the locals are not happy about the smell that they experience because of the Mariannhill Landfill Site. In addition, the odour that the locals experienced was also dependent on several factors; like the wind direction, the time of the day, the weather conditions along with the season and where they lived in relation to the Mariannhill Landfill Site. The following remark from one respondent reflects this notion:

> The odour is bad, seriously. But, primarily at night especially once it rains then it gets all sunny and stuff. At night when the wind blows, it takes it straight through to us, you can't even sleep with the windows open to be precise.

Figure 5.4 Pie Chart Showing the Responses Regarding the Odour Experienced by the locals



Source: Author (2016)

However, what can be done, because the municipality needs landfill sites to dispose of its waste in a correct manner to prevent the outbreak of diseases and illnesses. According to the IEA (2008), MSW should be collected, sorted and processed in a systematic manner that resembles a high standard of landfill management. In this way, the locals nearby will not experience the landfill by-products (such as the odour). Furthermore, figure 5.4 shows that only 5 respondents felt that there was no bad odour that originated from the Mariannhill Landfill Site. This reflects only 17% of the respondents. The following remark reflected this:

> I haven't experienced any smell from the Mariannhill Landfill Site, I even forget at times that I stay near a landfill site.

This response shows the other side to the coin; where some respondents felt strongly against the smell that they experienced and others did not experience any bad odour. According to Bonam (2009) flaring (burning/ destroying) of methane gas helps reduce the odour that originates from landfill sites. Even though only a small portion of the respondents felt they did not experience bad odour from the Mariannhill Landfill Site, the are a number of factors that come to play with regards to the respondents experiencing bad odour, for example the type of house plays a crucial role, the distance from the landfill site, the wind direction and speed along

with the topography. Moreover, the odour perhaps gets better after the waste has been treated. Thus, resulting in the waste giving off the odour for a short period till it is treated.

5.7 Attitude of the community on the noise they experience because of the Mariannhill Landfill Site

According to the respondents, the general perception about noise attributed to the Mariannhill Landfill Site was that the landfill site did not cause much noise. With the Mariannhill area being a residential area, it is generally quiet. However, some respondents did raise complaints on the trucks that moved in and out of the Mariannhill area; the general remark was that they (the trucks) did make some noise, but the noise level was on a very tolerable scale. The table below (table 5.1) shows the frequency and percentage of the respondents that did not experience any noise from the Mariannhill Landfill Site versus those that did experience noise from the Mariannhill Site. The table shows that a whopping 27 respondents (90% of the respondents) did not experience any noise from the Mariannhill Park and only 3 respondents (10% of the respondents) experienced noise from the Mariannhill Landfill Site. Thus, it can be safe to conclude that the Mariannhill Landfill Site caused very little noise if any for the locals that reside in the Mariannhill area.

Table 5.1 Responses Regarding Noise Experienced by Respondents

	Respondents who did not experience any noise	**Respondents experienced noise**
Frequency	27	3
Percentage (%)	90	10

Source: Author (2016)

Furthermore, of the respondents that felt that they did not experience any noise from the Mariannhill Landfill Site, the following quote can be used in support:

> To be honest, I don't want to lie. I haven't been affected by their noise. I've never heard any noise from the Mariannhill Landfill Site.

The terrain in the Mariannhill area is also quite steep and hilly; which could possibly help to deflect, absorb and minimise the noise that is created at the Mariannhill Landfill Site. This notion is in sync with the views of Frantzis (1993) who argues that the selection of the location for municipal landfill sites is very crucial and should be done with great care in order to prevent

the residents residing around the landfill site from experiencing disturbing agents of noise pollution. In addition, Vrijheid (2000) claims that residents living near landfill sites in European regions reported an increase in self-reported health symptoms such as headaches and sleepiness. This could perhaps be linked to the noise pollution experienced by the residents living around landfill sites. However, it is comforting to know that the Mariannhill Landfill Site performs its functions without disturbing the locals nearby in terms of noise pollution. In addition, the respondents that felt that the Mariannhill Landfill Site did in fact generate noise from the actual processes that involve heavy machinery, the following excerpt can be used in support:

> There is this continuous noise, even at night as if there is an engine. It's so powerful at night when everything is quiet. You think that maybe its cars outside but it's an engine, it's a disturbing noise.

5.8 Attitude of the community on how the heavy machinery (the trucks) affect the roads

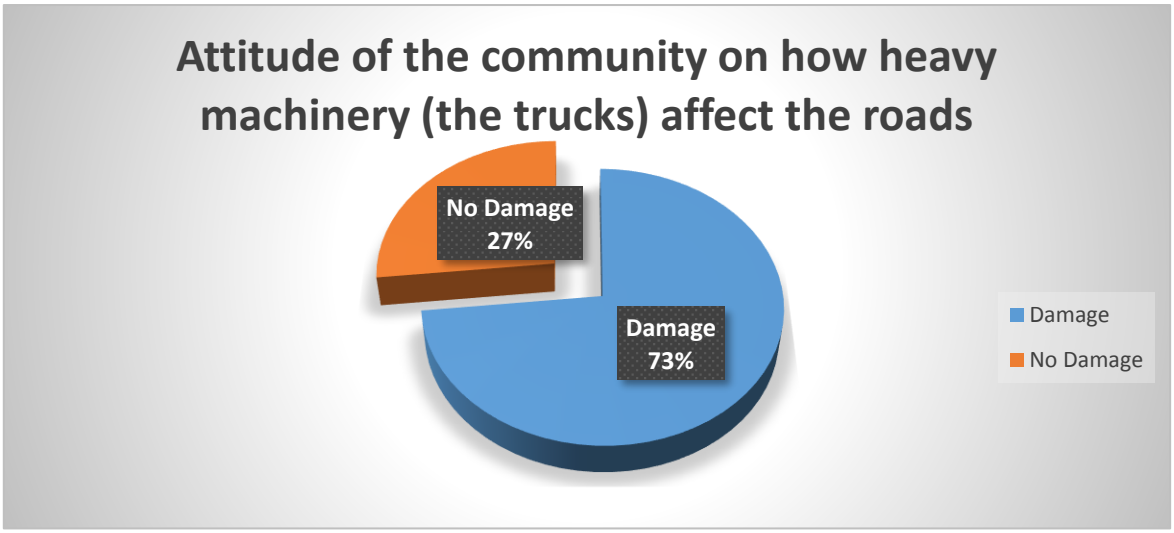
The municipal solid waste (MSW) trucks that collect the waste from households, industry and commercial areas have the daunting task of moving back and forth the hilly terrain of the Mariannhill area. Furthermore, with the area being a residential area, the roads are not designed to carry trucks carrying heavy loads and the corners along with the turns make it very awkward for the trucks to make the sharp turns. Most of the respondents expressed feelings of animosity towards the trucks being on the roads in their community. Some respondents had the following to say:

> The trucks cause potholes because of their heavy weight. You can also see over there the trucks spill dirt on the road by that corner. Sometimes trucks even breakdown here causing unnecessary congestion.

Figure 5.5 below shows a pie chart the illustrates how the respondents felt the trucks affected their roads. The pie chart shows that 27% of the respondents (8 out of the 30 respondents) felts that their roads are in good condition and the trucks did not damage them. However, 73% of the respondents (22 out of the 30 respondents) felt that their roads were being brutally damaged by the trucks that move in and out of their area. These respondents made note of several ways that the trucks destroyed the roads; namely, the trucks drive over storm drains and damage them, they spill the waste they are carrying on the roads and they cause pot holes. This shows how the heavy machinery associated with the Mariannhill Landfill Site causes an inconvenience in the lives of the locals. The views expressed by the majority on the respondents

converges with Vrijheid (2000), he also claims that spills by trucks could lead to a number of health disorders such as respiratory symptoms, psychological conditions, various cancers and gastrointestinal problems. This shows how the residents living around the Mariannhill Landfill Site may be at risk of suffering health dis-orders. Furthermore, Rushton (2003) also claims that human encounter with large concentrations of toxic materials could lead to illness. This shows how serious the issue of waste is and the importance of disposing of waste in the correct manner. Hence, this shows how the waste spills caused by the trucks is a serious issue that ought to be addressed with a high level of importance.

Figure 5.5 Pie Chart Showing how the Trucks affect the Roads



Source: Author (2016)

Picture 5.5 Durban Solid Waste Truck Turning a Sharp Bend

Source: Author (2016)

Picture 5.5 above shows one of the Durban Solid Waste trucks making a sharp bend to turn into the road leading up to the Mariannhill Landfill Site. This is a common area that experiences spills from the trucks. It is very problematic, because the gradient is steep and the turn is also sharp. The dirt left behind could be hazardous; sharp objects in the dirt can damage vehicle tyres (which can result in accidents) and the dirt could be hazardous to children playing in the area (Vrijheid, 2000). In as much as the trucks are responsible for spilling dirt onto the roads; the road design does not accommodate for trucks carrying heavy loads. Thus, the engineers that designed the roads are also to blame for the spills.

5.9 Attitude of the community on the traffic they experience because of the Mariannhill Landfill Site

According to some respondents, the Mariannhill area experiences traffic from time to time as a result of the Mariannhill Landfill Site. This traffic was mostly attributed to the slow-moving trucks that move in the community bringing in waste and leaving to go and collect more. This view is in line with Rushton (2003) and Hirshfeld et al (1992); these scholars argue that the establishment of a landfill site could and usually leads to increased traffic congestion. This can be expected as landfill sites offer a service to the locals, thus, drawing in higher numbers of people to a target area. However, the general response from the respondents was that the community did not experience much traffic if any. The following remark reflects that there is some traffic that is experienced in their community because of the Mariannhill Landfill Site:

> There are times when it's a bit bad and it is influenced by the trucks that are turning in or like even other vehicles turning into their driveways. It's usually trucks when they are turning at that corner, literally they drive very funny.

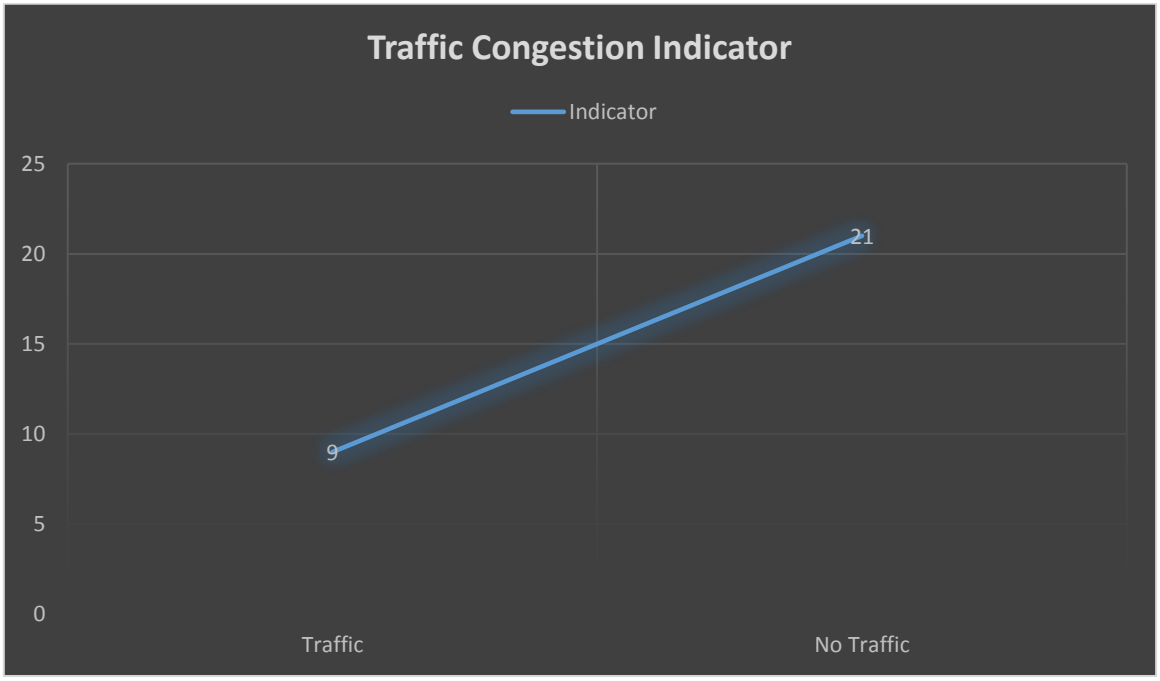
Contrary to the above quote, some respondents felt that the traffic congestion levels in their community were very minimal. The following remark reflected this:

> I haven't had any experience that has resulted from those trucks. Yea, not this landfill site, it might be somewhere else because during the peak hour everyone is busy anyway, but you won't find maybe three of four trucks that are occupying the road, it's just one truck in a while.

Figure 5.6 (below) shows the traffic congestion indicator based on the respondents that took place in the study. The respondents that felt that their community experienced traffic

congestion because of the Mariannhill Landfill Site are illustrated on the left-hand side; whereby only 9 respondents (30% of the sample size) were of this view.

Figure 5.6 Traffic Congestion Indicator



Source: Author (2016)

The respondents that felt that there was not much if any traffic congestion in their community have been illustrated on the right-hand side; 21 respondents (70% of the sample size) were of this view. This strongly shows that the Mariannhill area does not experience much traffic and if there are some stints of traffic congestion, they are very minimal. Picture 5.6 was taken during the observation phase and from this picture, one gets the indication that the Mariannhill Area does not suffer from traffic congestion. This shows how the traffic phenomenon within the Mariannhill area diverges from the views of Hirshfeld et al (1992) and Rushton (2003).

Picture 5.6 Durban Solid Waste (DSW) Trucks

Source: Author (2016)

5.10 Attitude of the community on the level of dirt that they experience because of the Mariannhill Landfill Site

According to some respondents, the level of dirt in their community was quite bad. Many of the respondents felt that this was attributed to the Mariannhill Landfill Site. This is what some respondents had to say:

> Well its disgusting because if you drive up the road there's an open section and everybody just goes and dumps. So, I mean it's disgusting. They just go and dump their black bags and its and absolute mess. Its hazardous, obviously to health and then ya, people must go and clean up after them.

This response shows that the level of dirt in the area is relatively high. With people simply dumping their waste on the side of the road to perhaps avoid paying the dumping fees at the Mariannhill Landfill Site, this could pose serious health risks. This view is in sync with Rushton (2003) who argues that toxic materials could lead to illness. However, one can supposedly argue that this is not directly linked or caused by the Mariannhill Landfill Site.

Picture 5.7 Illegal Dumping around The Mariannhill Landfill Site

Source: Author (2016)

In addition, picture 5.7 above is an image that shows illegal dumping outside the Mariannhill Landfill Site. This image clearly shows the negligence of people. According to Ramachandra and Bachamanda (2007) dumping waste in this manner not only causes a nuisance for those living in the area that is being dumped in; this impacts negatively on the appearance of the area and undermines the whole waste management process. Furthermore, such dumping attracts animals such as rats, stray cats and stray dogs. It is quite saddening that people would engage in such, the only explanation that one could give is that those who dump their waste in this manner do so knowing that it will not affect them as they do not stay in the area that is affected.

While illegal dumping cannot be directly linked to the Mariannhill Landfill Site, the trucks travelling to and from the Mariannhill Landfill Site can be perceived as being associated with the Mariannhill Landfill Site. These respondents argued that the trucks spill some of the waste that they are carrying onto the roads to make the community dirty. This was a dominant view from the respondents and the field observation phase of the study confirmed this; the pictures

taken in the field show waste spills on the roads that were caused by the trucks that move to and from the Mariannhill Landfill Site. The following remark reflects this notion:

> They (the trucks) are spilling waste all over and nobody is coming behind them to pick up this mess. It just stays there; I don't know whether the municipality sends some construction to come and pick it up, but it stays for days.

Picture 5.8 Demarcated spillage by truck

Source: Author (2016)

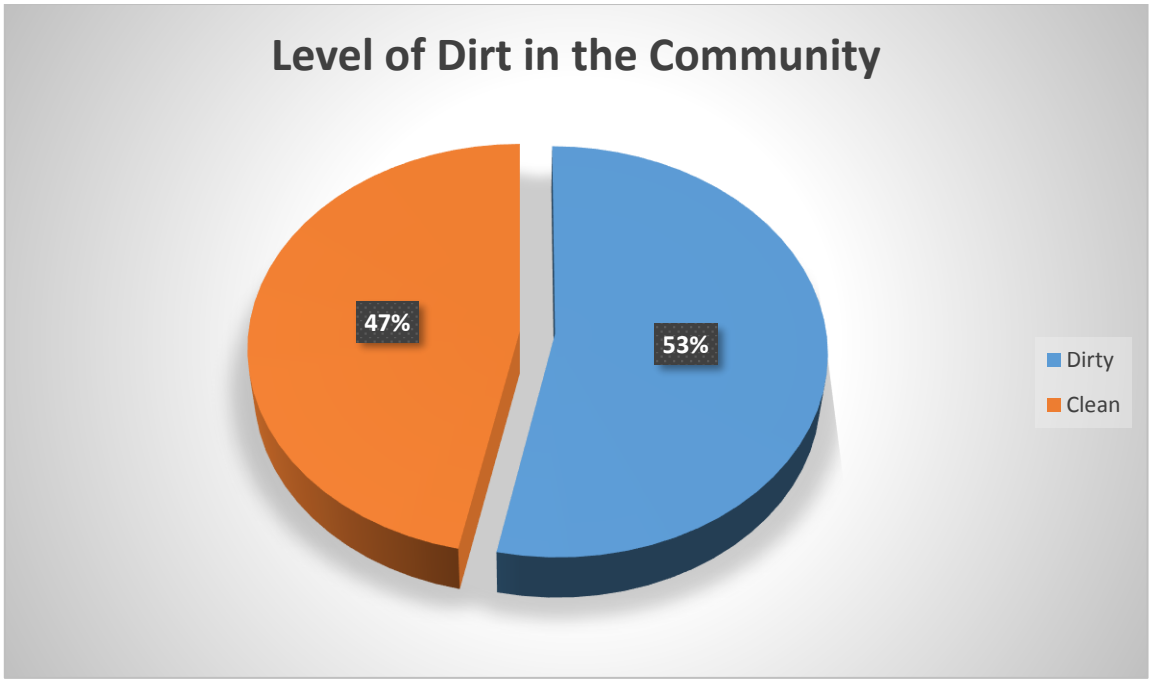
The above image (picture 5.8) shows what the above-mentioned respondent commented on. The area demarcated in red shows where there was previously a spill from a truck trying to turn the sharp bend. One can easily depict that this is an old spill; however, the traces are still visible and the spill still lingers in the atmosphere. According to Vrijheid (2000) this is how people can fall ill. Such dirt spills could have long term effects on the locals. Furthermore, Vrijheid (2000) argues that even though there is no known link between landfill waste and cancers, future knowledge brought forward could prove otherwise as this is an area of great research during this era.

On a diverging note, some respondents felt that the community around the Mariannhill landfill Site was/ is clean and did not experience any dirt because of the landfill. Furthermore, these respondents felt that the Mariannhill Landfill Site along with Durban Solid Waste (DSW) did their fair share to ensure that their community remained clean. This was reflected in the following responses:

> No, it's clean shame, our community is clean, I don't want to lie. We always encounter people (from Durban Solid Waste) cleaning and they even cut the grass on the side of the roads.

Furthermore, when looking at how the respondent's views went up against each other, the pie chart (figure 5.7) below gives a good illustration. The pie chart shows that 47% of the respondents (14 respondents) and 53% of the respondents (16 respondents) felt that the community was reasonably dirty. This pie chart shows that the respondent's views were quite balanced regarding the level of dirt in the community as opposed to the odour that is experienced from the Mariannhill Landfill Site.

Figure 5.7 Pie Chart showing the level of Dirt in the Community

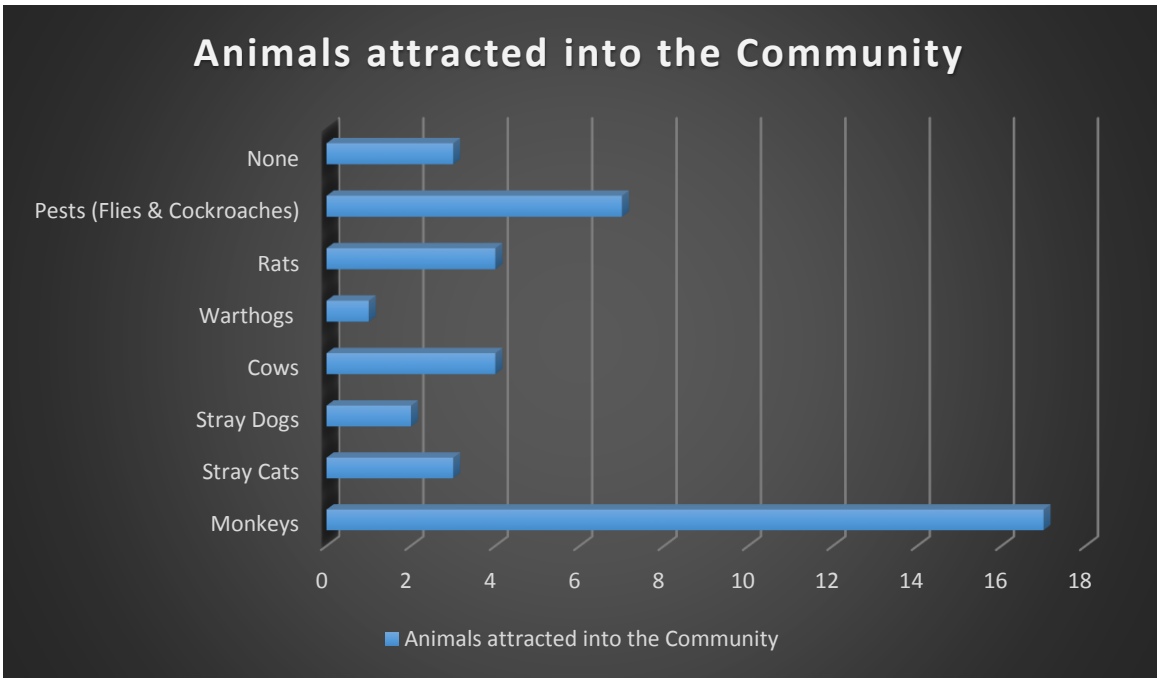


Source: Author (2016)

5.11 Attitude from the community on what kind of Animals the Mariannhill Landfill Site is perceived to attract

According to the respondents, there were a number of animals that the respondents felt the Mariannhill Landfill Site attracted into their community. However, the consensus was that there were a lot of monkeys in the area. In addition, the respondents reflected quite several animals that were attracted to their community because of the Mariannhill landfill site; these animals include stray cats, stray dogs, warthogs, rats, cows and pests (both flies and cockroaches).

Figure 5.8 Bar Graph showing the different Animals Attracted into the Community



Source: Author (2016)

Figure 5.8 above shows a bar graph that illustrates the animals that the respondents felt the Mariannhill Landfill Site attracted into their community. Where is reads 'none' this means that the respondent did not feel the Mariannhill landfill Site aided in attracting any animals into their community. Monkeys are the most frequently listed animals in the bar graph. This could be linked to the fact that the Mariannhill Nature Reserve is also found in the Mariannhill area. The following remark also reflected this:

> Those wild animals; those monkeys. And then there are cows. I don't know whether the cows come because of the grass here or they are attracted to that, but those two animals.

Furthermore, picture 5.9 shows a monkey that was spotted at the Mariannhill Landfill Site. There were also other animals such as stray cats, rats and stray dogs that were observed in the community as well as the Mariannhill Landfill Site itself during the field work phase of the study. According to Howard (2001) flies and other pests can also exist in abundance in and around a landfill site. This view is also supported by the above bar graph (figure 5.8) with pests and flies being the second most frequent animal attracted to the Mariannhill Landfill Site. This confirms the remarks made by the respondents on the kind of animals that are attracted to their community.

Picture 5.9 Monkey Spotted at Mariannhill Landfill Site

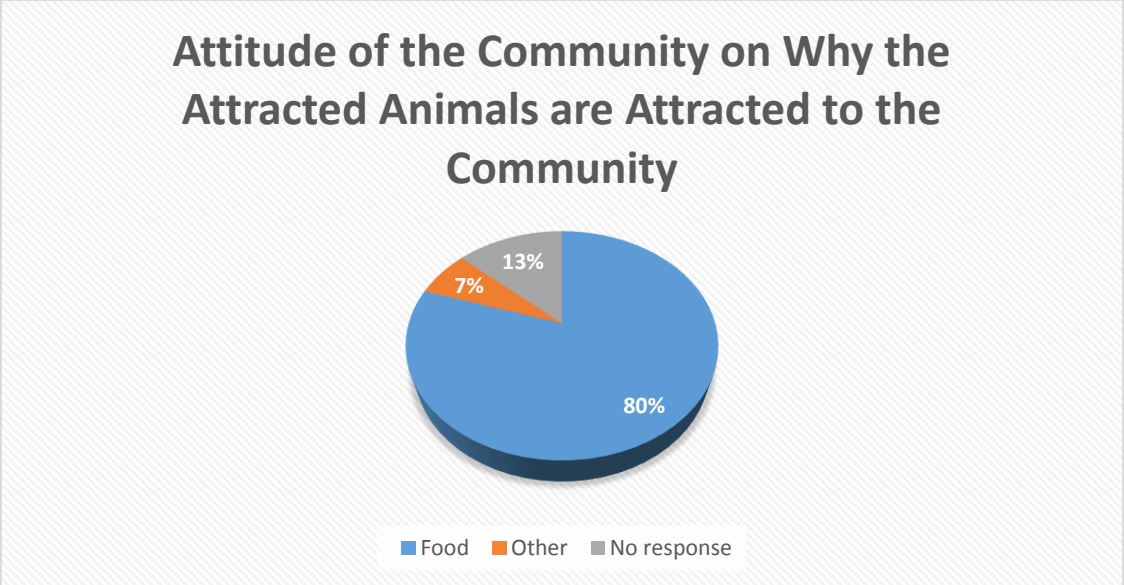
Source: Author (2016)

5.12 Attitude of community on why the attracted animals are attracted to the community

According to most of the respondents, the animals that are attracted to the Mariannhill Landfill Site are attracted to the landfill for the purposes of food; the smell coming from the landfill attracts these animals and the with there being dirt at the landfill (and also in the community) these animals use the landfill as a food source. The animals come into the community with the aim of finding food to scavenge on. In addition, Howard (2001) argues that flies in particular are drawn to landfill sites by other dead animals (for example, a dead pet bird).

Figure 5.9 below shows a pie chart depicting the feelings of the respondents on why the attracted animals are attracted to the community. Majority of the respondents, which was 80% of the respondents (24 respondents) felt that the attracted animals were drawn into their community in search of food. 7% of the respondents (2 respondents) felt that the attracted animals were attracted to their community for other reasons, such as seeking a place of habitat within the landfill dirt. And 13% of the respondents (4 respondents) did not give an answer for this question in the questionnaire; this was due to these respondents not giving an answer to the previous question that asked what kind of animals were attracted to their community because of the Mariannhill Landfill Site.

Figure 5.9 Pie Chart Depicting Why Attracted Animals are Attracted to the Community



Source: Author (2016)

In support of the view that the attracted animals were attracted into the community in a search of food, the following response serves as a good indicator:

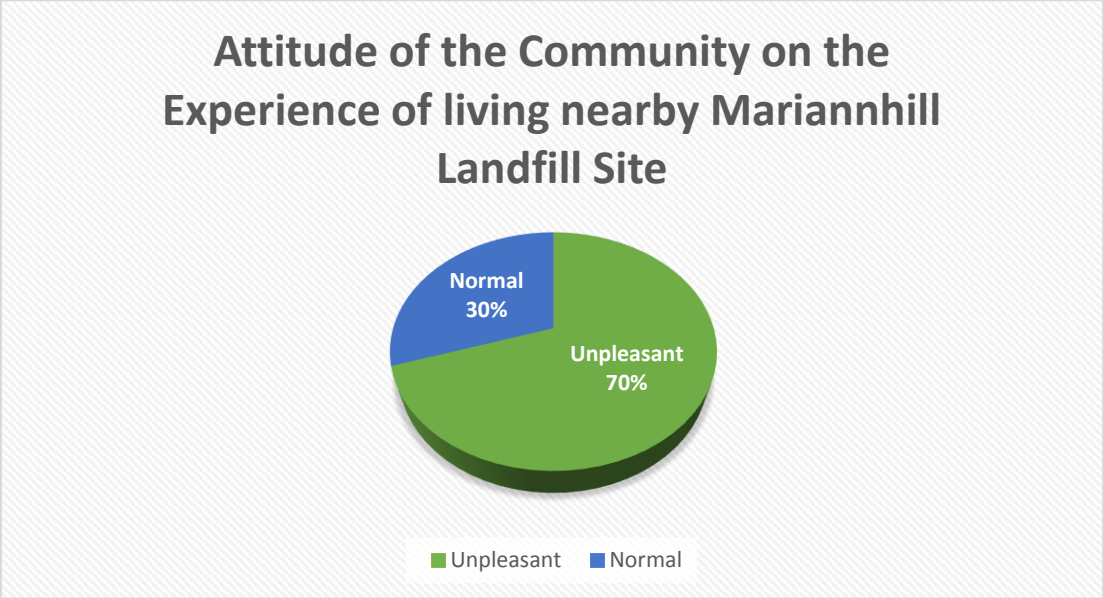
> I think they are searching for food. They go there (to the Mariannhill Landfill Site) they don't find anything they think it's a waste and end up coming to our community searching for food.

5.13 Attitude of the community on the experience of living nearby the Mariannhill Landfill Site

According to most of the respondents, the experience of living near the Mariannhill Landfill Site unpleasant and undesirable; the respondents made strong remarks about the malodorous odour, the dirt that can be found in the community and the pests (flies and cockroaches) that are drawn to their community. However, there was a fair portion of the respondents that felt that the experience of living in the community was normal and pleasant.

Figure 5.10 below shows a pie chart showing the respondents feelings on the experience of living nearby the Mariannhill Landfill Site. Of the respondents, 30% (9 respondents) felt that the experience was normal. And 70% of the respondents (21 respondents) felt that the experience was unpleasant.

Figure 5.10 Pie Chart showing Feelings of Community on the Experience of Living nearby Mariannhill Landfill Site



Source: Author (2016)

In addition, the respondents that felt that the experience was normal is supported by the following excerpt:

> It's normal, because at sometimes I even forget that its around. I think they are keeping the place (the Mariannhill Landfill Site) neat and professional.

This view from the respondent corresponds with the claim made by Zhu *et al* (2007) in the light of the importance of running a landfill site in a correct and professional manner to inflict

the least nuisance and/or harm on the locals nearby. The fact that only 30% of the respondents felt that the Mariannhill Landfill Site was running normally contradicts this assertion by Zhu et al with regards to Mariannhill Landfill Site.

However, most the respondents that felt that the experience of living near the Mariannhill Landfill Site was unbearable and that this was a constant challenge in their day-to-day lives, the following quote can be used in support:

> I wouldn't buy a house here. Beside the trucks, it's not nice to stay in a smelly place. Having a home in a stinky place and the next thing when you having a braai on the weekend you experience the smell. It feels somewhat embarrassing to you as the host.

5.14 Attitude of the community on how load shedding affects them

According to majority of the respondents, the Mariannhill community does not experience much load shedding (in the past and currently). These respondents felt that load shedding was very rare in their community. The following remark is coordinated with this notion:

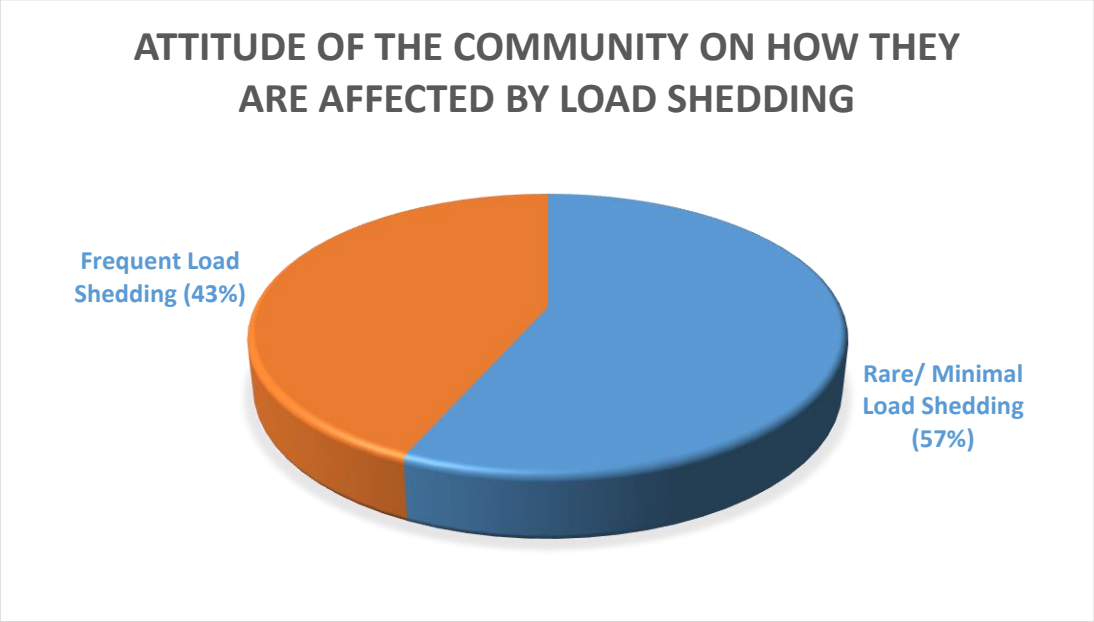
> We do not experience load shedding that much this side.

Contrary to this statement, some respondents felt that the community did in fact experience serious waves of load shedding. And this resulted in several problems and social ills in their community. Some respondents felt that the load shedding resulted in damage to their food stocks in the fridge, other respondents felt that load shedding resulted in increased crime as the community was suddenly dark and having no electrical power meant that their electric gates did not work (allowing criminals easy access into their homes) and some respondents felt that load shedding increased the chances of road accidents as the robots would not be functioning. This view converges with the views of Matthewman and Byrd (2014) who argue that blackouts (load shedding) cause food (more particularly meat) to perish before the due time. They also argue that in 2008 in South Africa when load shedding was very dominant, there was a considerable increase in crime rates. McGreal (2008) found in Matthewman and Byrd (2014) claims that 2008 saw South Africa experiencing increased violent robberies from cars returning home and being delayed on the road while their electric gates had to be opened manually. This shows how load shedding can create serious problems within a community. Thus, stressing the further expansion into alternative energy sources in an attempt to generate more energy and

keep up with the demand. The following remark shows great synergy with the negative implications of load shedding discussed above:

> It's bad, because when the robots are not working the traffic starts; and then you get congestion problems, there are problems with higher accidents occurring, when you get home you can't cook. Sometimes you can't even open the gate if it's an electrical gate, especially if it doesn't have a backup battery. So, it's sort of a mess; food goes off in our fridges .

Figure 5.11 Pie Chart showing the Feelings of Community on how they are Affected by Load Shedding



Source: Author (2016)

Figure 5.11 above shows a pie chart that illustrates how the respondents felt load shedding affected them. Majority of the respondents, 57% (17 respondents) felt that their community did not experience or they experienced very acute levels of load shedding. And contrary to this, 43% of the respondents (13 respondents) felt that their community experienced rampant levels of load shedding. This shows how locals of the same area can have different perceptions on the same phenomena. Perhaps the fact that people work different hours, could be a possible explanation as to why people would perceive the same phenomenon differently.

5.15 Attitude of the community on the benefit from alternative energy sources

According to majority of the respondents, there are a number of benefits that arise from the use of alternative energy sources; namely, eradication of load shedding, job creation, reduction of global warming and saving of electricity. A few respondents were not sure of the benefits that can be derived from using alternative energy. The table below (table 5.2) shows the responses from the respondents regarding their feelings on benefitting from alternative energy sources. The table shows that 90% of the respondents (27 respondents) felt that there are solid benefits that can be derived from the use of alternative energy. And the other 10% of the respondents (3 respondents) were not sure how the community could benefit from the use of alternative energy.

Table 5.2 Benefits Derived from Alternative Energy Sources

	Solid Benefits Derived	Not Sure
Frequency (number)	27	3
Percentage (%)	90	10

Source: Author (2016)

With regards to the respondents that felt that there were/ are actual benefits that can be derived from the use of alternative energy, the following remark was in support of this notion:

> Then there would be less load shedding and we can save more money on electricity bills. I think that's quite important because, with what's been going on, we get charged increasingly for electricity and it's the load shedding which we lose out of food stuff and the rotten stuff. I mean who's going the replace that back to us, no one compensates.

This is coordinated with the findings of Pindzola (2008) and Mohareb *et al* (2008) who both observed the multiple benefits of alternative sources of energy (specifically energy derived from LFGE projects). These benefits included the generation of enough energy to power 8000 households in the United States at the Iris Glen Landfill Site (Pindzola, 2008) and the energy the power 1500 households in Canada at the Harford Region Landfill Site (Mohareb *et al*, 2008). This shows the importance of this study; with LFGE projects providing the benefit of energy generation from a clean energy perspective, this can go a long way in helping lower the price of electricity. Thus, the implementation of LFGE projects across South Africa would make a considerable difference to the price of electricity. However, LFGE projects should be

implemented in the correct manner in order to derive the maximum benefits to the people. The following excerpt highlights this notion:

> If those alternative energy sources are cheaper, then Eskom will have a competitor and then the price of electricity will go down. However, what usually happens with the alternative energy sources is that Eskom buys them, so we end up buying electricity from Eskom again. Thus, if only the other energy sources could be independent, then it will benefit everyone.

With the process of distributing electricity back into the national grid being difficult; this suggests that Eskom has monopolized electricity provision in South Africa. And any new sources of electricity ought to go through them (Eskom) before it can reach the national grid. Thus, this gives Eskom the power to dictate the power of electricity. This suggests that the respondents are of the ideology that Eskom is ripping them off in terms of the price that they charge for electricity. Perhaps a solution to counter this effect would be to come up with policy that will ease the process of plugging the generated electricity back into the national grid under the guidance of Eskom. This would result in two problems being addressed by the same stone; this being due to alternative energy coming into the national grid ensuring that less coal is burned to generate electricity.

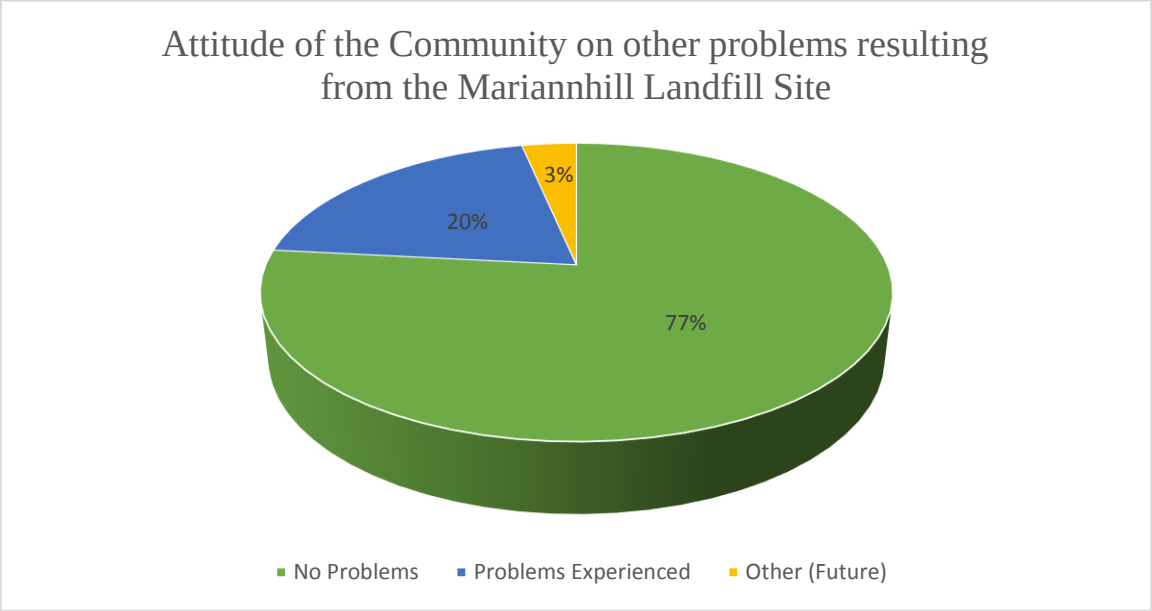
Furthermore, according to Boyd *et al* (2009) the establishment of the waste-to-energy plant in Bole Horizonte in Brazil brought with it a crucial benefit in the form of job creation. This suggests that the project in Brazil was adding to local development and reducing unemployment at the same time. This shows how alternative energy projects are interlinked in their implications. Hence, the generation of alternative energy is a necessity in South Africa. With South Africa being a developing country, development comes with steep energy demands (The Economic Development Department, 2016). This once again points the government to avenues that will diversify the energy sector.

5.16 Attitude of the community on other problems resulting from the Mariannhill Landfill Site

The general feeling of the respondents on other problems arising from the Mariannhill Landfill Site where quite passive; the respondents did not have much to say about other problems, but rather complained of problems already discussed in previous questions (problems such as the bad odour, traffic and the level of dirt). This suggests that the respondents generally feel that

the Mariannhill area is a habitable community where people can lead normal lives; it is only those minor issues from the Mariannhill Landfill Site that make it uncomfortable. Frantzis (1993) argues that landfill sites location selection should take into account the effects that will be transferred onto the nearby residents. One can argue that the Mariannhill area is a suitable location for the Mariannhill Landfill Site on the grounds that the residents are not affected in a significantly negative manner. Apart from the truck spills and the bad odour, the Mariannhill residents seem hardly affected by the Mariannhill Landfill Site.

Figure 5.12 Pie Chart showing Feelings of Community on other Problems resulting from the Mariannhill Landfill Site



Source: Author (2016)

Figure 5.12 shows a pie chart depicting the respondent's feelings on other problems resulting from the Mariannhill Landfill Site. Majority of the respondents, which accumulates to 77% of the respondents (23 respondents) felt that there were no other problems resulting from the Mariannhill Landfill Site. The following excerpt reflected this:

> Not much. Besides the smell, everything else is fine. Besides the fact that it lowers the value of the building (the complex), but it's not going to be here forever (the landfill site) as they close landfills after a certain period of time.

Still referring to figure 5.12, 20% of the respondents (6 respondents) felt that there were other problems arising from the Mariannhill Landfill Site. These problems include the children in the community being exposed to the dirt in the community (for example, on the side of the roads), crime (one respondent made the remark that some people go to the landfill in search of things to sell like copper and when they do not find such in the landfill, they look within the community) and the issue of poor and unreliable public transport (this is not linked to the Mariannhill Landfill Site, however, it was a problem that was raised none the less). The following excerpt reflected this notion:

> I don't see any other problems. But, other people are going into the landfill site with the hope of finding things there and if they can't find anything there then they involve themselves in criminal activities in our community. There have been so many people robbed and loosing cell phones.

In addition, one respondent made the following remark:

> The kids being exposed to what kind of dirt is around, I think basically it's a safety and security thing as a mother.

And lastly (still referring to figure 5.12), 3% of the respondents (1 respondent) gave remarks of the category of 'other'; they did not answer on whether they experienced any other problems or not in the community, but rather their response was based on the problems that they could possible incur in the future. This was surfaced from the following remark:

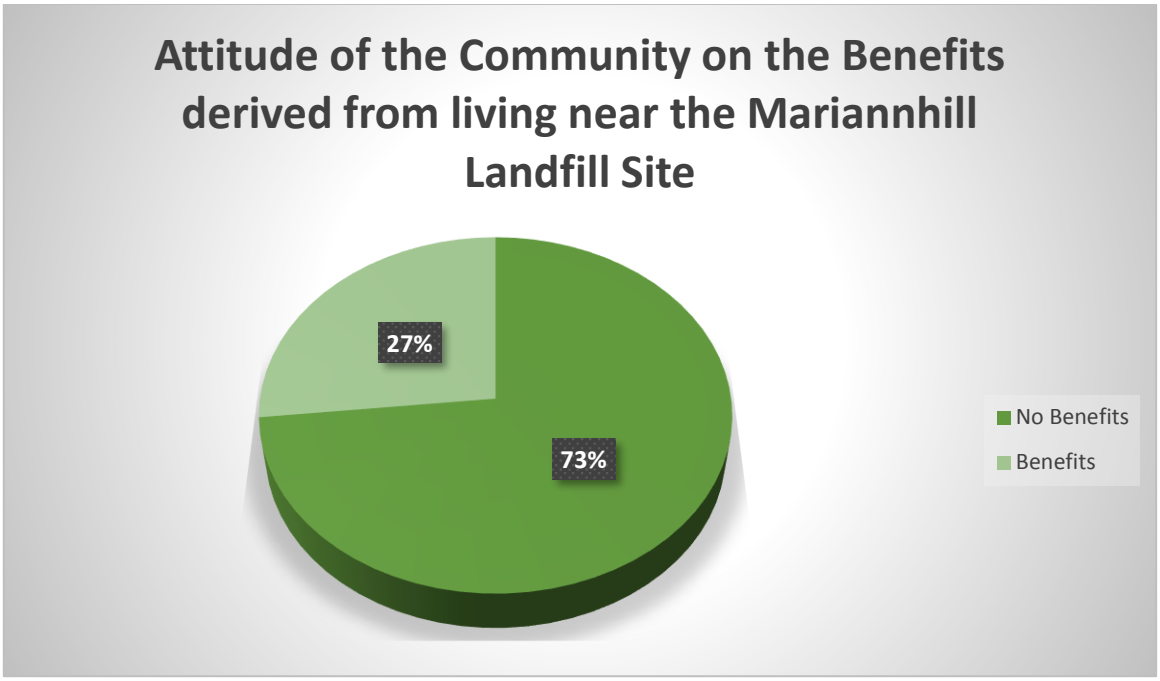
> Well, it could cause disease, it could cause ill-health. I think its hazardous to people's health.

5.17 Attitude of the community on the benefits from living near the Mariannhill Landfill Site

According to majority of the respondents that took part in the study; there are no known benefits of living near the landfill site. However, some respondents felt that they did in deed derive some benefits from living nearby the Mariannhill Landfill Site. This is in line with the IEA (2008) which argues that capturing methane gas can save people's lives, destroying the methane gas makes landfill sites safe. The respondents do not feel this way; this may be due to the fact that they do not derive any immediate benefits that they can tangibly pocket. In addition, Themalis and Ulloa (2007) argue that capturing methane gas helps reduce global

warming. Thus, this shows how people benefit from gas-to-electricity projects. Hence, one can safely say that the residents living near Mariannhill Landfill Site do benefit from the Mariannhill Landfill Site. Figure 5.13 below shows a pie chart showing the response from the respondents regarding their feelings on whether there are benefits from living near the Mariannhill Landfill Site. One can easy see that only 27% of the respondents (8 respondents) felt that there were tangible benefits from living near the Mariannhill Landfill Site. While 73% of the respondents (22 respondents) felt that there were/ are no known benefits from living near the Mariannhill Landfill Site. This suggests that more of the respondents would rather not have the Mariannhill Landfill Site near their community at all.

Figure 5.13 Feelings of Community on the Benefits derived from living near the Mariannhill Landfill Site



Source: Author (2016)

With regards to the respondents that felt that they derived benefits from living near the Mariannhill Landfill Site, the following remark is in line with this notion:

> I guess it's easier to just dump your dirt there because its close and our municipal waste pick up is on Fridays. So, if you cut your grass and trimmed your trees, it's easier to go throw the waste away at the Mariannhill Landfill Site instead of waiting for the following Friday.

From these responses one can deduce that having the Mariannhill Landfill Site nearby helps keep the area clean to a certain extent. One the other end of the stick, the majority of the respondents felt that they did not derive any benefits from the Mariannhill Landfill Site, the following excerpt can be used in support of this notion:

> I don't see any benefit because they still charging us to get rid of our waste. I don't see any benefit; it's not far if you want to dump but I live in a complex; so, in a complex I don't need to clean the yard and go dump things. So, I actually don't benefit.

The observations shown on table 5.3 above did not show much of the observed aspects as anticipated. When looking at the first aspect, namely, smoke – the Landfill Gas-to-Electricity Plant did not give off any smoke throughout the observation period. This makes it difficult to believe how the Mariannhill Landfill Site can lead to health disorders such as respiratory symptoms. Thus, this view is divergent to the view of Vrijheid (2000) as he argues that landfill sites can lead to health disorders such as respiratory symptoms.

5.18 Observation Checklist and Schedule

Table 5.3 Observation Checklist and Schedule

Observed Aspects	**Week One (Monday and Wednesday)**			**Week Two (Tuesday and Thursday)**		
	9am	**1pm**	**4pm**	**9am**	**1pm**	**4pm**
Smoke	None	None	None	None	None	None
Traffic	None	None	None	None	None	None
Noise Levels	Low	Low	Low	Low	Low	Low
Animals	Monkeys Stray cats Stray dogs	Monkeys Stray dogs Rats Cows	Stray cats Rats Cows	Monkeys Stray cats Cows	Monkeys Stray dogs Stray cats Cows	Monkeys Rats Cows

Source: Author (2016)

Even though one can observe that the exhaust pipes at the plant give off heat from the blurry sensation that occurs immediately outside the pipes, never at any point during the observations did the exhaust pipes give off smoke. Picture 5.10 below shows this phenomenon.

The observations showed that the Mariannhill area does not experience traffic. There are times when traffic is slowed by the odd truck or two, however, this does not constitute to traffic. If there is traffic in the area, it cannot be attributed to the DSW trucks as they start coming into the Mariannhill Landfill Site from 10am. Thus, it is safe to say that the Mariannhill Landfill Site does not induce traffic in the surrounding area. This notion goes against the notions of Rushton (2003) and Hirshfeld et al (1992) that claim that the establishment of a landfill site can lead to increased traffic congestion in the areas nearby the landfill site.

When looking at the amount of noise created by the Landfill Gas-to-Electricity Plant at the Mariannhill Landfill Site, it is very minimal. One can only hear the engine at the plant from approximately 10 metres from the plant fence. However, there are vibrations that one experiences when standing close (within approximately 5 metres from the actual plant). These vibrations are part of the plant operating procedures as the engine is generating energy. The same phenomenon is experienced from a vehicle engine.

Picture 5.10 Smoke Observation at the Landfill Gas-to-Electricity Plant at the Mariannhill Landfill Site

Source: Author (2016)

There are several animals that the Mariannhill Landfill Site attracts; these animals include cows, stray cats, stray dogs, rats and monkeys. The rats, monkeys, stray cats and stray dogs were observed both within the landfill and in the surrounding areas. The cows were observed outside the Mariannhill Landfill Site; they favoured a piece of lawn that was opposite to the landfill entrance. This is contrary to Howard (2001) who claims that landfill site attracts flies and other pests, it is very hard to think that a landfill site would attract cows picture 5.11 shows the piece of lawn were the cows were usually spotted during the observations.

Picture 5.11 Lawn Opposite Mariannhill Landfill Site where Cows Were Spotted

Source: Author (2016)

5.19 Chapter conclusion

The data analysis and interpretation chapter has done well on realising all the objectives that were set by the study in the first chapter. This chapter outlined the amount of electricity that Mariannhill Landfill Site Landfill Gas-to-Electricity generates. Even though this electricity is

not plugged directly into the national grid, it is still useful from an electricity shortage perspective. This chapter has also been able to identify the benefits that are derived from gas-to-electricity projects; the benefits may be minimal in terms of benefits towards local development, however, the benefits towards man-kind are humongous. Man-kind attains various environmental services; from the cleansing of the environment, to the reduction of greenhouse gasses and the protection of the ozone layer. These aspects show that the Landfill Gas-to-Electricity Project at the Mariannhill Landfill Site is environmentally sustainable. Furthermore, this chapter also showed how this process of electricity generation does not inflict any harm on humans. Even though some respondents made remarks of nuisances from the Mariannhill Landfill Site; namely, the bad odour, the damage to the roads by the trucks, the traffic and the noise – these nuisances were not felt to the same extent by all the respondents. On a more positive note, the respondents felt they could benefit immensely from the use of alternative energy. A very little portion of the respondents knew that Mariannhill Landfill Site produces clean energy. This may be due to the fact the respondents (and the locals at large) do not see the immediate benefits of this electricity as it is not fed straight into the grid or to their households to reduce their electricity bill. Therefore, the policy (the renewable energy feed-in tariff – REFIT) that restricts the electrification of renewable energy projects is heavily flawed and biased towards Eskom. This policy allows Eskom to dictate the price of electricity. Thus, for the people (especially the poorest of the poor in townships and rural areas) to start feeling the benefits of alternative energy of this nature, policy regulating renewable energy ought to be adjusted. In addition, academics and technical experts in the field of renewable energy need to form a caucus and enact new policies. The way that these renewable energy projects are continuing at present does not do justice to the magnitude behind gas-to-electricity projects.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 Introduction

The principal purpose of study was to evaluate the viability of generating electricity from methane gas capture within landfills. The study used the Mariannhill Landfill Site as a case study. Mariannhill Landfill Site forms part of the pioneer gas-to-landfill project that was established in the eThekwini Municipality; thus, making it a key case to investigate (more especially because the project has been in operation for a decade, as it went live in December of 2006). The evaluation was carried out during the field work phase of the study as the researcher gathered information from various respondents. This information was analysed using the thematic analysis data analysis method. Moreover, the conclusions and recommendations were based on this procedure.

Conclusions and recommendations are a pivotal part of any research project; this is where the researcher can make the connection between the research objectives and the research findings. In addition, the chapter on conclusions and recommendations sums up the whole study. The following chapter aims to adhere to the above principles of a conclusions and recommendations chapter. The chapter will give the conclusions of the analysed themes in the study. Then the chapter will provide recommendations for the concluded themes. In addition, this chapter will include a section pertaining to the realisation of the objectives.

6.2 Major Findings

6.2.1 Electricity generated by the Landfill Gas-to-Electricity Project

Conclusion:

With it being deduced that the Landfill Gas-to-Electricity Project at the Mariannhill Landfill Site produces 1MW of electricity, this project does its bit in reducing the load on Eskom. The process of generating electricity from landfills through methane gas capture is a technical process (incorporating both civil and electrical engineering), however, the process itself is one that is achievable. The Mariannhill Landfill Site have showed this. Picture 6.1 below shows the 1MW engine that is used at the Landfill Gas-to-Electricity Project at the Mariannhill Landfill Site. The problem comes in when the electricity has been generated; the process suddenly becomes highly political. The fact the generated electricity is not fed directly into the

national grid or even to the local grid poses a major concern. The REFIT policy that commands renewable energy projects (including gas-to-electricity projects) to sell their generated electricity to Eskom at a 'predetermined' price is not only flawed; however, it is undermining to the whole purpose behind the use of renewable energy. This policy not only allows Eskom to continue to bully the energy market through the electricity prices; it also advocates and perpetuates the further usage of coal as source of energy in South Africa.

Picture 6.1 MW Engine at the Landfill Gas-to-Electricity Plant at the Mariannhill Landfill Site

Source: Author (2016)

Recommendations:

The recommendation that is proposed here is to address the policy framework that guides renewable energy projects in South Africa. The REFIT policy is highly biased and impractical within the scope of promoting renewable energy avenues and as a result, very few renewable energy projects (especially gas-to-electricity) have been established in South Africa as a whole. Thus, academics and technical experts in the field of renewable energy need to congress and come up with new policy that will advocate for justice and rejuvenate renewable energy

projects in the country. Furthermore, the enacted policy ought to allow room for flexibility as each project is different and will present different challenges.

Moreover, the new policy or the upgraded REFIT legislation should allow renewable energy projects (making specific reference to gas-to-electricity projects) to be able to plug their generated electricity into the grid (at least the local municipality lines). Eskom should rather play the role of the guiding stakeholder during this process. In this way, the 'middle man' will be cut out and the benefits and profits from renewable energy will be translated into the pockets of the people through cheaper electricity prices.

6.2.2 Challenges and Constraints that Hinder Electricity Production

Conclusion:

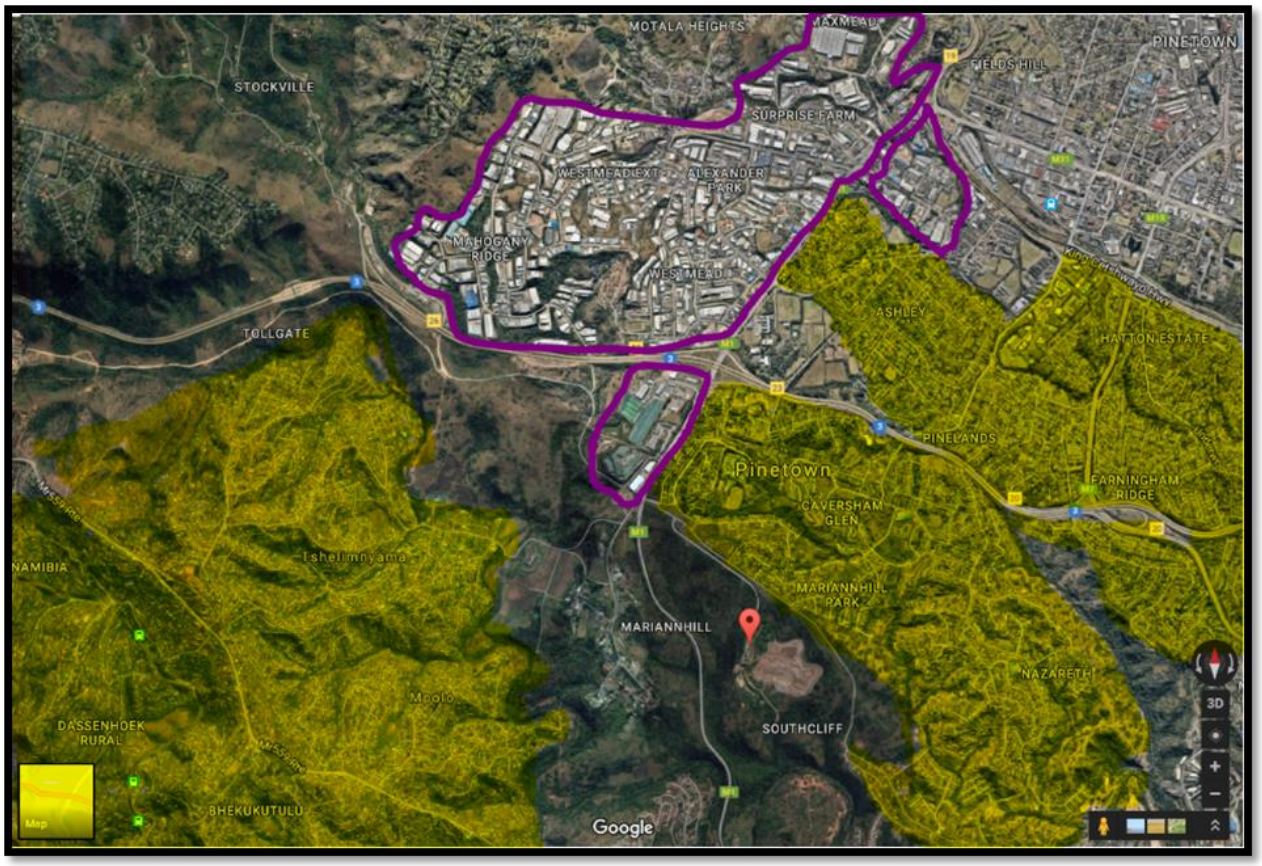
The cost of establishing gas-to-electricity projects is the first and most formidable challenge that hinders the generation of electricity from methane gas extraction; the case of the Mariannhill Landfill Site proved no different. These projects are very expensive; it costed eThekwini Municipality approximately R15 million to establish the Landfill Gas-to-Electricity Project (Project Summary Document, 2011). Thus, authorities within local municipalities are more concerned with providing basic services such as water, sewer facilities and housing. Thus, for gas-to-electricity projects to grow in South Africa, the government needs to find ways accumulate the funds from somewhere.

The next hindrance that was experienced at the Mariannhill Landfill Site was the fact that the area is an industrial area and slightly residential. Therefore, after peak periods the electricity demand rapidly drops. Thus, making it a problem pushing the electricity further into the network and resulting in trips. These electrical problems show how unique each gas-to-electricity project is. Thus, each project should be treated with some room to cater for such unique challenges. Map 6.1 below shows the residential areas highlighted in yellow and the industrial Westmead area outlined in purple in relation to the Mariannhill Landfill Site which sits in the middle of both these land uses.

The final challenge that was experienced at the Mariannhill Landfill Site is one that affects most renewable energy projects; this being the fact that these projects require technical knowledge. This suggests that majority of the people that should be involved in gas-to-electricity projects should be people that are trained and qualified in this field. Furthermore, this challenge brings with it the risk of a project not being successful. If the relevant personnel (skilled professionals) are not involved or consulted, the whole project can be unsuccessful and

thus resulting in money thrown down the drain. Thus, gas-to-electricity projects ought to be audited on a regular basis (perhaps annually) to ensure that the relevant personnel are technically engaging in the process of electricity generation from methane gas extraction.

Map 6.1 Industrial Area and Residential Area in Relation to The Mariannhill Landfill Site



Source: Google maps (2016)

Recommendations:

Several recommendations have surfaced from the above conclusion. Firstly, with regards to cost, the first recommendation that deals with addressing the policy framework can also go a long way in attracting investors into investing in renewable energy sources (making specific reference to gas-to-electricity projects). Therefore, these investors along with the government through local municipalities can overcome the challenge of costs. Furthermore, this recommendation also deals with the second challenge faced by Mariannhill Landfill Site (the electricity faults and trips). If the Landfill Gas-to-Electricity Plant had been allowed to connect directly to the grid (be it the national or the local connection lines), perhaps the electricity

problems experienced could have been avoided. When the peak hours are over in the Mariannhill area, Eskom would have been able to push the electricity further into the network (as this would not have been something new to them). Thus, avoiding the trips and electrical faults.

In addition, the second recommendation to address the cost factor is to establish strong private public partnerships. Once again, this recommendation links in with the above mention recommendation. This shows how gas-to-electricity projects are interlinked between several different sectors. Thus, they ought to be considered in a holistic manner as opposed to being engaged as singular and isolated developments. Furthermore, the New Growth Path (NGP) along with the National Development Plan (NDP) that has been implemented by government also strengthens the notion of private public partnerships as a strategy to diversify the electricity sector with the aim of granting impetus to development (National Development Plan, 2011).

The third recommendation arises from the challenge of technical knowledge. With gas-to-electricity projects requiring highly skilled professionals, it is the job of the government to ensure that they train such people to invest in renewable energy sources. Thus, the government can look at providing scholarships to enthusiastic young technical minds to study courses that are related to gas-to-electricity project. The government can even go as far as tasking the authoritative leaders of the tertiary sector to come up with a curriculum that can train students in the renewable energy field (making specific reference to gas-to-electricity projects). Furthermore, the department of education along with the government can provide means for enthusiastic young minds to spend some time in first world countries where they will gain practical experience on renewable energy sources (especially methane gas extraction projects).

6.2.3 The Benefits of Electricity Production from Methane Gas

Conclusion:

The benefits towards local development that are derived from electricity production through methane gas extraction are quite minimal. Gas-to-electricity projects involve a very technical array of skills; these skills are mainly outsourced from first world countries. Therefore, the local people living near these gas-to-electricity projects do not benefit much in terms of job opportunities as the jobs that they are employed in are unskilled jobs (such as cleaning and security posts). Furthermore, gas-to-electricity projects do not employ huge numbers of staff. The benefits to the locals and local development could be far greater if the generated electricity was plugged back into their portion of the electricity grid and this subsidised their usage. This

is the case with international examples that were discussed in the literature review where the gas-to-electricity projects form an island of the areas that they supply with electricity; namely, Iris Glen Landfill Gas to Energy Project in Johnson City in the United States and Halton Region in Canada.

The benefits of electricity generation from methane gas towards man-kind are far greater as opposed to the benefits towards local development. These benefits include destroying of the bad odour that originates from landfills (Bonam, 2009). From the respondents, it was deduced that the have been far less complaints about the odour since the induction of the Landfill Gas-to-Electricity Project in the eThekwini Municipality. However, there were some respondents that felt that the odour is still an issue in the Mariannhill area around the Mariannhill Landfill Site. This suggests that the odour associated with landfill sites is not completely eradicated with the establishment of gas-to-electricity projects, even though these projects go a long way in decreasing the odour.

The sale of CERs is another crucial way that man-kind can benefit from gas-to-electricity projects. With these CERs being sold via CDM, the projects earn large amounts of money. This money forms a form of financial security that the gas-to-electricity project will make a profit. However, with these CERs being sold in first world countries; this allows these countries to continue to industrialise further. This is because with the establishment of gas-to-electricity projects (along with other clean energy projects) within third world countries, the sale of CERs in these regions earns first world countries points. This system allows first world countries to use these points to emit more emissions (greenhouse gasses) into the atmosphere. Thus, this creates a catch-22 situation where by one of the main purposes of renewable energy sources is to reduce carbon emissions; this is achieved in the host country where the gas-to-electricity project is situated, however, across the globe, first world countries receive a licence to continue to raise carbon emissions through the burning of fossil fuels like coal.

Recommendations:

The implementation of a more effective system guiding the sale of CERs through the CDM is the most apparent recommendation with regards to this sub-section. The general operating procedures of the trade of CERs should remain the same; with only one added twist. The systems could look at implementing a policy that states that first world countries can only use the points earned from the purchase of CERs towards clean energy projects. This suggests that if a first world country has earned a certain number of points, these points can only be used to

establish a form of clean energy source (for example, solar energy projects, wind power projects and or gas-to-electricity projects). In this way, the purpose behind renewable energy will be upheld in both first and third world countries with clean energy being established in both regions. Thus, the environment receives environmental services from both first and third world countries.

6.2.4 Environmentally Sustainability of Methane Gas Electricity Generation

Conclusion:

The process of generating electricity from methane gas is one that is highly environmentally sustainable; the terminated methane gas that is found buried within landfills would eventually be vented off into the atmosphere. This aspect of gas-to-electricity projects proves that this process of electricity generation is environmentally sustainable on a rich level. This is because methane gas forms part of the greenhouse gases that perpetuate global warming (as carbon retains heat in the atmosphere) and methane gas also depletes the ozone layer if allowed to reach the atmosphere (Bonam, 2009). Furthermore, methane gas becomes highly explosive if allowed to reach concentrations of between 5 and 15%. Thus, destroying the methane gas reduces the risk of explosions within landfill sites. This also touches on the aspect of whether the process of generating electricity from methane gas can cause any harm on human beings. In the rare case of a freak accident and something like a fire breaks out, then perhaps this process could inflict harm on humans. However, this process is utterly environmentally sustainable and should be continued.

Recommendations:

With it being deduced that the process of generating electricity from methane gas is environmentally sustainable; the main recommendation concerning this sub-section would be to continue to ensure that this process remains environmentally sustainable. Regarding the risk of explosions; this is one aspect that ought to be evaluated to ensure that the process remains safe for humans. It is recommended that the relevant authorities at the Landfill Gas-to-Electricity Project in the eThekwini Municipality do regular checks at the landfills (Mariannhill, Bisasar and La Mercy Landfill Site) to inspect the concentration levels of the methane gas. These interval inspections could be conducted monthly; ensuring that the concentration levels of methane gas do not get to dangerous levels. This will aid in ensuring that this process of energy generation becomes environmentally sustainable to its totality.

6.2.5 The odour experienced in the community because of the Mariannhill Landfill Site Conclusion:

A large portion of the respondents that took part in the study felt that the odour originating from the Mariannhill Landfill Site was the most agonising aspect that they are faced with. The respondents reflected this with strong remarks that expressed their agony. In addition, the respondents felt that on hot days after experiencing rain was the time when the odour was the worst, along with hot days in the summer. Some respondents even went as far as comparing the odour to a burst sewer pipe. This suggests that the odour from the Mariannhill Landfill Site is a constant challenge that the residents have to face as a result of living near the landfill site. However, a small portion of the respondents did not have any problems of bad odour from where they live in relation to the Mariannhill Landfill Site. These respondents felt that the area smelt like any ordinary residential area. This suggests that there are several factors that come into play with regard to the situation of the odour. These factors include the wind direction, the specific unit of the resident in relation to the landfill site and the temperature on the day.

With the establishment of the Landfill Gas-to-Electricity Project at the Mariannhill Landfill Site; methane gas is being destroyed from this landfill site. Thus, this helps tremendously in reducing the odour that originates at the Mariannhill Landfill Site. This view is in sync with Bonam (2009) who argues that the termination of methane gas within landfill sites reduces the nuisance of odours. Furthermore, even though the general view of the respondents was in the form of complaints about the bad odour experienced from the Mariannhill Landfill Site; the number of complaints over the bad odour has decreased significantly since the gas-to-electricity project started in 2006 (Project Summary Document, 2011). This confirms that gas-to-electricity projects help reduce the bad odour given off by landfill sites.

Even with the inception of the Landfill Gas-to-Electricity Project at the Mariannhill Landfill Site, there still exists a bad odour at the Mariannhill Landfill Site. This is not surprising because there is new waste coming into the landfill daily; and the gas-to-electricity project is destroying the methane gas from the decomposed/ decomposing waste that has been buried in the landfill for at least 3 months (Project Summary Document, 2011).

Recommendations:

A recommendation here would be to use eco-friendly odour control sprays around the Mariannhill Landfill Site. These sprays can help to destroy bad odours originating from the landfill and thus lead to the locals nearby experiencing an odour free environment. These sprays should however be eco-friendly (not harmful to the environment), because using toxic chemicals to reduce the odour would be undermining to renewable energy as this would cause harm to the environment in any case. This recommendation is not however, a new phenomenon to the Mariannhill Landfill Site. The Mariannhill Landfill Site has already been engaging in eco-friendly odour control sprays. Thus, perhaps a follow-up recommendation could be to increase the dosage of these eco-friendly odour control sprays as the locals are still suffering from the bad odour originating at the Mariannhill Landfill Site. Picture 6.2 below shows a red arrow outlined in black that points to the eco-friendly odour control spray system parallel to the Mariannhill Landfill Site boundary fence. This system is secured with long wooded pillars that relate to tubing that contains the eco-friendly odour control spray. The spray is dispensed at specific time intervals.

Picture 6.2 Eco-Friendly Odour Control Spray System

Source: Author (2016)

6.2.6 The impact of the heavy machinery (the trucks) on the roads

Conclusion:

With the DSW trucks having to move in and out of the Mariannhill area carrying waste to the Mariannhill Landfill Site and then going back again to their respective bases, the roads in the area eventually become damaged. While some respondents felt that the trucks do not cause much damage to the roads in the area, some respondents felt that the trucks caused potholes on the roads. In addition, the overall remark made by the respondents was that the trucks spill waste onto the roads; thus, resulting in further bad odour problems and this also makes the area far less appealing. A major concern with the spilt waste is perhaps the content of the waste; perhaps the waste could be toxic or dangerous to humans (especially children). With hazardous waste, the children that play in the area could be at risks of falling ill due to this waste lying on the road. Moreover, if the waste contains dangerous items such as nailed wood or broken glass bottles; this could cause accidents for the drives in the area and again the children are a major concern as they could be badly injured.

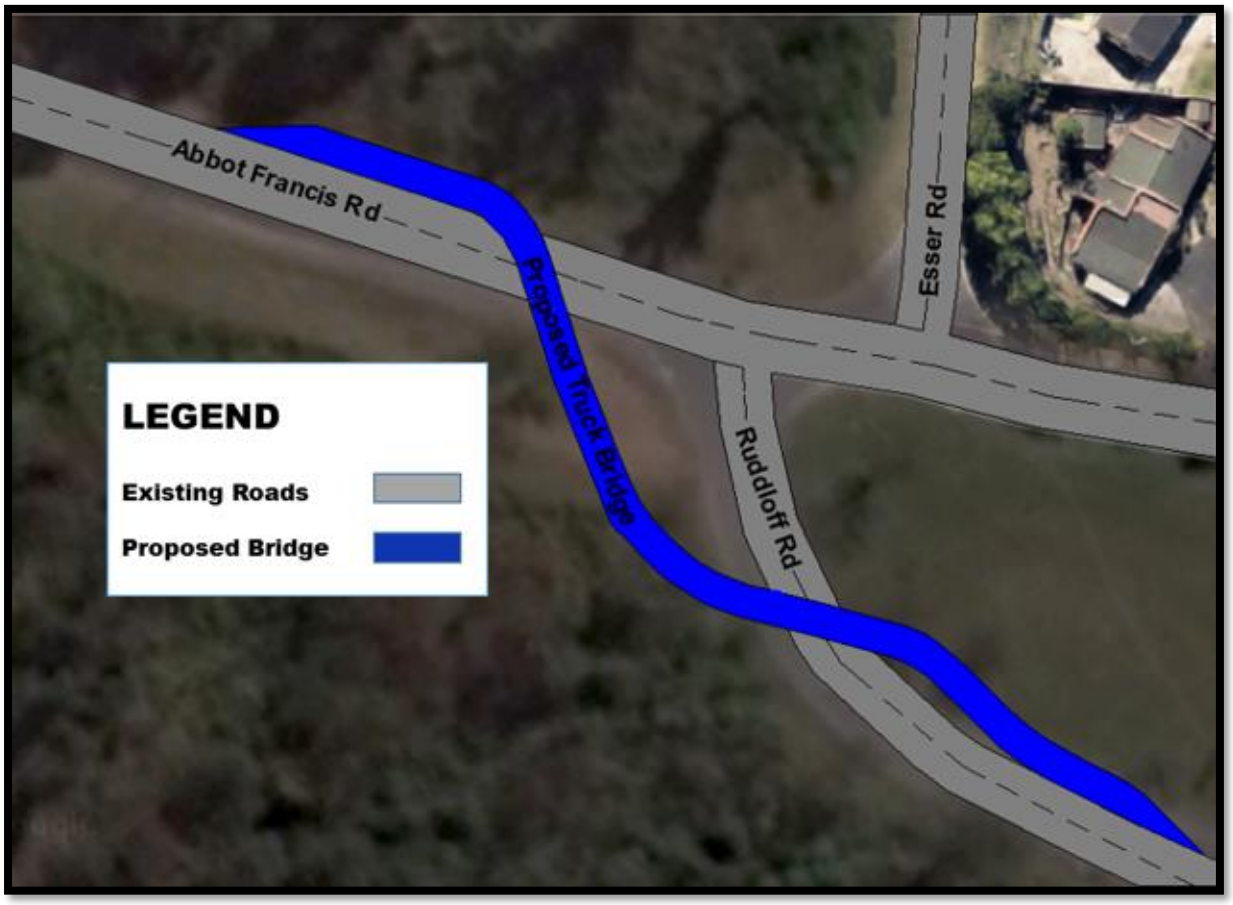
There is a specific turn that the trucks should make where the waste spills are most frequent. This turn is a right turn on a steep slope where Ruddloff Road meets Abbot Francis Street just before the Mariannhill Landfill Site. Perhaps the road engineers that designed the roads for this residential community at the implementation phase of the layout plan in the Mariannhill area did not envisage for trucks and heavy vehicles to use these roads. This explanation would make sense as the Mariannhill Landfill Site only opened in 1997 and the Pinetown area (along with the Mariannhill community) was established way earlier in 1849 (Strachan *et al*, 2002). Therefore, road upgrades ought to be made to this intersection to address the issue of waste spills.

Recommendations:

The recommendation here will seek to address the waste spills phenomenon in the area. The study proposes that road upgrades be made to the intersection that is causing this problem of waste spills. The following recommendation proposes a bridge to be added to this intersection. The bridge will be set aside only for trucks going to the Mariannhill Landfill Site and trucks returning from the Mariannhill Landfill Site must use the conventional route back. The bridge will make a gentle curve that will accommodate the trucks (heavy vehicles) to be able to move from Abbot Francis Road onto Ruddloff Road smoothly. Map 6.2 below shows the proposed

bridge. With the implementation of this bridge, the locals in the Mariannhill area will be protected from hazardous waste spills and their community image will not be tarnished by waste lying on the road. In terms of road safety; the bridge will go a long way in making the intersection safer. This is because with the current situation, waste spills can cause the road to be very slippery on rainy days. Thus, with town planning being the discipline governing this study; proactive planning of safe transport systems remains a priority - instead of waiting for an incident to occur and then only reacting.

Map 6.2 Proposed Truck bridge



Source: Google maps (2016) and Author (2016)

6.2.7 Level of dirt in the community because of the Mariannhill Landfill Site

Conclusion:

From the data collection phase and the observations done in the area, there were several spots in the area where waste had been dumped. Majority of the respondents also felt that the dirt in the area was a problem as some people just dumped their waste along the road. Picture 6.3 below shows a few spots in the Mariannhill area that were identified as dirt spots where people

had dumped their waste or trucks had spilt their waste. This suggests that dirt is a pressing issue in the Mariannhill area and it should to be addressed. However, a small portion of the respondents felt that their area was not affected that much by dirt; they felt that the area was generally clean. In addition, this small portion of respondents also felt that the DSW staff did a good job in ensuring that they pick up the dirt lying on the roads and on the grass. This perhaps suggests that the dirt occurs in sporadic time-intervals and it does not affect the whole community, hence, the surfacing of divergent views.

Picture 6.3 Dirt Spots where Waste has been Dumped in the Mariannhill Area

Source: Author (2016)

Recommendations:

The recommendation to deal with the illegal dumping in the area should be to give people some form of incentive to use the Mariannhill Landfill Site for their waste. The incentive that is recommended here is quite simple; if locals bring in a certain amount of waste to dump at the Mariannhill Landfill Site, they should be compensated with a certain number of free black plastic refuse bags. This incentive system could be coupled with other items such as gardening tools. Thus, from the money that the locals are charged to use the landfill, a small percentage

should be kept aside to purchase gardening tools (for example; a rake, a spade, a fork and a wheel barrow). This system could be taken even further with the Mariannhill Landfill Site approaching hardware stores in the area and asking them to donate gardening tools to support this initiative. Therefore, this will make the locals more enthusiastic about using the Mariannhill Landfill Site and reduce/eradicate dumping in the area. Picture 6.4 below shows the weighbridge system at the Mariannhill Landfill Site. The entrance weighbridge is on the left and the exit weighbridge is on the right. These bridges measure the vehicle weight as it enters and leaves the landfill, then the difference gives the weight of the waste that was dumped in the landfill. In this way, the customer dumping the waste can be billed.

Picture 6.4 Weighbridge System (Entrance Weighbridge - Left and Exit Weighbridge – Right)

Source: Author (2016)

Table 6.1 Proposed Incentive System

Weight of Waste Dumped	**Incentive (Reward)**
>4 & <5kgs (between 4 &5kgs)	5 black plastic refuse bags
>5 & <8kgs (between 5 & 8kgs)	5 black plastic refuse bags + garden gloves
>8 & <15kgs (between 8 & 15kgs)	5 black plastic refuse bags + watering can

>15 & <25kgs (between 15 & 25kgs)	5 black plastic refuse bags + rake
>25 & <35kgs (between 25 & 35kgs)	5 black plastic refuse bags + fork
>35 & <45kgs (between 35 & 45kgs)	5 black plastic refuse bags + spade
>45 & <55kgs (between 45 & 55kgs)	5 black plastic refuse bags + shovel
>55 & <65kgs (between 55 & 65kgs)	5 black plastic refuse bags + gardening boots
>65kgs (more than 65kgs)	5 black plastic refuse bags + wheelbarrow

Source: Author (2016)

Table 6.1 above shows the proposed incentive system that should be used to address illegal dumping in the area. The incentive system is strictly targeted at households and thus does not consider waste disposed of by companies. This recommendation is not cast and stone; it can be fine-tuned further depending on factors such as the availability of incentives (rewards) and the figures given the weight column are also subject to change according to the Mariannhill Landfill Site management. However, the idea behind the incentive system is sound; and could go a long way in changing the perception of landfill sites. Thus, encouraging locals to use landfills rather than dumping their waste on the side of roads.

6.2.8 The benefit of alternative energy sources

Conclusion:

There are certainly benefits that can be derived from alternative energy, especially with specific reference to gas-to-electricity projects. The respondents that took part in the study reflected this view quite vividly. The complete elimination of load shedding is just one aspect that alternative energy sources aim to address. Even though the respondents in the study felt that they do not experience much load shedding; alternative energy can help to eradicate load shedding in other areas along with the country at large if implemented in the correct manner with supporting policies. This is the focal point of the study as it aims to evaluate the viability of generating electricity from gas-to-electricity projects. Thus, gas-to-electricity projects (along with other renewable energy sources) ought to be implemented in a manner that will ensure the benefits reach the people at large. In this case, the most evident and most positive benefit that is derived from renewable energy sources is the reduction in the price of electricity. With this benefit, not being experienced on the ground; this raises questions of whether this form of renewable energy (gas-to-electricity projects) is in fact working and making a difference.

With the study making the realisation that gas-to-electricity projects perform two crucial environmental services; the cleansing of the environment through destroying the harmful methane gas and protecting the ozone layer. This shows that gas-to-electricity projects are environmentally sustainable. Moreover, this form of renewable energy serves two purposes; electricity generation and environmental services. With South Africa being a developing country; development brings with it great electricity demands. This shows the importance of further development of gas-to-electricity projects in the country. Thus, making this study very relevant to the context that South Africa currently finds itself in.

Recommendations:

The recommendation here is very simple; the encouraging of further upscaling of gas-to-electricity projects is a priority at this present time. Local municipalities along with the government at large should find avenues to drive gas-to-electricity projects. This places a huge role on the private sector to form private-public-partnerships that will grow gas-to-electricity projects. In addition, ways to secure funding to establish these gas-to-electricity must be made more of a priority within government structures. Furthermore, with the country moving more towards the renewable energy side of electricity production; the governing policies ought to be amended to promote electricity production that will be more beneficial to the people at large. The underlying recommendation is to develop more gas-to-electricity projects; perhaps the implementation of one (a gas-to-electricity project) in each metro region is a good place to start.

6.3 Realisation of the objectives

Objective 1*: To find out how much electricity the Mariannhill Landfill Site contributes towards the National Grid.*

The study did manage to find out how much electricity is generated at the Mariannhill Landfill Site. However, this electricity is not directly transferred into the national grid. Eskom purchases the electricity from the Landfill Gas-to-Electricity Project which is under the Department of Cleansing and Solid Waste. Eskom then transfers this electricity into the national grid. Nonetheless, this objective was realised as the amount of electricity was determined.

***Objective 2**: To identify the constraints that hinder electricity production from methane gas.*

This objective was realised with the study surfacing the constraints that hinder/ hindered electricity production at the gas-to-electricity project at the Mariannhill Landfill Site. These constraints were the costs of implementing the project, electrical problems arising from the Mariannhill area being a residential and industrial area and the lack of technical knowledge.

***Objective 3**: To identify the benefits of electricity production from methane gas.*

Even though there are very little benefits that are derived from gas-to-electricity projects towards local development, the benefits towards mankind are very substantial. Benefits to mankind include a reduction in the bad odour, termination of the harmful methane gas and protection of the ozone layer. Even though 83% of the respondents experienced a poor odour originating from the Marianhhill Landfill Site, imperical evidence from scholars such as Bonam (2009) claim that methane gas extraction does reduce odour nuiceances to the neighbouring residents of the landfill site. Thus, this objective was realised to some degree.

***Objective 4**: To find out whether the process of generating electricity from methane gas is environmentally sustainable or not.*

Gas-to-electricity projects are environmentally sustainable in their totality. This has been covered in the environmental services part concerning the benefits to mankind; the destruction of the odour, the protection of the ozone layer and the termination of the methane gas. Furthermore, with the destruction of methane gas, this reduces the risk of fires caused by explosions. Therefore, it is easy to see that this objective has been realised.

***Objective 5**: To find out how energy production from methane gas within landfill sites affects people living around the landfill.*

This objective was realised during the data collection phase where some locals living around the Mariannhill Landfill Site took part in the face-to-face questionnaires; the respondents were given a chance to express their feelings on how the Mariannhill landfill Site affects them. The responses received varied diversely, however, there were aspects where the respondents shared similar sentiments. The remarks made by the respondents went a long way in conscientising the researcher on how the phenomena associated with the Mariannhill Landfill Site impacted on the locals. Furthermore, the observations made during the observation phase of the study also showed how the electricity project impacted on the residents (for example, the smoke observations). Thus, this objective was also realised.

6.4 Concluding Remarks

The results presented in this chapter have done well in tying the objectives of the study from chapter one with the findings in chapter four along the engine of the study, the literature review covered in chapter three. From the results presented in this chapter, conclusions have been drawn and all these conclusions are reinforced with recommendations. Gas-to-electricity projects are environmentally sustainable to the highest degree. With these projects destroying methane gas, this protects the environment from further global warming, this also protects the ozone layer and helps reduce the odour given off by landfills. Thus, further development of gas-to-electricity projects will do great justice to the environment.

However, on the other side of the coin, with Mariannhill Landfill Site generating 1MW of electricity, this resembles a substantial amount of clean energy that is being generated in the eThekwini Municipality. However, the policy framework that gas-to-electricity projects find themselves in is one that is very hostile and biased at the same time. The Renewable Energy Feed in Tariff (REFIT) policy is biased towards Eskom and this undermines the core goal of renewable energy (which is to reduce the use of fossil fuels). Hence, for gas-to-electricity projects (and other forms of renewable energy projects) to expand and make a significant difference towards electricity generation, the policy framework in South Africa needs to be re-evaluated and changed in a manner that will give more flexibility to the process of electrification concerning renewable energy projects. This new era of policy can also go a long way in addressing the challenges and constraints that arise within renewable energy sources. With Mariannhill area being a residential and industrial area, electrical problems could have been addressed through effective policy.

This chapter has also shown how all the objectives of the study have been realised. The objectives of this study serve as the benchmark by which the electricity project can be said to be viable or not. Furthermore, with the objectives being realised, this suggests that the research methodology discussed in chapter two was followed accordingly with a high level of accuracy. Therefore, with all the objectives of the study being realised, this gives this study impetus towards the concerns of electricity generation within the country. This highlights the importance of this study, especially with all the plans that have been made to develop the country further (making specific reference to the New Growth Path and the National Development Plan). Consequently, the viability of using methane gas produced within landfill

sites to generate electricity has been evaluated and the findings show that it is indeed viable to generate electricity through this process. The multitudinous environmental services that arise from gas-to-electricity projects along with the considerable electricity generated make these projects a definite sector that ought to be explored with more enthusiasm in the upcoming years. With adjustments to the policy framework, an injection of skilled professionals and strategic ways to secure funding – gas-to-electricity projects are not only feasible, it is the right thing to do.

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ANNEXURES

Appendix 1: Interview Questions

INTERVIEW WITH THE KEY INFORMANT AT THE GAS-TO-ELECTRICITY PLANT ON THE MARRIANHILL LANDFILL SITE

1. How much electricity does the gas-to-electricity plant at the Mariannhill Landfill Site generate towards the national grid?
2. What are the challenges and constraints that hinder or disrupt energy production from methane gas at the gas-to-electricity plant?
3. What are the benefits of energy production from methane gas towards local development?
4. How can man-kind and the city at large benefit from this process?
5. Is the process of generating energy from methane gas within landfill sites environmentally sustainable?
6. Do you think that this process can inflict any harm on humans?

Appendix 2: Questionnaire

FACE-TO-FACE QUESTIONNAIRE

1. How would you describe the kind of odour you experience at different times of the day living around the Mariannhill Landfill Site?
2. How would you describe the noise that is associated with the Mariannhill Landfill Site?
3. How do the heavy machinery affect the roads in your community leading to and from the Mariannhill landfill Site?
4. How would you describe the traffic at different times of the day in your community that is associated with the Mariannhill Landfill Site?
5. How would you describe the level of dirt that your community experiences as a result of the Mariannhill Landfill Site?
6. What kind of animals do you think the Mariannhill Landfill Site has attracted into your community?
7. Why do you think these animals have been attracted to your community?
8. How would you describe the experience of living nearby the Mariannhill Landfill Site?
9. How does load shedding affect your community?
10. How do you feel the community can benefit from alternative energy sources?
11. What other problems do you think your community (the Mariannhill area) faces because of the Mariannhill Landfill Site?
12. What benefits do you feel come from living nearby the Mariannhill Landfill Site?