The Advancement of the Waste Resource Optimization and Scenario Evaluation Model: The Inclusion of Socio-Economic and Institutional Indicators

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Declaration

As the candidate's supervisor I agree/do not agree to the submission of this dissertation

....

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I would like to dedicate this research to all the people who have supported my development over the years.

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Abstract

The need for improved waste management systems has gained momentum globally in order to work toward the reduction of GHG emissions and the impact it has on global climate change. In South Africa the disposal of unsorted waste to landfill is still the primary waste management method across the country, however, legislative developments aim to drive integrated waste management and the circular economy, putting the disposal of waste to landfill as the least favourable waste management solution.

This study was aimed at assisting South African municipalities in achieving these goals in line with sustainable development at the forefront and the drive towards a circular economy. The study assessed the socio-economic and institutional indicators related to the five waste management strategies which were identified in the development of phase 1 of the Waste Resource Optimization and Scenario Evaluation Model (WROSE). WROSE is a zero-waste model developed as a decision support tool for municipalities and the private sector. These strategies are: the disposal of waste to landfill, landfill gas extraction, recycling, anaerobic digestion and composting of waste. The development of phase 2 incorporated social indicators such as: job creation potential, health risks and public participation for each of the five waste management strategies. The institutional indicators for each waste management strategy was assessed to determine the legislative requirements of each strategy.

The indicators developed for phase 2 of the WROSE model was applied to three case study municipalities, these are the eThekwini, Msunduzi and Newcastle. The outcome of the development of phase 1 determined that all of the waste diversion scenarios resulted in GHG emission reductions when compared to the baseline scenario. However high capital and operational costs was the primary barrier to the implementation of alternative strategies.

The outcome of this study determined that the waste diversion strategies that are low technology allow for the highest job creation potential. The diversion strategies towards zero waste such as composting emerged as the most suitable for the three case study municipalities in terms of best environmental benefits, lower costs, higher job creation potential, minimal health risks and institutional red tape

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List of abbreviations

AD – Anaerobic digestion

CO2 – Carbon dioxide

CDM – Clean Development Mechanism

CH4 – Methane

CSIR- Council for Scientific and Industrial Research

DEA – Department of Environmental Affairs

DAT – Dome aeration technology

DSW – Durban Solid Waste

EIA – Environmental impact assessment

EASETECH - Environmental Assessment System for Environmental TECHnologies

GHG – Greenhouse gases

GWP – Global warming potential

IPCC – Intergovernmental Panel on Climate Change

IWMP – Integrated waste management plan

LFG – Landfill gas

LCA – Life Cycle Assessment

LSS – Landfill space savings

MBT – Mechanical Biological Treatment

MPT - Mechanical Pre-Treatment

MRF – Material recovery facilities

MSW – Municipal solid waste

MTCO2eq – Metric tons of carbon dioxide equivalents

MW – Mega Watt

NERSA – National Electricity Regulator of South Africa

NLM – Newcastle Local Municipality

RE – Renewable Energy

SDS – Semantic Differential Scale

SETA - Sustainable/environmental technology assessment

UKZN – University of KwaZulu-Natal

US EPA – United States Environmental Protection Agency

WARM – Waste Reduction Model

WRATE - Waste and Resources Assessment Tool for the Environment

WROSE – Waste Resource Optimisation Scenario Evaluation WSA – Waste stream analysis

Chapter 1: Introduction

1.1 Introduction

The impacts of global warming have been induced through anthropogenic activities such as the use of fossil fuels, rapid urbanization and industrialization (Houghton ,2002). The result of which is the exorbitant increase of greenhouse gas (GHG) which are emitted into the atmosphere and ultimately its contribution to global climate change. Mitigation measures have been established globally to combat the issue of global warming. Waste management activities contributes to 18% of the global methane emissions (GMI, 2011).

The shift towards sustainable development has grown steadily over the years, with environmental sustainability and global development at the forefront (Korhonen, Honkasalo and Seppälä, 2018). One of the challenges faced by sustainable development is the linear flow of materials and energy through the economy. One way to address the linear flow of materials that are ultimately disposed of into landfill as an end of life solution, is to consider the concept of a circular economy (Korhonen, Honkasalo and Seppälä, 2018).

The circular economy can be defined as: "an economy constructed from societal production-consumption systems that maximizes the service produced from the linear nature-society-nature material and energy throughput flow. This is done by using cyclical materials flows, renewable energy sources and cascading type energy flows. A successful circular economy contributes to all the three dimensions of sustainable development. A circular economy limits the throughput flow to a level that nature tolerates and utilises ecosystem cycles in economic cycles by respecting their natural reproduction rates" (Korhonen, Honkasalo and Seppälä, 2018). Similar concepts linked to the circular economy are industrial symbiosis, whereby by-products, materials, energy and waste are exchanged as resources to reduce the impact of the disposal of waste to landfill(Walls and Paquin, 2015).

The waste management legislative landscape in South Africa has experienced a gradual shift in the management of municipal solid waste from the primary disposal of waste to landfill to the valorization of waste as a resource. This aligns with the legislative advancements within the country from the Environmental Conservation Act No 73 of 1989 up until the development of the National Environmental Management: Waste Act No 59 of 2008 as well as the introduction of the waste hierarchy.

Integrated solid waste management illustrates the most effective waste management solutions that can be employed to decrease the impacts of GHG emissions on the atmosphere and promote good waste disposal practices. This includes various laws that have been implemented such as the National Waste Management Strategy to address solid waste as well as putting into effect the waste hierarchy in Figure 1.1 below which considers disposal of waste to landfill as the least desirable step in waste management. The climatic benefit of waste avoidance and recycling are said to be far greater the benefits of many waste treatment technologies e.g. energy from waste, anaerobic digestion, even if energy is recovered during the process (Couth & Trois ,2011).

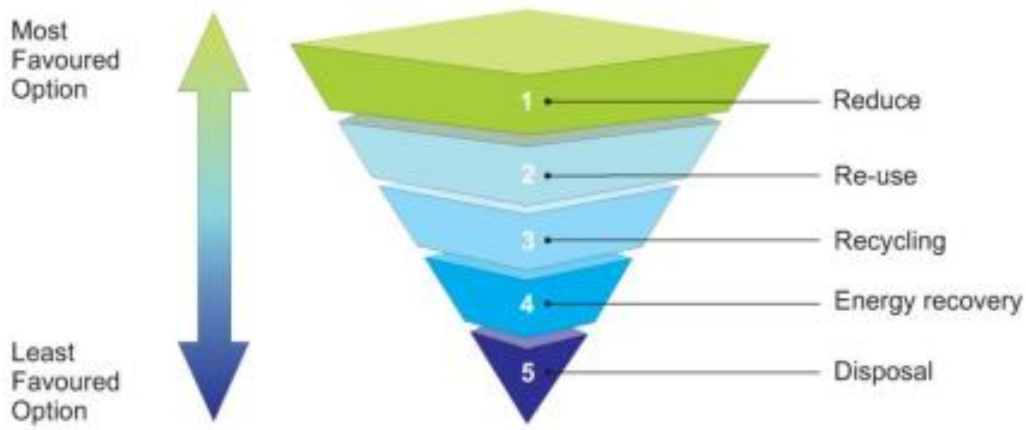


Figure 1.1 Waste Hierarchy National Waste Management Strategy of South Africa (DEA)

Within South Africa the disposal of waste to landfill is the primary waste management method employed by local municipalities. The South African government has committed to GHG emission reduction across all sectors and have put in place laws, norms and standards to achieve these targets. Furthermore, landfills are reaching their maximum capacity, and with the implementation of new laws, the availability of space for the development of new landfill disposal facilities are limited. Therefore, there is a need for alternative waste management solutions.

Municipal officials are regularly inundated with proposals for waste management technologies as alternatives to the development of new landfills which could expand the life span of existing facilities. However, deciding on a technology and overall waste management strategy that is most appropriate to the specific municipality circumstances is a difficult task. The Waste Resource Optimization and Scenario Evaluation (WROSE) model was developed to assist waste management companies and officials in the decision making process for implementing alternative waste treatment technologies (Trois and Jagath, 2011). The WROSE model was developed to assist municipalities in aligning with national legislative requirements and achieving zero waste. This will be achieved through the application of the waste hierarchy into municipal solid waste management practices as well as through the promotion of the circular economy.

The WROSE model provides the user with details of technical, economic and environmental impacts and implications for multiple waste management scenarios which will be discussed in detail in later chapters. Under current circumstances and with the global drive towards sustainable development, all four pillars of sustainability must be taken into consideration. These are: environmental, economic social and institutional considerations of implementing waste management strategies. The inclusion socio-economic and institutional indicators allows for a well informed decision making process by the user. Decision making can be achieved based on the critical needs of the user, such as, the need to drive economic development and create jobs or the need for the most cost effective solution. Seeing as the WROSE model already includes environmental and economic indicators which was developed in phase 1 of the model's development, the inclusion of social and institutional indicators is required to transform and optimize this tool into a comprehensive zero waste model. Therefore, the purpose of this study is the second phase of the advancement of the WROSE model to include social and institutional indicators.

1.2 Motivation

The motivation of this research stems from various contributing factors.

Firstly, the Polokwane declaration signed in 2001 was one of South Africa's legislative developments with a focus on the mitigation of GHG emissions, which has committed the country to the targets of 50% reduction of waste generated and 25% reduction of waste disposal by 2012 and the target of achieving zero waste by 2022.

Further to legislative commitments is the inability of municipalities to sustain landfilling as a primary waste management strategy for municipal solid waste (MSW) (Reddy, 2016). The disposal of waste to landfill is a contributing factor to the increased volumes of methane emitted into the atmosphere alongside industrialization and rapid urbanization. Therefore, integrated waste management strategies are necessary for improvement of waste management practices in order to promote activities with the least harmful environmental impacts.

The mitigation of impacts through the reduction of GHG emissions can be achieved by implementing alternative waste management strategies to the disposal of waste to landfill. Nevertheless, trying to determine the most appropriate alternative waste management method to landfill requires structured decision making. This includes knowledge of waste volumes, waste streams and quality of waste material. The Waste Resource Optimization and Scenario Evaluation (WROSE) model was developed by the University of KwaZulu-Natal (UKZN) to assist municipal officials in the decision making process when looking to implement alternative waste management options. The model provides decision makers with the relevant information needed to aid in informed decision making on the most appropriate integrated waste management solution for each individual case.

Following on previous research on the WROSE model conducted by Reddy (2016) it is recommended that further developments of the model focus on the inclusion of socio-economic and institutional indicators. The addition of qualitative information into a qualitative model is a complex task. This process will drive the development of WROSE to include all 4 pillars of sustainability which will assist in well informed decision making.

The purpose of the study intends to produce a comprehensive decision making tool which encompasses all 4 pillars of sustainability for alternative waste management strategies that can be used by municipal engineers and private sector individuals. This aims to promote sustainable integrated waste management practices across the waste sector. This will be achieved through the incorporation of 2 additional pillars of sustainability into the WROSE model. Both qualitative social science techniques and quantitative scientific techniques will be employed to achieve the goals of this study. The study will be conducted through the use of systematic literature reviews, surveys and the testing of the accuracy of the model through the use of case studies.

1.3 Aim

To advance the Waste Resource Optimization and Scenario Evaluation (WROSE) Model through the addition of socio-economic and institutional indicators.

1.4 Objectives

- To identify social and institutional indicators for inclusion into the WROSE model.
- To develop social indicator assessments for the upgrade of the WROSE model.
- Optimize the WROSE model through the inclusion of all four sustainability indicators.
- Validation of the WROSE model with suitable case studies.

1.5 Methodological Approach

This outlines the methodological framework used in this study. It covers the purpose for the research as well as the process involved in designing the study. The methodological approach used is highlighted and discussed.

The initial stages of the study were carried out by an in-depth literature review. The literature review served as a gap analysis that identified a lack of depth in the socio-economic and institutional implications of alternative waste management strategies such as, but not limited to, job creation potential.

The primary objective of this research is to develop socio-economic and institutional indicators for optimization of the WROSE model. This will be established by identifying social and institutional indicators relevant to implementing alternative waste management strategies.

A qualitative multi criteria evaluation matrix was developed to evaluate which of the identified indicators will be explored further for inclusion into the WROSE model. Once the advanced indicators were developed, the model was applied, and a comparative analysis was conducted on three case study municipalities. This analysis involved the assessment of the outcome of the phase 1 development of the WROSE model as a baseline and a comparison of the outcome of the results with the phase 2 indicators included. The variance in results depicts the impacts of socio-economic and institutional indicators on the decision making process

1.6 Research Framework

The diagram below illustrates the framework used for conducting this study. This study consists of six chapters: Introduction, Literature Review, Methodology, Case Studies, Results and Discussion, Conclusion and Recommendations.

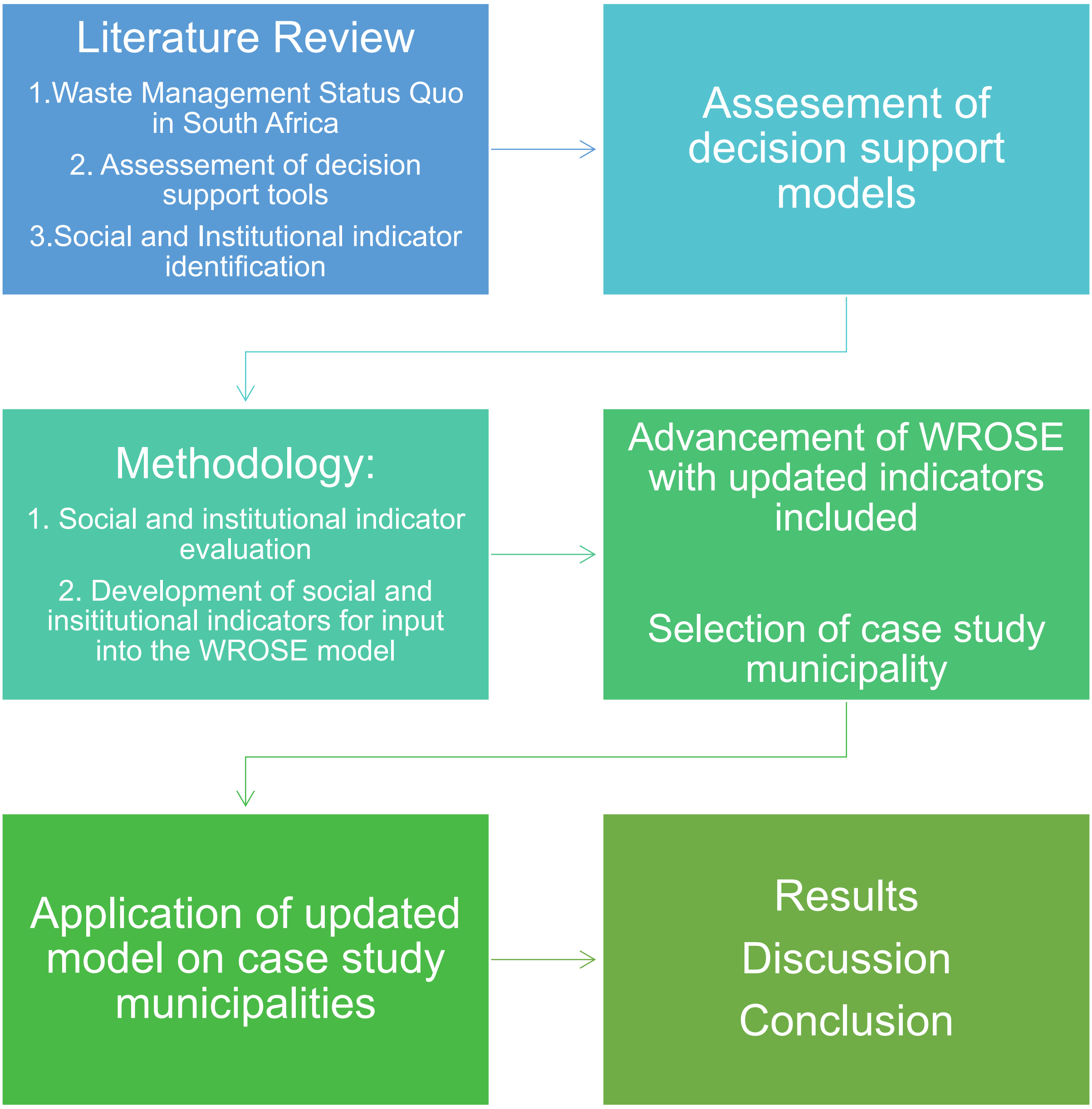


Figure 1.2: Research Framework

1.7 Chapter Summary

This chapter provides background insight to the problem that will be addressed through this study along with the rationale and motivation behind conducting this type of research. The intended outcome of this study is to develop a Zero Waste decision making tool that incorporates all 4 pillars of sustainability. The WROSE model is intended for use by municipalities and the private sector in the realisation that waste management strategies and the decision making process is a non-linear process. Chapter 2 presents a literature review which was conducted to add further context to the study through previous research as well as to serve as a gap analysis for this study.

Chapter 2: Literature Review

This chapter outlines a contextual exploration of MSW management in South Africa. South Africa is home to 278 municipalities, these municipalities vary in surface area size and population density, therefore the application of integrated waste management scenarios/ strategies vary from case to case (RSA, 2016).

This chapter examines the evolution of the institutional changes in the waste management landscape with particular emphasis on legislation. Thereafter a range of waste management models/decision support tools are assessed and analysed for potential gaps. Sustainability indicators are identified and waste management legislation in other developing countries are discussed.

2.1 Waste Management in South Africa

According to the National Waste Information Baseline Report of 2012, in the year 2011 South Africa generated 108 million tonnes of waste, 98 million tonnes of which was disposed into landfill (DEA, 2012).

The Table below was obtained from the South African Waste Information Centre (SAWIC) in which the waste data that was uploaded in 2016 by willing participants was analysed. Table 2.1 below details the waste management activities underway in the country and is measured in tonnes.

Table 2.1: 2016 Waste Management Activities by tonnes in South Africa (SAWIC, 2016)

Report			
Tonnes of Waste for 2016, All Activity Types, All Provinces			
By: Management Option			
Group	**General**	**Hazardous**	**Total**
D1: Disposal of waste to land (e.g. specially engineered landfill)	27,822,539.0	2,321,020.4	30,143,559.4
D2: Disposal of waste to landfill (e.g. non-engineered landfill)	4,885,704.2	2,084,228.2	6,969,932.5
D3: Storage/disposal of waste in surface impoundments (e.g. placement of liquid or sludge discards into pits, ponds, lagoons etc.)	413,162.1	51,746.0	464,908.1
D5: Permanent storage (stabilization, micro-encapsulation, macro-encapsulation)	0.0	27.6	27.6
R1: Direct recovery of energy from waste	64,538.0	633.9	65,171.9
R2: Direct recovery of raw material from waste	3,300,814.0	17,441,112.9	20,741,926.9
R3: Regeneration or rejuvenation of waste (solvents, carbons, acids and alkalis)	12.8	91,897.0	91,909.8
R4: Recycling of organic substances	868,254.8	52,253.4	920,508.2
R5: Recycling of metals and metal compounds	12,164,174.0	4,909.9	12,169,084.0
R6: Recycling of other inorganic materials	337,433.9	11,869.0	349,303.0
T1: Biological treatment (e.g. biodegradation, composting, biogas generation)	157,526.7	17,464.9	174,991.6
T2: Physical treatment	185,800.2	1,779,312.7	1,965,112.9
T3: Chemical treatment	4.7	56,796.2	56,800.9
T4: Thermal treatment (incineration, pyrolysis etc.)	8,311.0	3,911,684.7	3,919,995.7
Total	**50,208,275.4**	**27,824,957.8**	**78,033,233.2**

Figure 2.1 below is a graphical representation of the data obtained by SAWIC in 2016 in which it is evident that the disposal of waste to landfill is still the most dominant waste management method in the country.

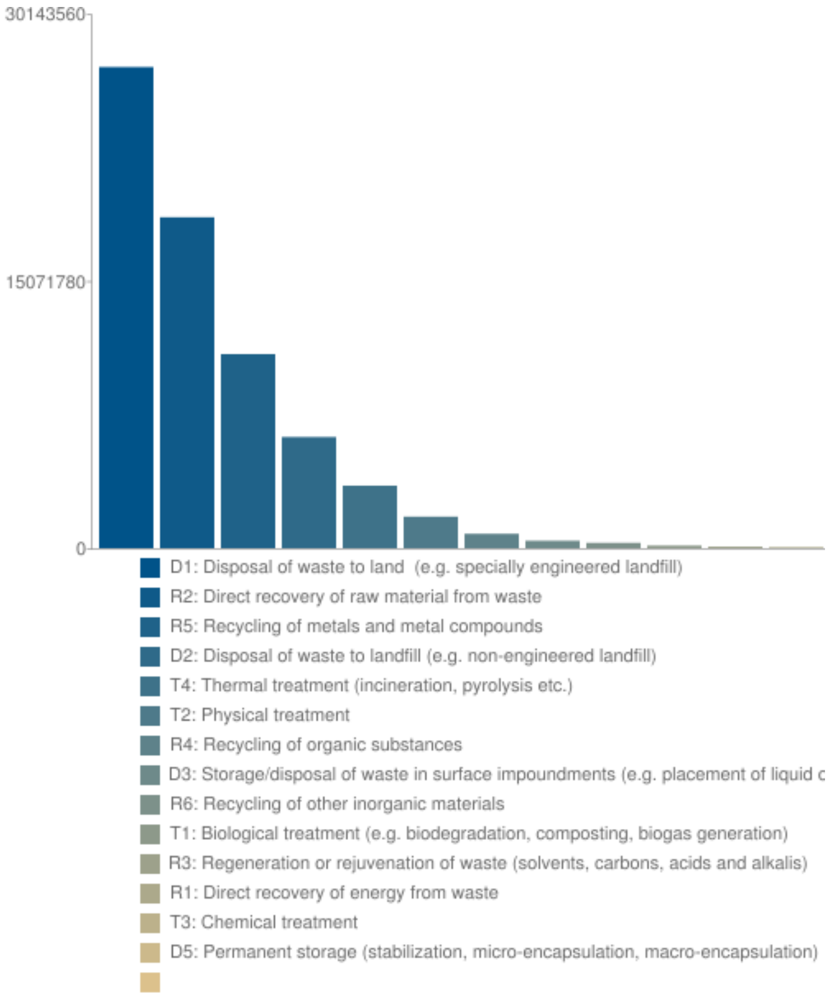


Figure 2.1 Graphically represented trend of 2016 waste management activities in South Africa (SAWIC, 2016)

Based on the above-mentioned table and figure, it can be concluded that the disposal of waste to landfill is still the most utilised method of waste management in the country. Therefore, the disposal of waste to landfill will serve as the baseline scenario for this study.

The South African government functions at three levels, national, provincial and local government, each with its defined roles and objectives. According to the Constitution of the Republic of South Africa, waste management is a local government function. Typically, this translated to the collection of waste and its disposal to landfill. In more recent years through the development of waste management legislation as well as the requirements for landfill development, local municipalities are forced to explore alternative methods of waste management. Approximately 98 million tons of waste are disposed of in South African landfills every year (DEA, 2012a).

The introduction of the waste hierarchy puts the disposal of waste to landfill as an end of life solution (DEA, 2008). This gives rise to the need for implementing alternative strategies such as recycling and the reuse of waste as a resource. However local municipalities lack the required human capital and financial resources to implement such new systems. Up to forty percent of the South African population receives little or no waste services (DEA, 2010) The high associated costs and complex municipal supply chain processes make alternative systems difficult to obtain. To date landfilling in South Africa is still the cheapest for example the tipping fee at the eThekwini Municipality is at R65 per ton as per the municipal solid waste tariff model developed by the Department of Environmental Affairs (DEA) using eThekwini Municipality as a case study and is therefore the most preferred waste management option for majority of the municipalities in the country.

However, the disposal of waste to landfill although the most cost effective poses many disadvantages among which are soil, water and air pollution. Alternative waste management solutions can provide communities with services such as waste management, access to renewable energy, organic fertilizer for farming and overall improvement of life.

2 .1.1. Waste Management Legislation in South Africa

Waste in South Africa is managed primarily by the National Environmental Management: Waste Act No. 59 of 2008 (NEM: WA). This act superseded the Environmental Conservation Act No 107 of 1998 which was the first act to give attention to environmental conservation in South Africa. The waste act defines waste as:

"(a) any substance, material or object, that is unwanted, rejected, abandoned, discarded or disposed of, by the holder of the substance, material or object, whether or not such substance, material or object can be re-used, recycled or recovered and includes all wastes as defined in Schedule 3 to this Act; or

(b) any substance, material or object that is not included in Schedule 3 that may be defined as a waste by the Minister by notice in the Gazette,

but any waste or portion of waste, referred to in paragraph (a) and (b) ceases to be a waste -

(i) once an application for its re-use, recycling or recovery has been approved or, after such approval, once it is, or has been re-used, recycled or recovered;

(ii) where approval is not required, once a waste is or has been re-used, recycled or recovered;

(iii) where the Minister has, in terms of section 74, exempted any waste or a portion of waste generated by a particular process from the definition of waste; or

(iv) where the Minister has, in the prescribed manner, excluded any waste stream or a portion of a waste stream from the definition of waste." (DEA, 2008).

The waste act incorporates instruments which promote the effective management of waste, these include the implementation of norms and standards, principles, integrated waste management plans and extended producer responsibility for waste. However the implementation of these instruments lack the required human and financial capital, due to waste management services being a local government function. Further to this, achieving the goals set nationally to reduce waste generation as well as waste disposal levels each municipality must be addressed on a case by case basis. The WROSE model which will be discussed in detail in later chapters, was developed to assist municipalities in achieving integrated waste management and ultimately zero waste.

2.1.2 National Waste Management Strategy (NWMS)

The NWMS was developed to achieve the objectives set out in the Waste Act (SAWIC, 2016). One such objective is the application of the waste hierarchy as set out by the waste act that promotes the sustainable use of waste such as waste minimization, reuse, recycling, waste treatment and the disposal of waste to landfill as an end of life method for waste management (SAWIC, 2016).

2.1.3 Institutional Structure

The South African government functions on three levels, national government, provincial government and local government/ municipal government.

- National government is responsible for the development of laws and regulation in line with that of the Constitution of the Republic of South Africa. In terms of the Waste Act, national authority is responsible for its overall implementation, this includes the development of norms and standards the development of a National IWMP.
- Provincial government is responsible for ensuring the implementation of the NWMS. The role of provincial government is to coordinate the local government activities in line with national government requirements. In addition provincial government serves as an intermediate body for communication between national government and local municipalities.
- Local government/municipalities are responsible for the on the application of the waste act. Local government is mandated by the Constitution of the Republic of South Africa to make waste management services available. These services include waste removal, storage and disposal. In accordance with the requirements of the waste act, municipal waste services must also follow the waste hierarchy. In line with other national government directives, municipalities must also promote source separation and the diversion of waste from landfill.

2.2 Decision Support Tools

A wide array of decision support tools exist globally. Commonly used methodologies for the development of waste management tools are, life cycle assessment (LCA) and environmental impact assessment (EIA) and sustainable/environmental technology assessment (SETA). For the purpose of this study four decision support tools were assessed. These are Waste Reduction Model (WARM), EASETECH, WRATE and the Waste Resource Optimization and Scenario Evaluation Model (WROSE).

- **Waste Reduction Model (WARM)**

The WARM was developed by the United States, Environmental Protection Agency (US EPA). The purpose of the model is to assist solid waste planners and organizations track and report GHG emission reductions from several waste management practices (US EPA 2017). The output of WARM is the GHG emission reductions from activities such as source reduction, recycling, composting, anaerobic digestion, combustion and landfilling (US EPA 2017). WARM is an online model available for download and public use, designed for assisting officials in the waste sphere understand the environmental consequences of alternative waste management practise. Economic indicators such as capital and operation costs and social indicators such as job creation potential are not taken into consideration in this model. WARM is a lifecycle based tool which is used for GHG emissions accounting, its primary purpose is landfill management, methane emissions, long term carbon storage, avoided utility emissions and transport emissions (Heller and Keoleian, 2015). The WARM model does not take into consideration the biogenic CO_2 emissions as a contribution to global warming (Heller and Keoleian, 2015).

- **EASETECH**

The Environmental Assessment System for Environmental TECHnologies (EASETCH) is a life cycle assessment based model developed by the Technical University of Denmark. It was designed for a material flow analysis for the assessment of environmental technologies. The purpose of the model is to perform LCA's on complex waste streams (DTU, 2017). Use of the EASETECH model requires training and is available through purchase of a licence. The model explores a range of waste management activities such as landfilling, LFG recovery, anaerobic digestion, recycling and composting (DTU, 2017). The output of EASETCH are environmental factors such as landfill airspace savings and GHG emissions reductions based on waste diversion volumes. The EASETCH model has the potential to include economic indicators based on European figures however social indicators and institutional are not included in the model. The primary focus of EASETECH is the materials flow modelling which incorporates a mix of materials at different fractions with different properties (Clavreul *et al.*, 2014). The tool can be used to set up scenarios which calculates the emissions of a heterogenous flow of materials (Clavreul *et al.*, 2014).

The development of EASETCH has evolved over 4 iterations since its development in 2004, from an Excel model to a fully licenced software package (Clavreul *et al.*, 2014)

- **WRATE**

The WRATE model was developed for the Environment Agency in the United Kingdom by Golder Associates and is an LCA model with a particular focus on environmental impacts. The model is used to assess the environmental impacts of waste management activities throughout its life cycle (Golder Associates, 2017). WRATE assesses various types of environmental impacts of waste management activities such as acidification, aquatic ecotox, human toxicity, resource depletion and eutrophication (Golder Associates, 2017). WRATE was designed to ensure that complex environmental and waste information can be analysed and communicated to various stakeholders (Gentil, 2006). The databases incorporated in the WRATE model include:

- Electricity mix;
- Waste composition;
- Foreground processes;
- Background inventories of emissions; and
- Life Cycle Impact Assessment methodologies.

(Gentil, 2006)
One key challenge of the WRATE model is the reliability of the data. Furthermore, he WRATE model does not consider all aspects of sustainability as economic and social indicators are not included as part of the model.

- **Waste Resource Optimization and Scenario Evaluation (WROSE)**

The WROSE model is a zero-waste model developed by UKZN in 2010. The WROSE model was developed in conjunction with the private sector for municipal officials looking to implement alternative waste management strategies. The model is Microsoft Excel based and considers GHG emission reduction as well as landfill airspace savings of various waste management activities (Trois and Jagath, 2011). The model uses South African data and emission factors that makes it relevant to developing countries. It covers a range of waste management technology options such as landfilling, landfill gas extraction, recycling, anaerobic digestion and composting. In addition, the WROSE model covers basic capital and operating cost of the waste management activities listed above. However social indicators are not included in the WROSE model. The development of the WROSE model began with five selected strategies relevant to the South African context these are:

Scenario 1: landfill disposal of unsorted, untreated MSW

This represents the baseline scenario, it is a typical representation of the waste management strategy employed by the majority of municipalities in South Africa, which is the collection and transportation of unsorted, untreated MSW into a landfill facility (Trois and Jagath, 2011).

Scenario 2 landfill disposal of unsorted, untreated MSW with landfill gas recovery

The second scenario involves the collection and disposal of unsorted, untreated MSW into landfill facilities, with the extraction of methane gas that has developed through the decomposition of the biogenic waste fraction (Trois and Jagath, 2011).

Scenario 3: Mechanical pre-treatment of MSW, recovery of recyclable fraction through a Material Recovery Facility (MRF) with landfill gas recovery.

The third scenario introduces mechanical pre-treatment via a material recovery facility (MRF), within which the recyclable fractions are extracted and the residual portion of waste along with the wet biogenic fraction is disposed of into landfill (Trois and Jagath, 2011).

Scenario 4: MBT (MPT, recovery of recyclables through MRF and anaerobic digestion of biogenic food waste with landfill gas recovery).

The fourth scenario of the Zero Waste model looks at Mechanical Biological Treatment solutions whereby the recyclable fraction of waste is extracted for recycling, the residual waste is disposed of to landfill with gas recovery and the remaining biogenic fraction is digested in an anaerobic digestion facility (Trois and Jagath, 2011).

Scenario 5: MBT (MPT, recovery of recyclables through MRF and composting of biogenic food waste with landfill gas recovery).

The last and final scenario selected for the Zero Waste model employed the same process as that of Scenario 4 whereby the recyclable fraction of waste is extracted for recycling, the residual waste is disposed of to landfill with gas recovery and the remaining biogenic fraction is composted using windrow composting via Dome Aeration Technology (DAT).

The scenarios described above were selected based on the efficiency of the technologies and the cost implications as well as environmental benefits.

Figure 2.2 below depicts a schematic each of the scenarios that the model is based on.

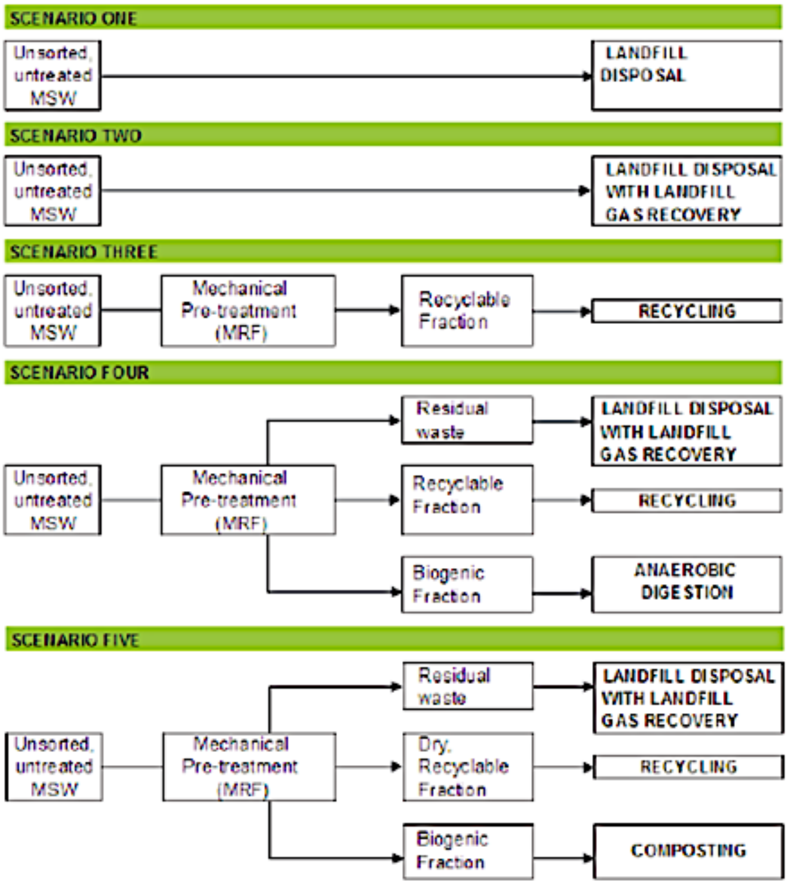


Figure 2.2 WROSE Waste management scenarios (Trois & Jagath 2010)

The development of a Zero Waste Model was aimed at simulating dry-wet waste models, the purpose of which was to maximise the diversion of dry recyclables from the disposal of landfills. The selected scenarios were seen as most applicable to the South African context in terms of implementation requirements, technical feasibility, potential environmental impacts and benefits to municipal waste management systems (Trois and Jagath, 2011). However, the socio-economic and institutional indicators were gaps that could be addressed through further development if the WROSE model.

2.2.1 An assessment of solid waste treatment technologies in accordance with the scenarios in the WROSE model

This section describes the waste management technologies that were used for the development of the WROSE Zero Waste model scenarios. The technologies that will be looked at in the section below are: landfills, landfill gas to energy, material recovery facilities, anaerobic digestion and composting.

Scenario 1: Landfilling

The disposal of waste to landfill is the primary waste treatment method for the majority of South African municipalities. The best practice for landfills is sanitary landfills, this allows for the isolation of waste from the environment until it is safe with sufficient biological, chemical and physical degradation (MIT, 2012). Within South Africa landfill requirements are set out in the National Norms and Standards for the Disposal of Waste to landfill. This determines the minimum engineering design requirements that landfills must comply with in order to receive certain types of waste.

The disposal of waste is not in itself an unsustainable practice but rather the impacts for the disposal of waste on the environment and human health is unfavourable (Scharff, 2007). Although efforts are being made globally to introduce recycling, recovery and closed loop waste management strategies, landfills will always be required for those wastes that cannot be recycled or otherwise treated (Scharff, Van Zomeren and Van Der Sloot, 2011). Landfills will continue to play an important role in any integrated waste management system as an end of life waste management solution for residual wastes (Scharff, 2007)

Scenario 2: Landfill Gas to Energy

Landfills are responsible for 12% of the global greenhouse gas emissions, making the disposal of waste to landfill harmful to the environment. The extraction of landfill gas for the production of electricity or biomethane are some of the methods that could be used for limiting the amount of greenhouse gases emitted into the atmosphere. This is done through the disposal of biogenic waste into a sanitary landfill which decomposes naturally emitting methane gas which contributes to global warming (Niskanen *et al.*, 2013). A network of pipes underground works as a vacuum, sucking out the gas and transporting it through a series of processes that allows it to be transformed into a renewable energy source. Landfill gas extraction has a strong impact on the reduction of GHG emissions into the atmosphere (Niskanen *et al.*, 2013)

Scenario 3: Material Recovery Facilities

Material recovery facilities (MRF) forms part of an overall waste treatment process. Within MRF waste is separated into a recyclable fraction and a residual fraction. All recyclables are bailed and sent to waste processing facilities and the residual waste is then sent to a sanitary landfill.

A typically representative model for a MRF in South Africa is the dry-wet model as depicted in the figure below. The dry components of recyclables such as plastics, glass, cans, paper and cardboard are separated from the wet biogenic fraction. The dry components can be sorted, bailed and sent to recycling facilities whereas the wet fraction can be composted or anaerobically digested(Trois and Simelane, 2010)

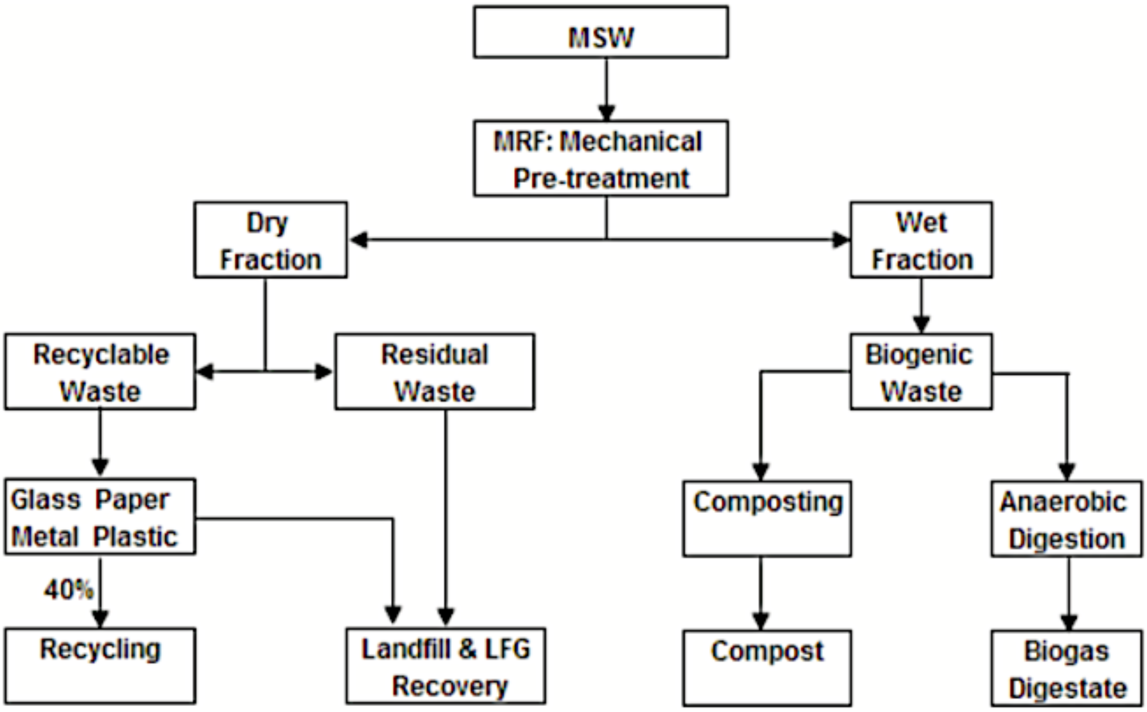


Figure 2.3: Dry-Wet waste diversion model (Trois and Jagath, 2011)

In developing countries like South Africa with high unemployment rates, high technology MRF are not recommended. The use of manual sorting, high labour intensive MRF are preferred due to job creation potential. Key materials extracted in MRF are plastics, glass, tin and cardboard (Couth and Trois 2010). The resources recovered in these processes have economic value and can be sold for reprocessing back into the market value chain.

Scenario 4: Anaerobic Digestion

Anaerobic digestion (AD) is a biological waste treatment method for organic waste fractions, whereby a mixed culture of microorganisms break down in the absence of oxygen (Zhang *et al* 2016). This process results in the production of digestate and biogas. Biogas has the potential to be converted into alternative fuels and energy. The valorization of the biogas produced from the AD process is not only energy efficient but also environmentally friendly due to lower emissions (Appels *et al.*, 2011). The use of AD technology has the potential to fulfil a number of policy objectives (Holm-Nielsen, Al Seadi and Oleskowicz-Popiel, 2009).

Scenario 5: Composting

Composting is the controlled decomposition of organic matter under measured conditions. Composting is an aerobic process that results in the production thermophilic bacteria due to the release of biologically produced heat (Kelly 2015). There are two primary methods of aerobic composting, pre-fermentation and post-fermentation (Kumar *et al.*, 2009). The pre-fermentation process entails the composting of unsorted MSW whereas the post-fermentation process involves using sorted MSW whereby the non-compostables are removed from the process. Three types of composting systems are typically employed, these are: aerated static pile system, enclosed system and windrow system (Kumar, 2011). For the purpose of the WROSE model the post-fermentation process is considered. Compost from efficiently managed organic waste can fertilizer, this can be used as an effective replacement for mineral fertilizers thereby reducing nitrate leaching (Kelly 2015).

2.3. Sustainability Indicators

The overall concept of sustainable development was defined as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs” as per the Brundtland Commission report of 1987. In order to achieve sustainable development three elements must be incorporated, environmental economic and social capital (Couth and Trois, 2012). Environmental sustainability includes long and short term environmental risks and liabilities of projects (Couth and Trois, 2012).

Sustainability indicators aid in quantifying impacts and the overall decision making process. The key pillars of sustainability are environmental, social and economic and institutional.

In order to evaluate the sustainability of waste management strategies and projects, a multitude of indicators are important to take into consideration. The following have been identified as key sustainability indicators for consideration when evaluating the sustainability of waste management strategies, these indicators were identified based on the work carried out by Friedrich, (2013), Rigamonti et al., (2009), Maharaj (2014), Armijo et al (2011) Trois & Jagath, (2010) and Matete (2009):

Environmental Indicators:

- Global warming potential
- Landfill Space Saving
- Acidification potential
- Eutrophication potential
- Ozone depletion potential

Economic Indicators:

- Capital cost
- Operational cost
- Income
- Financial sustainability
- Sensitivity to variables

Social Indicators

- Jobs Creation
- Noise Generation
- Public Acceptance and Social Perception
- Cleanliness and Smell
- Social Participation Required

The abovementioned indicators were extracted from previous research conducted on the WROSE model by Reddy, (2016). In the interest of the optimization of the WROSE model the identified social and institutional indicators must be evaluated based on selected criteria to determine which of the indicators will be used for the study

2.4. Institutional Mechanisms for Waste Management in Developing Countries

The following section provides a brief description of waste management activities in other developing countries. The countries discussed are India, China and Brazil. The purpose of the review is to examine institutional mechanisms employed by other developing countries and what lessons can be learnt through other experiences both positive and negative.

2.4.1 India

India holds the second largest population in the world, next to China, with more than 1.27 billion people (Nandan *et al.*, 2017). India like most other developing countries is faced with rapid urbanization resulting in an increased volume of waste generation (Nandan *et al.*, 2017). Solid waste management practice in India is primarily the collection and transportation of waste. The lack of proper waste management systems results in large scale illegal dumping and burning of waste in rural areas and in the outskirts of cities. This also resulted in overflowing landfills across the country (Gupta *et al.*, 1998).

There are various environmental implications associated with such activities, ground water pollution due to leachate leakage into the soil, air pollution from the burning of waste, and further contribution to greenhouse gas emission (Gupta *et al.*, 1998). At present there are no integrated solid waste management systems in place. Recyclable fractions of materials such as paper and plastics are extracted by informal waste pickers.

The quality and quantity of MSW generated in each area varies in accordance with the socio-economic status, urban structures and population and commercial habits (Esakku *et al.*, 2007). In the year 2000 the Ministry of Environment, Forest and Climate Change in India established rules for the management of solid waste in the country. Despite the introduction of rules for the management of solid waste in a more scientific manor, the targets set within these rules have not been met. Some major reasons for failure are, lack of awareness, inappropriate technical knowledge, lack of funding and lack of implementation of policies and legislation on the ground (Joshi and Ahmed, 2016).

Despite the previous lack of formal recycling and waste separation systems, the recycling of waste is still a thriving sector, this is due to waste material availability and market demands for cheaper recycled products (Gupta *et al.*, 1998).

In 2016 the Ministry of Environment, Forest and Climate Change revised the rules for the management of municipal solid waste. The new rules established in 2016 for the management of MSW has shifted from MSW segregation being a municipal responsibility to a waste generators responsibility. The purpose of such a shift is to target separation of waste at the source and enhance the upcycling of waste as a resource (MoEF, 2016).

2.4.2 China

China holds the largest population in the world and is currently the largest generator of MSW, this is attributed to rapid urbanization and economic growth(Cheng and Hu, 2010). Due to the volumes of waste generated, it is essential to understand how waste is managed (Chen *et al.*, 2010). China’s total MSW generation spiked from 31.1 million tonnes in 1980 to a staggering 212 million tonnes in 2006 per annum (Zhang *et al.*, 2010). The predominant method for the treatment of MSW is the disposal of waste to landfill, this is due to landfills being the most cost effective method for waste treatment, furthermore, landfills are able to accommodate fluctuations in volumes and types of waste (Zhang *et al.*, 2010).

In 2006 148 million tonnes of MSW was collected and transported in China, 91.4% of which was disposed of into landfills (Zhang *et al.*, 2010). In recent years the need for the use alternative waste treatment technology, as a method of waste treatment for MSW has been emphasised. At present 13% of MSW is disposed of in waste to energy facilities(Cheng and Hu, 2010). China is the second largest consumer of energy, therefore it is necessary to meet massive energy demands to promote economic growth (Cheng and Hu, 2010). In addition to meeting the necessary energy demands, waste to energy also addresses the MSW disposal issues of over capacitated landfills in the country.

Source separation of MSW is not systematically implemented in China, however high value recyclables are extracted by the informal sector. This impacts the implementation of alternative waste treatment solutions such as composting, as the quality of the organic materials are contaminated and produce low value nutrients (Cheng and Hu, 2010).

Overall waste collection system includes both formal and informal collection of waste. The informal sector being twice the size of formal waste collection makes it difficult for the government to implement standardized waste collection and management systems (Zhang *et al.*, 2010). Despite the development of comprehensive technical standards for landfills, developed by the Ministry of Construction, landfills in China are still poorly operated (Zhang *et al.*, 2010).

In 2015 the Chinese government introduced a new environmental protection law that addressed the issues of pollution in the country, holiding the generators of pollution liable for their emissions (Tianjie, 2015).

2.4.3 Brazil

Brazil is one of the largest developing countries in the world. Much like other developing countries Brazil faces rapid urbanization and economic growth. Along with these is the global issue of solid waste management, in 2011, Brazil generated 61.9 million tons of soild waste, 42% of which was inappropriately disposed (De Sousa Jabbour *et al.*, 2014). MSW is primarily disposed of into landfills in Brzail, incineration facilities are available, however this is primarily for medical or hazardous waste (Münnich *et al.*, 2006). Over the past 20 years, the state of Rio de Janeiro had developed over 15 plants for the sorting an recycling of waste to the valuse of US$50 million, many of which had never gone into operation (Münnich *et al.*, 2006).

In 2010 the Brazilian authories enacted the National Policy for Solid Waste (NPSW). The new waste policy was designed to promote the use of the waste hierarchy, develop and adopt clean technologies to minimize environmental impacts and aide in the uptake of the recycling industry through the introduction of incentives (De Sousa Jabbour *et al.*, 2014). Despite the encatment of the NPSW, recent studies show that in 2015, only 58.7% of the total waste collected was properly disposed and treated (Alfaia *et al.,* 2017).

2.5 Chapter Summary

This chapter provided contextual insight to waste management in South Africa, taking into consideration the institutional instruments to assist in more integrated MSW management solutions. This study also assessed various zero waste models as a gap analysis, which identified the need for the development of socio-economic and institutional indicators in a sustainable zero waste model. The literature review also assessed waste management in other developing countries to determine how institutional instruments succeeded or failed and what could be adopted in the South Africa context for successful MSW management.

Chapter 3: Methodology

This chapter presents the methodology applied to this study. The primary purpose of this research is to advance the WROSE model to include socio-economic and institutional indicators to convert the model into a comprehensive sustainable waste management decision support tool. Given the research question proposed in this study, a mixed method research design is the most appropriate method given the dimensions of this study combining both quantitative and qualitative data collection and analysis.

3.1 Structure of Methodological Approach

The first step of conducting this study was an in-depth literature review which served as a gap analysis. The literature review covered the status quo of waste management in South Africa, existing GHG models, waste management legislation in the country and sustainability indicators. Through this exercise it was identified that the majority of the zero waste models identified were LCA based or looked at the environmental and economic assessment of waste streams or waste quantities with little or no focus on the socio-economic and institutional sustainability indicators. Through the assessment of various studies on sustainable waste management, five social indicators were identified as relevant to waste management practices.

The second phase of this research was the development of a framework for the assessment and quantification of the social indicators identified in the literature review. This was established through the formulation of a social indicator evaluation matrix which was administered to waste management experts across the country. Based on the feedback received, three of the five identified social indicators were selected for inclusion into the WROSE model. Using Microsoft Excel as a modelling tool, the job creation potential and health risks and public participation of each scenario were identified and developed.

Following the development of socio-economic indicators was an institutional indicator analysis, this involved the assessment of all necessary legislation and regulation that would be applicable for each of the scenarios in the WROSE model. This analysis resulted in the development of an institutional indicator matrix per scenario. Both indicators that were developed into an excel model were added into the pre-existing WROSE model.

Three case study municipalities were identified for the testing of the newly updated WROSE model. eThekwini Municipality, Msunduzi Municipality and Newcastle Municipality were used for the initial application of the WROSE model to determine GHG emissions reduction potential, landfill space savings and economic feasibility. The results produced by this study provides a baseline for the outcome of the initial scenario analysis. A comparative analysis was conducted between the initial results generated and the outcome generated using the advanced model outcomes. Figure 3.1 below illustrates how the study was carried out.

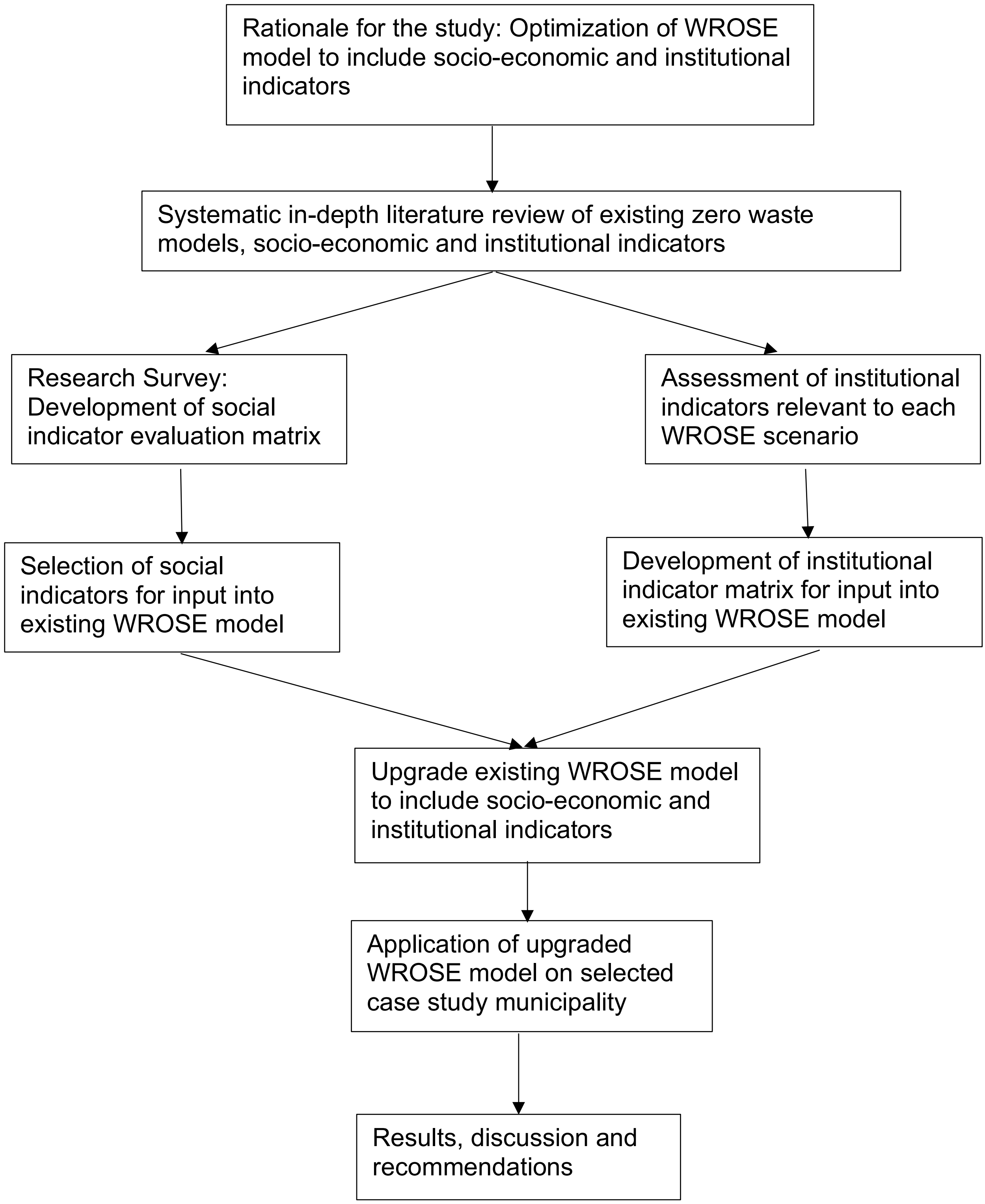


Figure 3.1 Structure of Methodology

3.2 Investigative Approaches

A pragmatic paradigm uses a context driven approach, this method is employed such that the research methods are chosen based on the type of research questions posed (Godfrey, 2011). Taking into account the purpose of this study and the nature of the research questions identified, a mixed-methods research design was selected as the most relevant research design for the study (Brannen, 2005). The investigative approaches employed in this study consist of both qualitative and quantitative data.

3.2.1 Quantitative research

Quantitative research relies on coherent and logical reasoning and makes use of a variety of quantitative analysis techniques (Khalid et al., 2012). Quantitative research uses numerical data to predict and explain phenomena. In addition it quantifies the relationship between different variables (Khalid et al., 2012). Quantitative research will be adopted for determining the job creation potential for each scenario within the WROSE model. This will be done using the employment factor method developed for the renewable energy sector (Breitschopf, Nathani and Resch, 2011).

3.2.2 Qualitative research

Qualitative research aims to acquire an in-depth understanding of human behaviour and the reason for the occurrence of that behaviour (Khalid et al., 2012). The purpose of qualitative research is to provide a deeper interpretation of a specific phenomenon (Khalid et al., 2012). Qualitative research is prominent in the social sciences and market research. A semantic differential scale will be used to measure qualitative data for the social impacts of each scenario beyond job creation potential (Al-hindawe, 1996).

3.2.3 Mixed methods research

Mixed methods research involves collecting and analysing quantitative and qualitative data in the same study (Leech and Onwuegbuzie, 2009). The combination of the two approaches has the potential to enhance the outcome of the study. Therefore, for the purpose of this study qualitative techniques to determine which social indicators will be included is used and quantitative techniques for the examination for the job creation potential will be used.

3.3 Assessment of existing zero waste models

Various zero waste models have been developed globally to tackle the issue of GHG emissions. These are available, either via subscription or downloadable for use to the public. An assessment of indicators in existing decision support tools/ waste management models was conducted in the literature review chapter to determine what indicators they possessed. The table below summarizes the findings of the assessment.

Table 3.1: Assessment of existing zero waste models

Decision Support Tools	Environmental Indicators	Economic Indicators	Socio-Economic Indicators	Institutional Indicators
WARM	Yes	No	No	No
EASETECH/EASEWASTE	Yes	Yes	No	No
WRATE	Yes	No	No	No
WROSE	Yes	Yes	No	No

Each of the above models contained specific limitations and served a different purpose. WARM is environmentally focused which allows one to determine the environmental implications of waste related activities (US EPA 2017). EASETECH/EASEWASTE is LCA based with some economic functions (DTU 2017). WRATE is also LCA based with a main focus in the environmental indicators (Golder Associates 2017). WROSE is excel based with environmental indicators and basic economic functionality (Trois and Jagath, 2011).

3.4 Simulated waste management scenarios

During the initial stages of the development of the WROSE model five waste management strategies were identified for the development of scenarios which would be used for the assessment of environmental and economic indicators for municipalities. The scenarios identified included current waste management practices in South Africa as well as potential disposal strategies relevant to the South African context (Reddy, 2016).

The scenarios chosen for the evaluation are as follows:

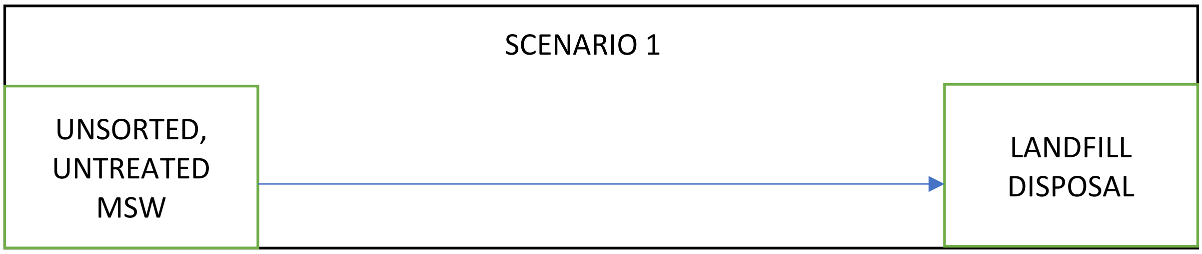


Figure 3.2: Scenario 1

Scenario 1 acts as a baseline scenario which evaluates the environmental and economic implications of the disposal of unsorted, untreated MSW to landfill. The disposal of unsorted untreated MSW into landfill is the most applied method of waste management across South Africa.

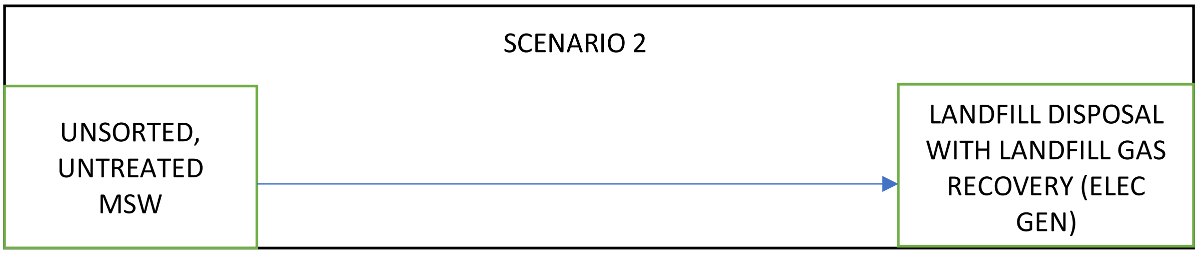


Figure 3.3: Scenario 2

Scenario 2 looks at the disposal of unsorted, untreated MSW into landfill with the generation and recovery of methane gas from the decomposition of organic waste. This scenario evaluates the environmental and economic implications of landfill disposal with landfill gas recovery on a municipality.

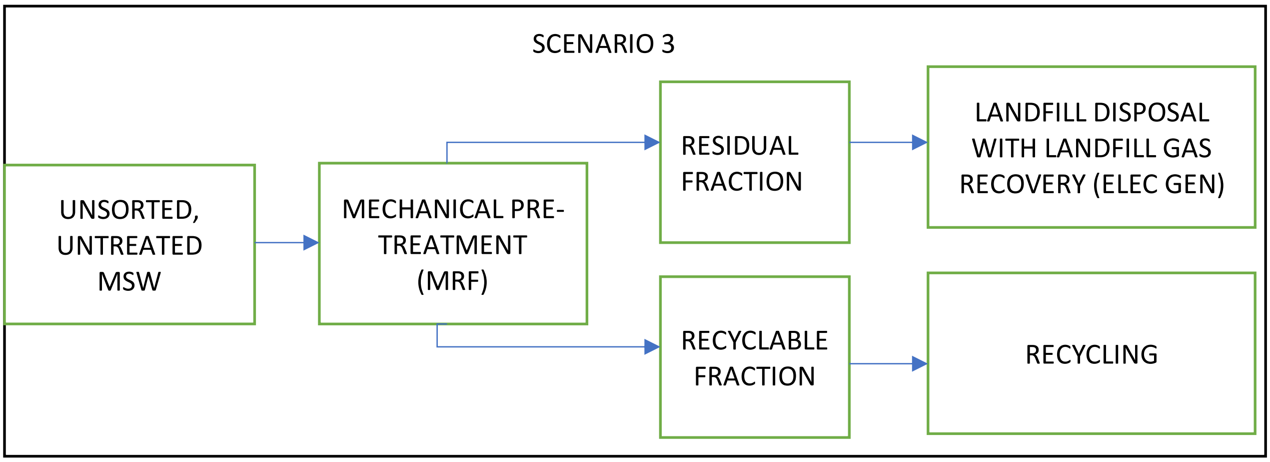


Figure 3.4: Scenario 3

Scenario 3 evaluates the potential for the mechanical pre-treatment of unsorted, untreated MSW. The sorting of waste through a MRF allows for the extraction of recyclable materials to be separated and sold to recycling companies and the residual fraction to be disposed of into landfill with landfill gas recovery for electricity generation.

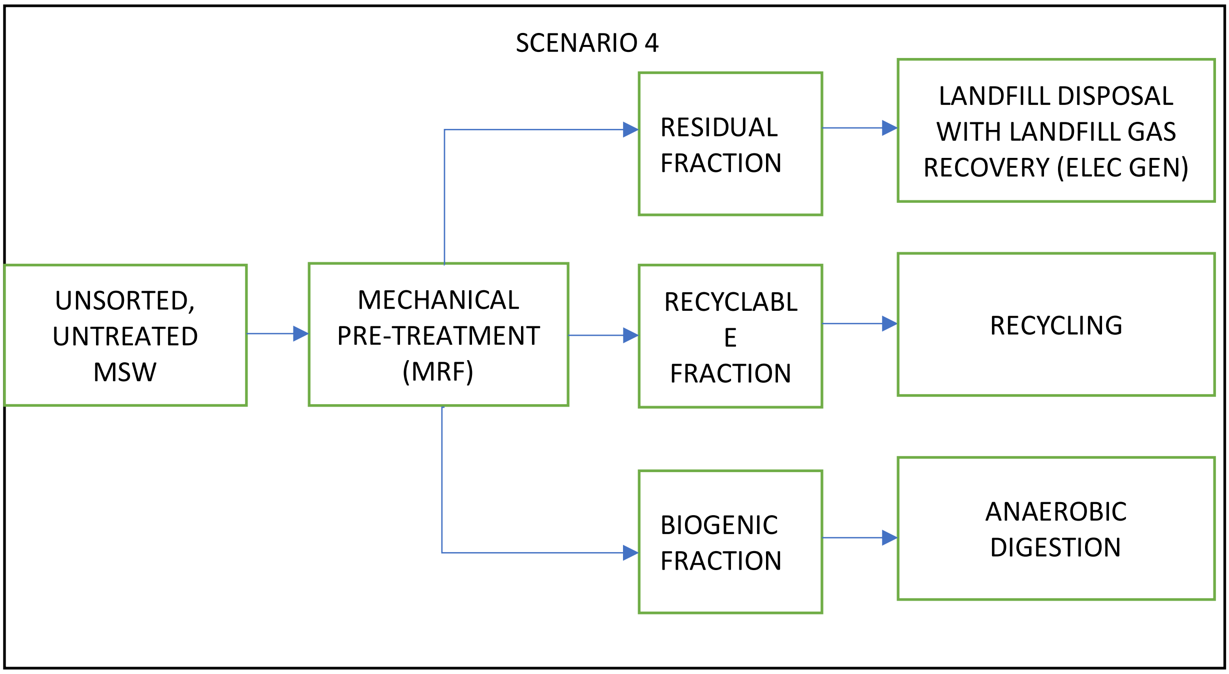


Figure 3.5: Scenario 4

Scenario 4 evaluates the mechanical pre-treatment of unsorted, untreated MSW with the waste streams being separated into three fractions, residual, recyclable and biogenic. The residual fraction of waste is landfilled with the inclusion of landfill gas recovery for the generation of electricity. The recyclable fraction is sold to recycling companies and the biogenic fraction of waste extracted for anaerobic digestion is to produce electricity.

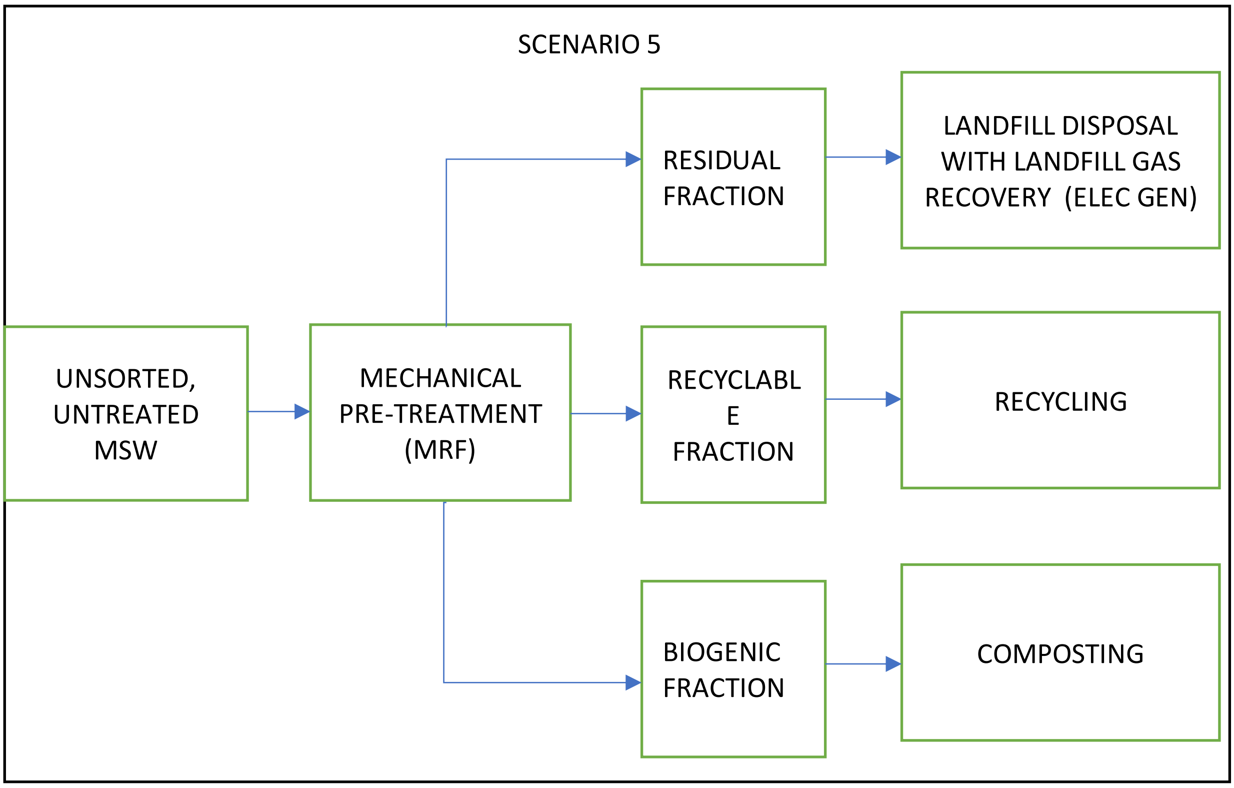


Figure 3.6: Scenario 5

Scenario 5 evaluates the mechanical pre-treatment of MSW with the residual fraction landfilled along with the extraction of landfill gas for electricity generation. The recyclable fraction is sold to private recycling companies and the biogenic fraction is aerobically composted and can be sold to the public.

3.5 Indicator Evaluation

A semantic differential scale (SDS) is a commonly used tool in the social sciences, the SDS is typically used in language and attitude studies. The SDS is a bipolar rating scale using adjectival opposites(Al-hindawe, 1996). For the purpose of this study SDS ratings were selected on a scale of 1 to 3, with the adjectives of unimportant to important attached to each figure with 1 being unimportant and 3 being important.

Table 3.2: Semantic differential scale parameter and relevance

PARAMETER	RELEVANCE
1	Unimportant
2	Neutral
3	Important

1 – Unimportant : This represents the indicator which has the least importance for the inclusion into the WROSE model.

2 – Neutral : This is regarding the indicators that are neither the least or most important for the inclusion into the model.

3 – Important : This represents the indicator most relevant and important for the purpose of this study.

3.5.1 Social Indicator Selection

At present the WROSE model contains five indicators of assessment, these are, GHG emissions, landfill space savings, capital expenditure, operational expenditure and income Reddy (2016). In order to develop WROSE into a comprehensive zero waste model, social and institutional indicators were taken into consideration. The social indicators were identified through an in-depth literature review of the WROSE model, sustainability indicators and waste management indicators. Based on previous studies on waste management strategies by Armijo (2011); Couth and Trois (2012) and Jagath (2010), a total of five social indicators were identified for the purpose of this study. These indicators are:

- Job creation potential DEA (2016)
- Health Risks Couth & Trois (2012)
- Public acceptance and social perception Armijo, Puma and Ojeda (2011)
- Cleanliness and smell Reddy (2016)
- Social participation required Armijo, Puma and Ojeda (2011)

3.5.1.1 Indicator characteristics and evaluation criteria

In order to determine which of the abovementioned indicators were to be selected for use in the optimization of the WROSE model, an indicator evaluation matrix needed to be developed. This led to the formulation of a multi criteria evaluation matrix in the table below. The evaluation criteria for sustainability indicators are based on existing studies and literature. Important characteristics of sustainability indicators based on the Regions for Sustainable Change (RSC) tool kit include:

- Simple
- Representative
- Scientifically grounded
- Measurable
- Comparable
- Policy relevant
- Timely
- Results oriented

(Hart, 2010)

Various social science and qualitative analysis employ the use of indicator characteristics. Taking the abovementioned characteristics into consideration the following evaluation criteria matrix was developed. This would be used to rank each indicator according to its related characteristic using the semantic differential scale parameters discussed above. Based on this scale, a sample population consisting of 21 waste experts in government, academia, NGO's and the private sector were selected to rate the indicators below. The matrix was sent via email followed by telephonic follow ups. Nine responses were received the highest scoring indicators were then selected for inclusion into the WROSE model.

Table 3.*3*: Indicator evaluation matrix

Social Indicators	**Relevance**	**Transparency/User friendly**	**Policy relevant**	**Data Availability**	**Data Quality**	**Measurable**
Job creation						
Health risks						

Public acceptance and social perception						
Cleanliness and smell						
Public participation required						

The indicator evaluation survey found in Appendix A, was distributed to relevant experts in the field of waste management, the results of the survey are discussed in the results chapter, following which three social indicators were selected for use in the optimization of the WROSE model. The selected indicators were, job creation potential, health risks and public participation.

- **Job creation potential**

The waste sector survey conducted by the Department of Science and Technology determined that the formal waste sector employs almost 30000 people at municipal level (DEA, 2016). The National Policy Brief 8 focused on the opportunities for green jobs in the waste sector, this recognises the potential for growing the green economy through the waste sector. The policy brief suggests the creation of 55014 direct jobs in the waste to energy sector and 15918 jobs in the recycling sector (DEA, 2016). The waste sector has the potential to create income opportunities though the collection and sorting of waste (DEA, 2016). The use of employment factors to project job creation potential for each of the scenarios in the model was selected for this study, this is due to a lack of reliable data. The use of this methodology is fast growing as an economic analysis tool for the forecasting of the renewable energy industry (Stands *et al.*, 2016). The job creation potential for each of the waste management scenarios identified above were calculated by averaging data from existing facilities across South Africa. In order to determine the job creation potential for each scenario, a detailed literature review was conducted on various existing and operational facilities across all five scenarios. The formula below depicts how the job creation figures were estimated.

The methodology developed to calculate job creation potential of renewable energy projects was developed and utilised in various studies. Employment factor approaches were developed by multiplying the capacity of RE facilities (MW) by the employment factor (jobs per MW) (Breitschopf, Nathani and Resch, 2011). This process was carried out for that scenarios that include electricity generation i.e. AD and LFGTE.

$$\frac{Megawatts\ of\ electricity}{Number\ of\ employees} = x\ MW\ of\ electricity\ per\ job$$

A similar process was carried out for the scenarios that look at landfills, MRF's and composting facilities and the final figures averaged out and input into the WROSE model.

$$\frac{Tons\ of\ waste\ per\ day}{Number\ of\ employees} = x\ tons\ of\ waste\ per\ job$$

It is important to note that the job creation figures were calculated based on the volumes of waste per day and not annually to get a clear indication of daily staff requirements per scenario. Therefore, figures identified in the case study will be divided into daily volumes for the estimation of job creation potential. Furthermore, the figures input into the advanced model were divided according to the percentages of waste fractions identified in the waste characterization study.

- **Health risks**

Various studies have assessed the impact of waste management activities on employees at waste management facilities and surrounding residents, these health issues are present at every step of the waste management process from handling of waste to treatment and disposal (Giusti, 2009). The health risks of each of the identified waste management scenarios were established by conducting a detailed review of the most common risk factors associated with each technology type. The risk to public health is a product of exposure to pathogenic agents, toxic substances and gases. This could also result in the exposure to odour issues (Domingo and Nadal, 2009)

The natural generation of gas and leachate through the microbial decomposition process are some of the outcomes of the disposal of waste to landfill (Domingo and

Nadal, 2009). Human exposure to such emissions result in negative health impacts to the general public. Some of these include low birth weight, congenital anomalies, cancer and cardiovascular defects (Giusti, 2009). A study conducted on the staff of a MSW landfill in Delhi determines that the direct health risks if the staff was much higher than that of a control group. Direct exposure to pathogens and bioaerosols resulted in diarrhoea, fungal infections and lung reactions among other issues(Ray *et al.*, 2005)
There are typically three types of exposure mechanisms that contribute to health risks of the handling of MSW, these are:

a) Exposure through ingestion of composting in treated soil.
b) Ingestion of contaminated foods exposed to compost,
c) Exposure to dust from compost that contains microorganisms and toxicants.

(Domingo and Nadal, 2009)
Some of the associated health risks identified through this type of exposure include, nausea, vomits, reactions to hyper sensitivity and respiratory issues (Domingo and Nadal, 2009). Landfill gas extraction has a strong impact on the reduction of GHG emissions into the atmosphere (Niskanen *et al.*, 2013). This therefore reduces the amount of health risks and exposure of local communities and onsite staff to airborne pathogens.
Although health risks differ between each type of technology, they do not differ per municipality. The health risks have been incorporated into the socio-economic indicators depicted in Table 3.4 below.

- **Public participation**

In recent years, there has been a growing need for public inclusion and involvement in the development of policies and procedures in the science and technology sector with emphasis on the environmental risks (Rowe and Frewer, 2000). There is increasing realization from governmental, scientific and industry bodies that the general public should be involved and responded too in the decision making process where feasible(Rowe and Frewer, 2000). Various countries across the world, South Africa among them, have embedded in policy the need for public participation when making decisions on the establishment of high risk waste facilities(Rowe and Frewer, 2000). Therefore the need for public participation per scenario were also assessed. Public participation was looked at from public involvement in the waste separation at source point of view as well as the participation of the public in the EIA process. The table below is an example of the addition of the selected socio-economic indicators into the WROSE model.

Table 3.4 Example of socio-economic indicators in WROSE model

WASTE RESOURCE OPTIMIZATION AND SCENARIO EVALUATION MODEL: SOCIO - ECONOMIC INDICATORS						
	WASTE QUANTITY (tons per day) /MW OF ELECTRICITY	**NO. OF JOBS**	**DIRECT HEALTH RISKS**	**INDIRECT HEALTH RISKS**	**PUBLIC PARTICIPATION IN WASTE MANAGEMENT PROCESS**	**PUBLIC PARTICIPATION IN EIA PROCESS**
SCENARIO 1: LANDFILLING	0	0.0	Respiratory Issues, Fatigue, Headaches, Influenza type Symptoms	Cancer, Low Birth Weight, Birth Defects	No public participation necessary	Public participation process required
SCENARIO 2: LANDFILL WITH GAS RECOVERY /ELEC GEN	0	0	Wheezing, nausea, headaches	Asthma, respiratory issues	No public participation necessary	Public participation process required
SCENARIO 3: RECYCLING	0	0.0	Respiratory issues, influenza type symptoms, nausea, headache, tiredness	Asthma, respiratory issues	No public participation necessary due to separation at MRF	Public participation process required
SCENARIO 4: ANAEROBIC DIGESTION	0	0	Tiredness, headache, nausea	N/A	No public participation necessary due to separation at MRF	Public participation process required
SCENARIO 5: ANAEROBIC COMPOSTING	0	0	Fungal spores and bacteria causing Breathing problems, nausea	Fatigue and headaches	No public participation necessary due to separation at MRF	Public participation process required

3.6 Institutional Indicators

Perceived regulatory barriers to the implementation of alternative waste management solutions is a common cause for delays to the development and implementation of projects across the country (Oelofse and Mouton, 2014). The development of the waste economy and driving integrated waste management solutions requires a host of legislations and licences that require navigation in order to ensure legally compliant waste management businesses (Oelofse and Mouton, 2014). The primary law regulating waste management in South Africa is the National Environmental Management, Waste Act, 2008 through the Department of Environmental Affairs (DEA) (Schoeman *et al.*, 2012). According to the Waste Roadmap Reports status quo assessment Figure 3.7 below highlights the seven key issues associated with waste management in South Africa

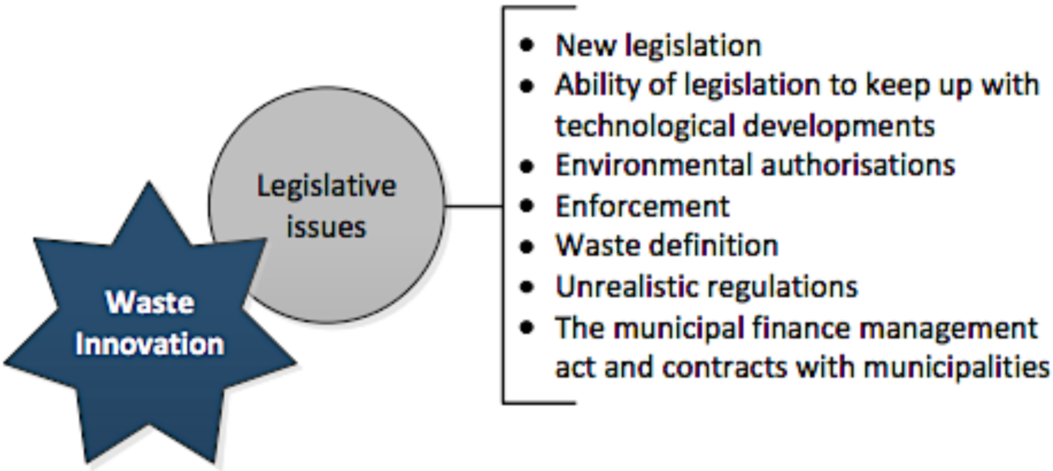


Figure 3.7: Legislative constraints, gaps and opportunities for waste innovation *(Schoeman* et al.*, 2012)*

The main purpose of the development of institutional indicators in the WROSE model is to address some of the legislative issues identified in Figure 3.7. Institutional indicators include the legal requirements and/or implications of the scenarios identified in the WROSE model which will assist the user to determine legal requirements of suggested solutions and estimate appropriate cost and time frames. A similar study conducted in 2014 was commissioned by the Western Cape Department of Economic Development and Tourism to determine the cost and time implication of regulation and legislation on the waste sector. The outcome of the study is summarized in table 3.4 below.

Table 3.5: Cost and time impacts of regulation and legislation on the waste sector *(Oelofse and Mouton, 2014)*

Activity	Law/regulation	Cost	Timeframe
Outsourcing a municipal service	Section 78 assessment (MSA)	R 180 000 (Sec 78(1)) typically for evaluation of a single facility or service Up to R10 million for full Sec 78	14 months on average for full Sec 78
Outsourcing a municipal service	RFP if job <R200 000	Insignificant	11 weeks based on the prescribed tender process to follow
Establish a PPP	Section 120 (MFMA) read with the PPP regulations	R2 million (typically for one facility/property) Per PPP established	9 months minimum depending on complexity and size of PPP (this excludes tender process time described, which will be longer due to the complexity of the tender specification that increases when asking for transaction advisor services needed to complete the PPP process in terms of regulations)
Contracts beyond 3 years	Section 33 of (MFMA) requirements		2-3 years (12 months is more realistic, as discussed)
Investigation to determine if municipal land is available for use by PPP or business	Section 120 of MFMA	R 4 000 – R 5 000 upfront admin fee only for zoning application	6 months minimum (if rezoning is required, this involves a process and decision by province, with public participation that could stretch the timeline to approx. 3 years)
Listed Activity Category A	Basic Assessment in terms of 2013 listed Activity	R 45 000 – R 180 000 excluding specialist studies	7-9 months (will depend on public participation and what effect comments will have on the process to do more studies or supply more information)
Listed Activity Category B	Full EIA in terms of 2013 listed Activity	>R150 000 Up to R6 million per site	11-24 months (will depend on public participation and what effect comments will have on the process to do more studies or supply more information)
Closure of landfill sites	NEW:WA	R10 million/hectare	Non specified
Water use licence	DWA water use licence	>R45 000	No time frame specified 2.5 year backlog in licence processing (mostly related to WWTW's)
Rectification of unlawful commencement or continuation of listed waste management activity	Section 24 G NEMA	R 50 000-R 5 million Administrative fine	Fine must be paid before the EIA process may start
Analysis, Classification and compilation of SDS for waste	Waste Classification and management regulations	R 20 000 - R70 000 per sample	30 working days Depending on the capacity of the lab to process the samples

For the purpose of this study the institutional indicators were identified based on the relevant technologies identified in each scenario. The legislation applicable to each scenario was separated into three categories, environmental, energy and financial and administrative. Table 3.5 below is an example of how the information has been organized into an excel document. The purpose of organizing the information in this manner is to allow an easy addition into the existing WROSE model.

Institutional requirements differ in each scenario, however the same legislative requirements are applicable to all municipalities across the country. Prior to any external feasibility studies, all municipalities must first conduct as section 78 process of the Municipal Systems Act. In doing so, the municipality assesses their inhouse capabilities in implementing and managing waste management projects. Should the municipality not possess the resources to conduct the project inhouse, external mechanisms must then be assessed (RSA, 2000). This process has the potential to add considerable delays to project implementation time frames. It is therefore important for municipal officials to understand what processes are required in advance and allocate realistic time frames for project planning. This will also reduce unforeseen red tape that usually result in project delays.

Table 3.5 below is an example of the collation of information into the WROSE model on a per scenario basis. The information gathered was obtained through a desktop study of relevant legislative requirements for the development of phase 2 of the indicator development.

Table 3.6: Institutional Indicators in WROSE model

SCENARIOS	WASTE STREAMS	ENVIRONMENTAL LEGISLATION	ENERGY LEGISLATION	FINANCIAL & ADMINISTRATIVE REGULATION	LICENCE REQUIRED
SCENARIO 1: DISPOSAL OF UNSAORTED UNTREATED MSW TO LANDFILL	General MSW	The Constitution	N/A	Occupational Health and Safety Act 1993	
		The Environmental Conservation Act	N/A	Municipal Systems Act 2000	
		National Environmental Management Act	N/A	Municipal Structures Act	
		National Environmental Management Waste Act	N/A	Municipal Finance Management Act with Particular Reference to:	Atmospheric Emissions Licence
		National Environmental Management: Air Quality Act	N/A	Supply Chain Management	Waste Licence (For Storage, Treatment, Disposal and Processing of waste)
		Atmospheric Pollution Prevention Act	N/A	Asset Management	
		National Integrated Coastal Management Act	N/A	Generally Recognised Accounting Practices 17 & 19)	

3.7 Application of phase 2 of the WROSE model

The eThekwini Municipality, Msunduzi Municipality and New Castle Municipality were selected due to their representation of diverse South African municipalities. The results obtained from the development of phase 1 of the indicators of the WROSE model will serve as a benchmark for the application of the additional indicators. The schematics below outline the manner in which the research will be carried out for each of the municipalities selected.

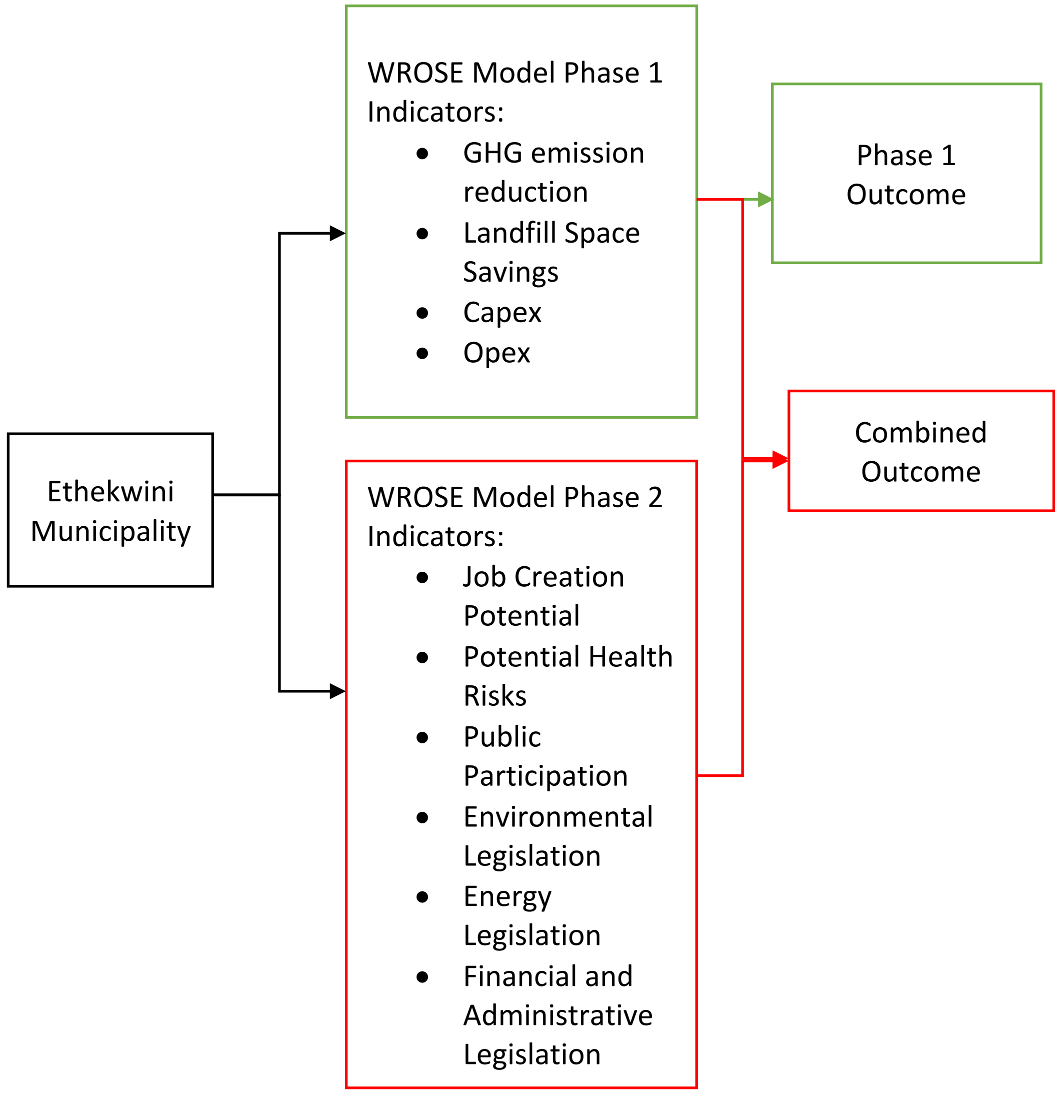


Figure 3.8: Application Phase 1 and 2 of the WROSE model on eThekwini Municipality

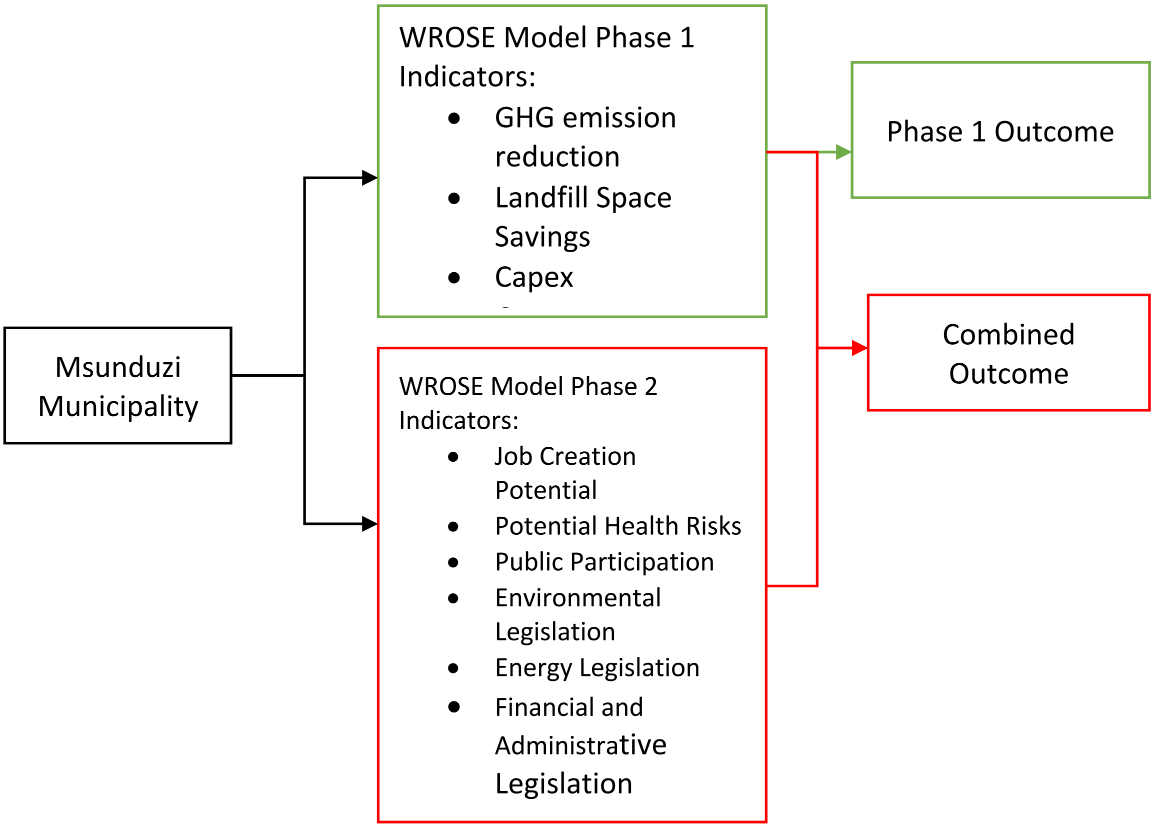


Figure 3.9: Application Phase 1 and 2 of the WROSE model on Msunduzi Municipality

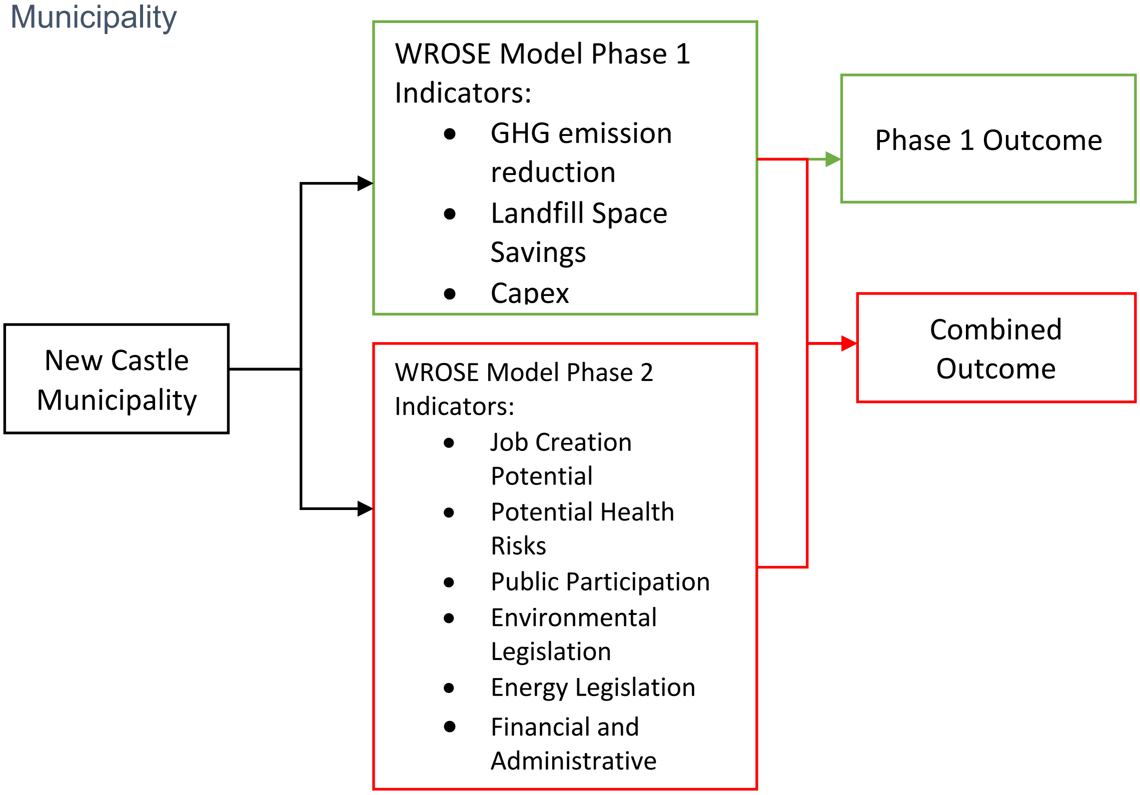


Figure 3.10: Application Phase 1 and 2 of the WROSE model on New Castle Municipality

3.8 Chapter summary

The methodology adopted for this study comprised of both quantitative and qualitative researched methods. The quantitative analysis was used for the evaluation of social indicators as well as determining the job creation potential of each scenario. The qualitative aspects of the research involved the literature review required in identifying potential health risks as well as legislative requirements of each scenario in the WROSE model. Using the methodology developed a comparative analysis will be conducted using the three case study municipalities identified in the initial development of the WROSE model. The analysis will include the discussion of the baseline outcome of the initial study and the outcome post the application of the models advancements. The case studies will be discussed in detail in the following chapter and a comparative analysis will be discussed in the results and discussions chapter.

Chapter 4: Case Studies

4.1 Introduction

The following chapter describes the case study identified and selected for this research. The case studies for this research have been selected based on existing research conducted during the development stages of the WROSE model. The development of the WROSE model was conducted in a phased manner. Phase 1 of the WROSE model's development incorporated the first set of sustainability indicators which were environmental and economic indicators (Reddy, 2017). Within phase 1 GHG emission reduction potential and landfill space savings were estimated per scenario. Phase 1 of the model was applied on three case study municipalities which will serve as the benchmark for the analysis of each of the scenarios in phase 2 of the models development. The eThekwini Municipality, New Castle Municipality and Msunduzi Municipality were selected for a comparative analysis. Using the case study results obtained as a baseline outcome of the model, a comparative analysis was conducted through the application of socio-economic and institutional indicators. The results examined will determine if the addition of further sustainability indicators will alter the decision regarding the most appropriate waste management scenario.

The key outcomes extracted from the development and application of the WROSE model are:

1. Waste stream analysis
2. GHG quantification
3. Scenario analysis
4. Landfill diversion rates
5. Economic analysis

4.2 eThekwini Municipality

The eThekwini Municipality is one of 3 metropolitan municipalities in South Africa and is located in the province of KwaZulu-Natal, on the east coast of South Africa. The eThekwini Municipality is home to the City of Durban and certain surrounding towns with an estimated population of 3.5 million people.

The cleansing and solid waste department in eThekwini Municipality is known as Durban Solid Waste (DSW) and provides services such as collection, transportation, storage, treatment and disposal of waste. There are four landfill disposal facilities within the region, these are Mariannhill Landfill, Bisasar Road Landfill, Buffelsdraai Landfill and Illovu Landfill.

- Bisasar Road Landfill

The Bisasar Road landfill is located in Springfield near the DSW head office. The landfill is surrounded by both formal and informal settlements (Couth *et al.*, 2011). The landfill operated for a period of 35 years from 1980 to 2015. The facility accepted domestic MSW, garden refuse and commercial and industrial waste. The landfill also hosts a LFGTE facility with spark ignition engine generators for the generation of electricity (Couth *et al.*, 2011)

Figure 4.1: Bisasar Road Landfill (Google Maps 2018)

- Mariannhill Landfill

The Mariannhill landfill facility is located west of Durban. The facility receives garden refuse, medical waste as well as construction and demolition waste. The landfill receives between 450 to 700 tons of waste per day. The landfill also hosts a LFGTE facility with spark ignition engine generators for the generation of electricity (Reddy, 2016). The facility also has a MRF, leachate treatment plant and a nursery for the preservation of biodiversity. The MRF has been operational since 2007 with the addition of mechanical sorting equipment.

Figure 4.2: Mariannhill Landfill (Google Maps 2018)

- La Mercy Landfill

The La Mercy landfill was established in 1933 and closed in 2006. The landfill is located in northern Kwa-Zulu Natal and accepted up to 250 tons of waste per day.

Figure 4.3: La Mercy Landfill (Google Maps 2018)

- Buffelsdraai Landfill

The Buffelsdraai Landfill is located 8kms west of Verulam. The landfill was commissioned in 2006 and receives up to 450 tons of general MSW per day. The facility has an estimated life span of approximately 50 years with the capacity to receive 2000 tons of waste per day.

Figure 4.4: Buffelsdraai Landfill (Google Maps 2018)

- Lovu Landfill

The Lovu Landfill facility is located south of Durban CBD. The Lovu landfill facility handles general MSW has a remaining 25 year life span left. The Lovu landfill facility receives the lowest volumes of waste as opposed to other municipalities.

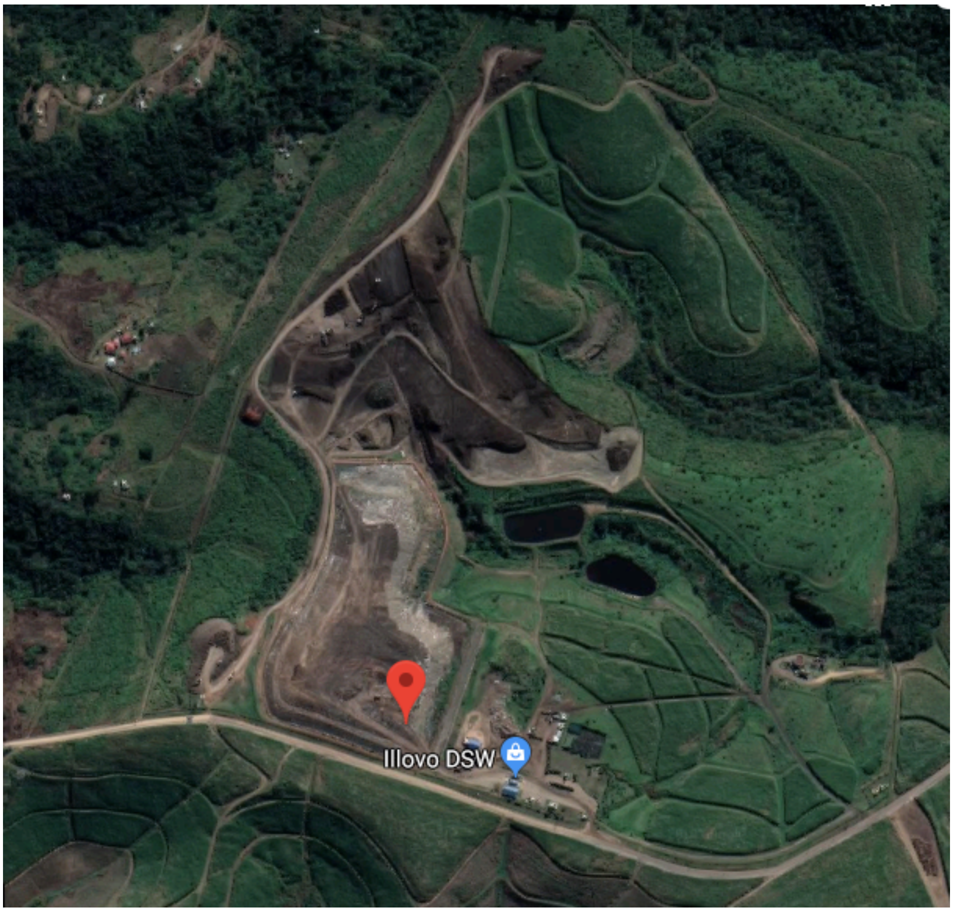


Figure 4.5 Lovu Landfill (Google Maps 2018)

4.3 Msunduzi Local Municipality

The Msunduzi local municipality is located in the uMgungundlovu District Municipality, 45 minutes west of Durban and includes the Pietermaritzburg area. The Msunduzi Municipality has one landfill facility located on New England Road. The municipality provides public services such as, street sweeping, waste collection, removal of illegal dumping, management of garden refuse sites as well as transfer stations. The New England Road Landfill

- New England Road Landfill

The New England Road Landfill began operation in 1950 and receives up to 700 tons of waste per day. The landfill had a lifespan of 70 years. At present the landfill is nearing the end of its lifespan and the search for a new landfill site is underway. There are no waste treatment facilities currently in place.

Figure 4.6 New England Road Landfill (Google Maps 2018)

4.4 Newcastle Local Municipality

The Newcastle Local Municipality is located in the Amajuba District Municipality. The municipality aims to provide effective and efficient waste management services to all areas in Newcastle. The municipality stresses the need for the implementation of recycling in the municipality. The municipality has implemented a fully integrated waste management system which includes litter collection and clean up. Refuse bins are provided to formal and informal areas.

- Newcastle Landfill

The Newcastle landfill facility is located on Madadeni Road on the outskirts of Newcastle. The facility began operation in 1971, the municipality has incorporated a source separation programme with a 2 bag system for the separation of recyclables from organic wet waste. The source separated material is transported to a transfer station and then to a mechanical, biological treatment plant (MBT). The recyclables are sent to a recycling company and the organics undergo an in-vessel composting system.

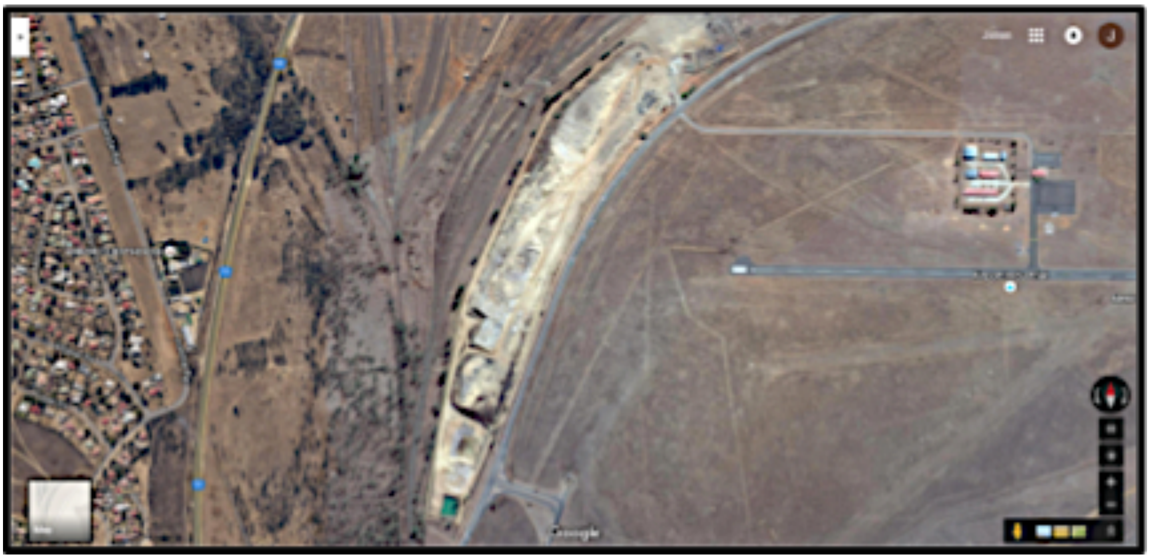


Figure 4.7: Newcastle Landfill (Google Maps 2018)

4.5 Waste stream analysis outcomes

A waste stream analysis is essential for each municipality to get an indication of the quantities and quality of each waste stream. The data generated by the waste stream analysis is then used as input data into the WROSE model to generate outcomes such as potential GHG emission reductions and landfill space savings as well as some level of economic analysis.

- eThekwini Municipality

A detailed waste stream analysis was conducted in 1998 for the eThekwini municipality by SKC Engineer/ Haultech, these outdated results were later updated by averaging results in more recent studies. In 2013 Friedrich and Trois used the waste stream analysis results depicted in the figure below, this image was extracted from a report conducted by UKZN for the KZN Department of Economic Development and Tourism in 2013. This figure was later used by Reddy 2016 in the development of phase 1 of the WROSE model.

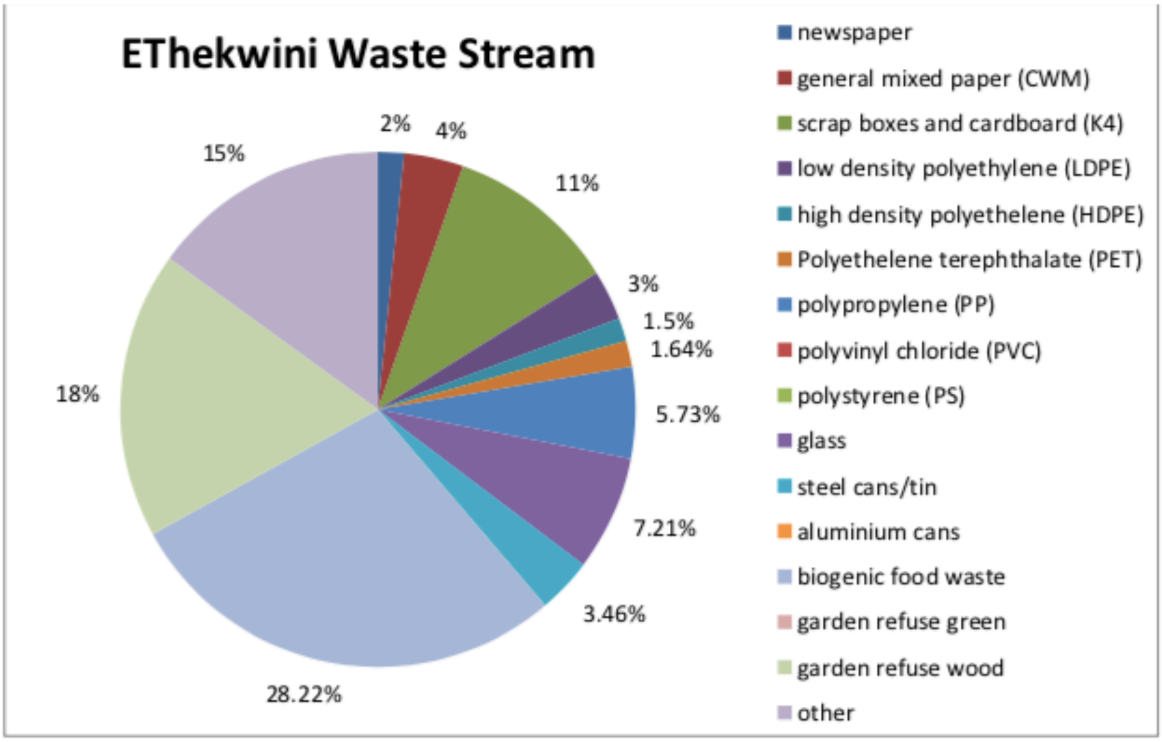


Figure 4.8: eThekwini Municipality Waste Stream Analysis (KZN-DEDT 2012-2013)

A large fraction of biogenic food waste is depicted in the figure above in addition to a large fraction of garden refuse. Approximately 40% of the total waste generated is recyclables.

- Msunduzi Municipality

The Msunduzi municipality waste stream analysis was carried out at the New England Road Landfill. Jagath (2010) conducted physical random sampling, sorting and characterising of the waste. Reddy (2016) extracted the results which is represented in the diagram below.

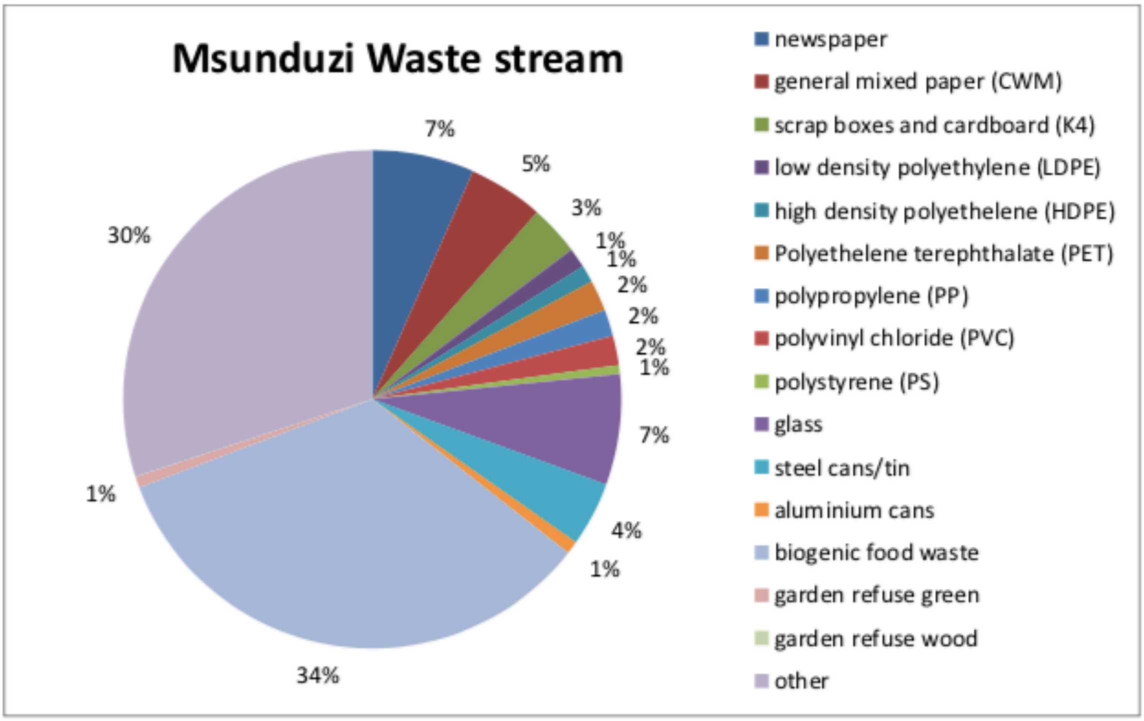


Figure 4.9: Msunduzi Municipality Waste Stream Analysis (KZN-DEDT 2012-2013)

The Msunduzi waste stream contained 34% biogenic food waste with 30% of the waste characterised as "other". Recyclables amounted to 36% of the total waste and on 1% of garden waste.

- Newcastle

A waste stream analysis was conducted by Newcastle Municipality for the 2013 integrated waste management plan. The figure below extracted from Reddy (2016) depicts the outcome of the waste stream analysis conducted. It can be seen that biogenic food waste comprised only 11% of the total waste, while garden refuse contributed 8%. The largest stream was recyclables which came in at 60% with 21% of the total waste characterised as other.

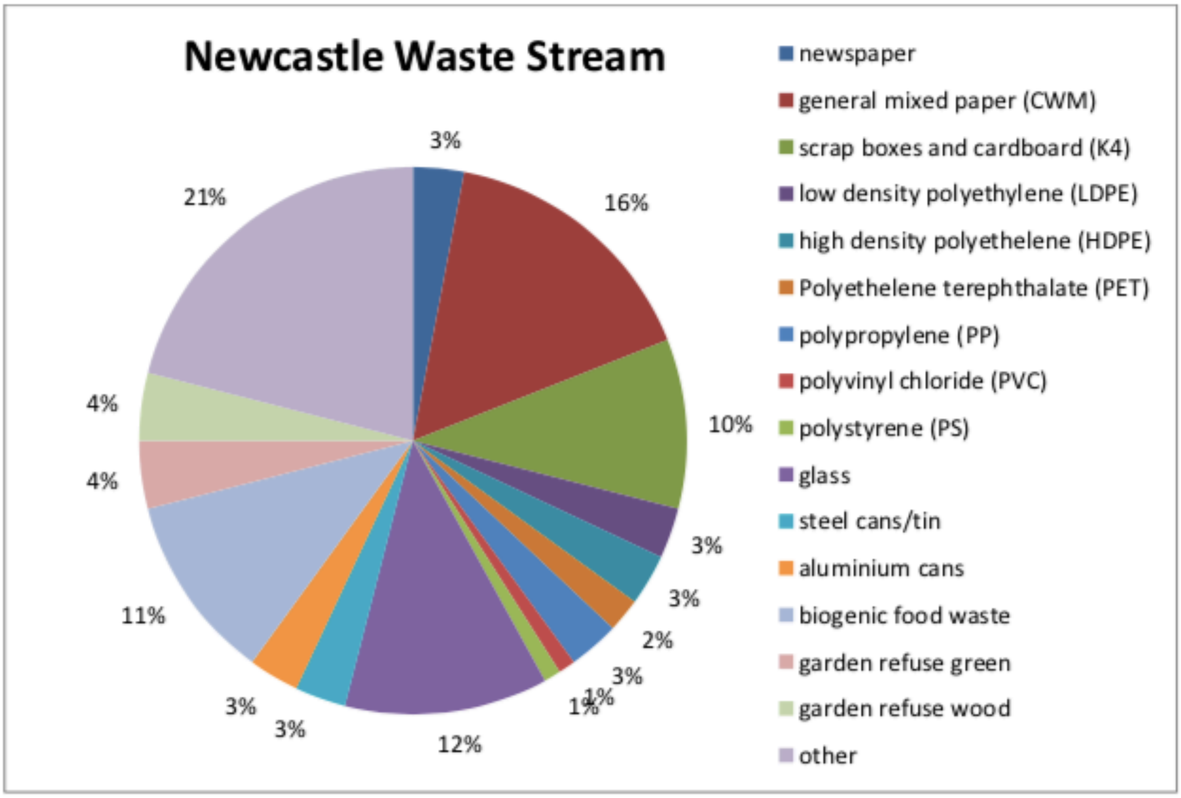


Figure 4.10: Newcastle Municipality Waste Stream Analysis (Reddy, 2016)

4.6 WROSE Model Baseline Outcome

The above data was used as input data into the WROSE model, the results obtained are graphically represented below. Detailed tables of the input data and the suggested outcome are represented below.

eThekwini Municipality GHG Emission Input and Output Data

WASTE & RESOURCE OPTIMIZATION STATEGY EVALUATION MODEL W.R.O.S.E		
	PERCENTAGES	WASTE DISPOSED (TONS)
WASTE MATERIAL OR WASTE FRACTION	WASTE STREAM ANALYSIS	ETHEKWENI 2015
newspaper	1.62	16183.59912
general mixed paper (CWM)	3.75	37462.035
scrap boxes and cardboard (K4)	10.76	107491.0658
low density polyethylene (LDPE)	3.13	31268.31188
high density polyethelene (HDPE)	1.45	14485.3202
Polyethelene terephthalate (PET)	1.64	16383.39664
polypropylene (PP)	5.73	57241.98948
polyvinyl chloride (PVC)	0	0
polystyrene (PS)	0	0
glass	7.21	72027.00596
steel cans/tin	3.46	34564.97096
aluminium cans	0	0
biogenic food waste	28.22	281914.3007
garden refuse green	0	0
garden refuse wood	18	179817.768
other	15.03	150147.8363
TOTAL WASTE DISPOSED/DIVERTED	100	998987.6
TONNAGE REPORTS		998987.6
RECYCLED TONS		376055.0
RR %		27%

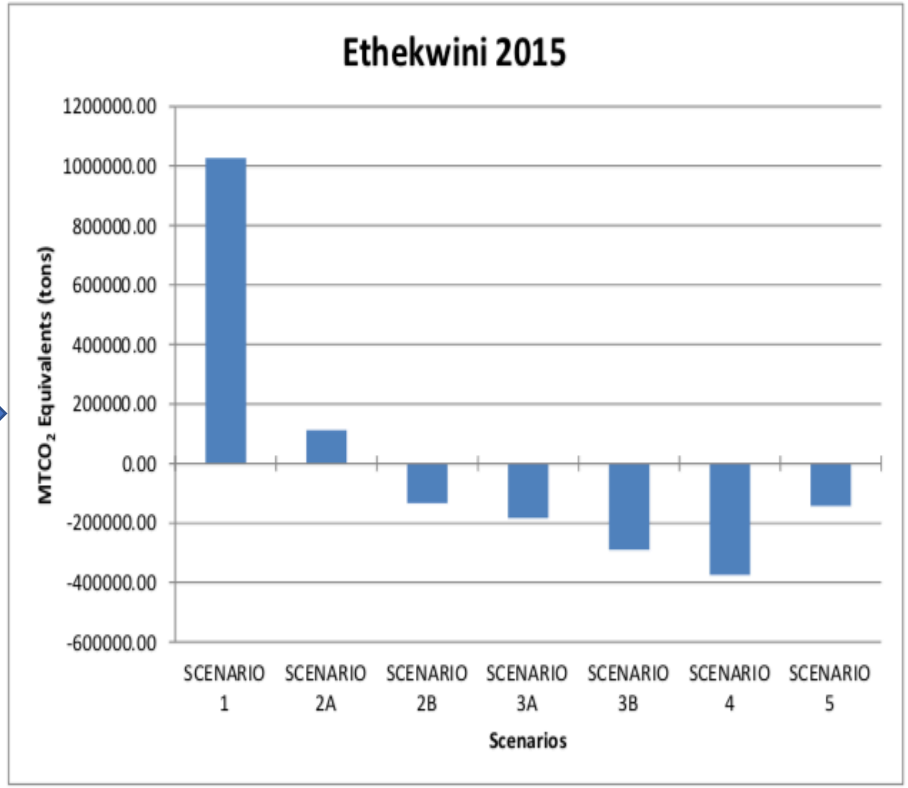


Figure 4.11: eThekwini Municipality GHG Emission Input and Output Data (Reddy, 2016)

The table and figure above depict the WROSE input data gathered from the waste stream analysis results and the GHG emission reduction potential in the output graph. According to figure 4.4 above the disposal of waste to landfill results in the emission of 1 026 600 $MTCO_2eq$. Substantially lower emissions can be seen in the other scenarios. Each of the above scenarios has the potential for GHG emission reduction and significant environmental benefits. Scenario 4 in particular which includes the mechanical pre-treatment of waste with the disposal of residual waste to landfill, sale of recyclables and the anaerobic digestion of the biogenic fraction has the greatest environmental benefit for the eThekwini Municipality.

Msunduzi Municipality GHG Emission WROSE Input and Output Data

WASTE & RESOURCE OPTIMIZATION STATEGY EVALUATION MODEL W.R.O.S.E		
WASTE MATERIAL OR WASTE FRACTION	PERCENTAGES WASTE STREAM ANALYSIS	WASTE DISPOSED (TONS) MSUNDUZI 2015
newspaper	6.64	9915.6448
general mixed paper (CWM)	4.88	7287.4016
scrap boxes and cardboard (K4)	3.23	4823.4236
low density polyethylene (LDPE)	1.3	1941.316
high density polyethelene (HDPE)	1.13	1687.4516
Polyethelene terephthalate (PET)	2.01	3001.5732
polypropylene (PP)	1.71	2553.5772
polyvinyl chloride (PVC)	1.92	2867.1744
polystyrene (PS)	0.57	851.1924
glass	7.18	10722.0376
steel cans/tin	4.17	6227.1444
aluminium cans	0.84	1254.3888
biogenic food waste	33.64	50235.2848
garden refuse green	0.74	1105.0568
garden refuse wood	0.02	29.8664
other	30.02	44829.4664
TOTAL WASTE DISPOSED/DIVERTED	100	149332
TONNAGE REPORTS		149332
RECYCLED TONS		17490.3
RR %		10%

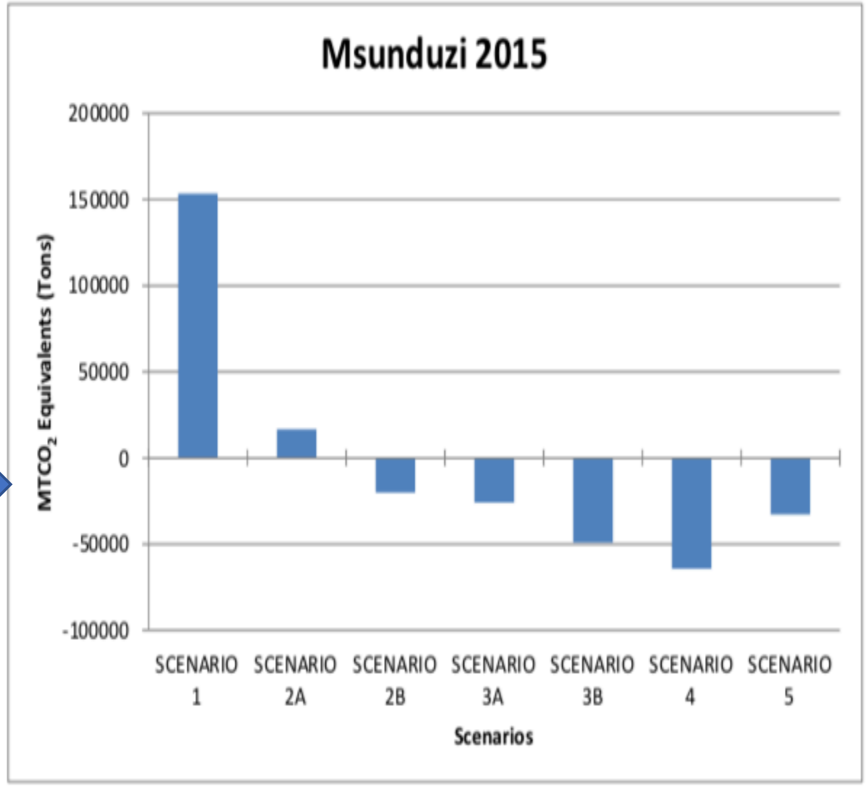


Figure 4.12: Msunduzi Municipality GHG Emission WROSE Input Data (Reddy, 2016)

The Msunduzi Municipality's carbon emission/reduction assessment results depict scenario 1 of landfilling as the least environmentally favoured waste disposal method. The potential for the implementation of alternate waste treatment technology significantly reduced the amount of GHG emissions. Much like the eThekwini municipality, due to the fraction of biogenic waste available, scenario 4 is the most environmentally favourable.

Newcastle Municipality GHG Emission WROSE Input and Output Data

WASTE & RESOURCE OPTIMIZATION STATEGY EVALUATION MODEL W.R.O.S.E		
WASTE MATERIAL OR WASTE FRACTION	PERCENTAGES WASTE STREAM ANALYSIS	WASTE DISPOSED (TONS) NEWCASTLE 2015
newspaper	3	580.98
general mixed paper (CWM)	16	3098.56
scrap boxes and cardboard (K4)	10	1936.6
low density polyethylene (LDPE)	3	580.98
high density polyethelene (HDPE)	3	580.98
Polyethelene terephthalate (PET)	2	387.32
polypropylene (PP)	3	580.98
polyvinyl chloride (PVC)	1	193.66
polystyrene (PS)	1	193.66
glass	12	2323.92
steel cans/tin	3	580.98
aluminium cans	3	580.98
biogenic food waste	11	2130.26
garden refuse green	4	774.64
garden refuse wood	4	774.64
other	21	4066.86
TOTAL WASTE DISPOSED/DIVERTED	100	19366
TONNAGE REPORTS		19366
RECYCLED TONS		5869
RR %		23%

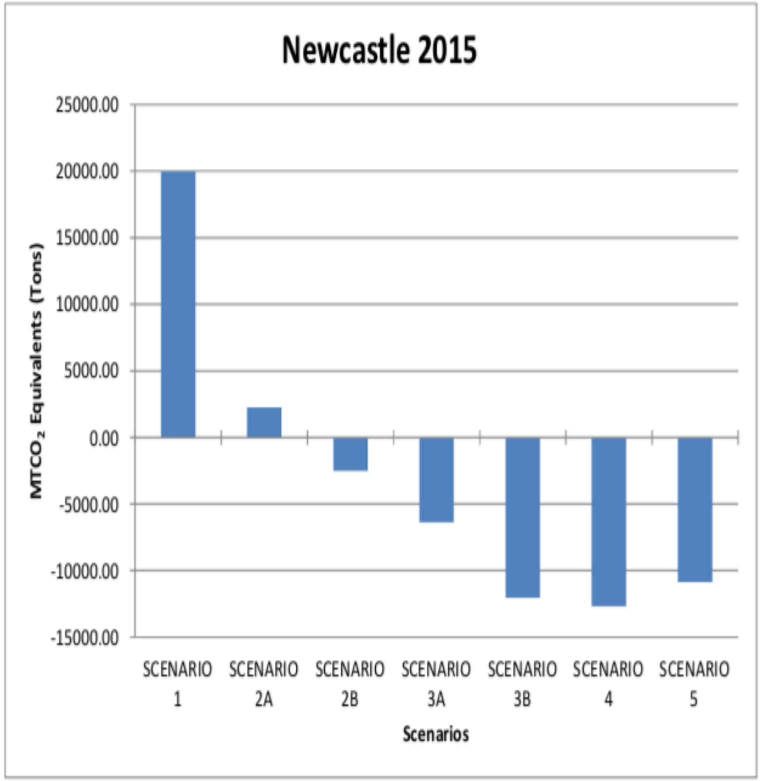


Figure 4.13 Newcastle Municipality GHG Emission WROSE Input and Output Data (Reddy, 2016)

The Newcastle Municipality results showed similar findings to the municipalities above, with highest amount of GHG emissions coming from the disposal of waste to landfill. Alternative treatment options provide significant emission reductions, however due to the high fraction of recyclables present as well as organics, scenario 4 and 5 are the most environmentally favoured options.

4.7 Scenario Analysis

Using the WROSE model Reddy (2016) conducted a comparative scenario analysis for each municipality. This was done by using the waste stream analysis data and applying the data into all 5 scenarios of the model to determine the percentage of GHG emissions from each fraction of waste.

Scenario 1: In the table below, it can be seen that the largest contributor of GHG emissions is the biogenic food waste fraction along with the garden refuse portion.

Table 4.1: Scenario 1 Municipal Comparative Analysis (Reddy, 2016)

	Ethekwini		Msunduzi		Newcastle	
Waste Fraction	Emission (MTCO2EQ)	% Emission contribution	Emission (MTCO2EQ)	% Emission contribution	Emission (MTCO2EQ)	% Emission contribution
newspaper	16447	1.6	10077	6.6	590	3.0
general mixed paper (CWM)	38073	3.7	7406	4.8	3149	15.8
scrap boxes and cardboard (K4)	109243	10.6	4902	3.2	1968	9.9
low density polyethylene (LDPE)	31778	3.1	1973	1.3	590	3.0
high density polyethelene (HDPE)	14721	1.4	1715	1.1	590	3.0
Polyethelene terephthalate (PET)	16650	1.6	3050	2.0	394	2.0
polypropylene (PP)	58175	5.7	2595	1.7	590	3.0
polyvinyl chloride (PVC)	0	0.0	2914	1.9	197	1.0
polystyrene (PS)	0	0.0	865	0.6	197	1.0
glass	73201	7.1	10897	7.1	2362	11.8
steel cans/tin	35128	3.4	6329	4.1	590	3.0
aluminium cans	0	0.0	1275	0.8	590	3.0
biogenic food waste	286510	27.9	51054	33.3	2165	10.8
garden refuse green	0	0.0	1123	0.7	787	3.9
garden refuse wood	182749	17.8	30	0.0	787	3.9
other	152595	14.9	45560	29.7	4133	20.7
Transport Emissions	11329	1.1	1532	1.0	283	1.4
TOTAL	1026600	100.0	153298	100.0	19964	100.0

Scenario 2: The application of scenario 2 which incorporates LFGTE shows a significant reduction in the emission of GHG's.

Table 4.2: Scenario 2 Municipal Comparative Analysis (Reddy, 2016)

	Ethekwini		Msunduzi		Newcastle	
Waste Fraction	Emission (MTCO2EQ)	% Emission contribution	Emission (MTCO2EQ)	% Emission contribution	Emission (MTCO2EQ)	% Emission contribution
newspaper	-2339	1.8	-1433	7.1	-84	3.3
general mixed paper (CWM)	-5413	4.1	-1053	5.3	-448	17.8
scrap boxes and cardboard (K4)	-15532	11.7	-697	3.5	-280	11.1
low density polyethylene (LDPE)	-4518	3.4	-281	1.4	-84	3.3
high density polyethelene (HDPE)	-2093	1.6	-244	1.2	-84	3.3
Polyethelene terephthalate (PET)	-2367	1.8	-434	2.2	-56	2.2
polypropylene (PP)	-8271	6.2	-369	1.8	-84	3.3
polyvinyl chloride (PVC)	0	0.0	-414	2.1	-28	1.1
polystyrene (PS)	0	0.0	-123	0.6	-28	1.1
glass	-10408	7.8	-1549	7.7	-336	13.3
steel cans/tin	-4995	3.8	-900	4.5	-84	3.3
aluminium cans	0	0.0	-181	0.9	-84	3.3
biogenic food waste	-40737	30.6	-7259	36.2	-308	12.2
garden refuse green	0	0.0	-160	0.8	-112	4.4
garden refuse wood	-25984	19.5	-4	0.0	-112	4.4
other	-21696	16.3	-6478	32.3	-588	23.4
Transport Emissions	11329	-8.5	1532	-7.6	283	-11.2
TOTAL	-133025	100.0	-20046	100.0	-2516	100.0

Scenario 3: Biogenic and food waste are still the highest contributors to GHG emissions in eThekwini and Msunduzi, however recycling efforts in Newcastle municipality shows significant reduction of emissions.

Table 4.3: Scenario 3 Municipal Comparative Analysis (Reddy, 2016)

	Ethekwini		Msunduzi		Newcastle	
Waste Fraction	Emission (MTCO2EQ)	% Emission contribution	Emission (MTCO2EQ)	% Emission contribution	Emission (MTCO2EQ)	% Emission contribution
newspaper	-15860	5.5	-7247	14.7	-535	4.5
general mixed paper (CWM)	-14467	5.0	-2289	4.7	-1144	9.5
scrap boxes and cardboard (K4)	-38398	13.3	-1417	2.9	-663	5.5
low density polyethylene (LDPE)	-17260	6.0	-836	1.7	-304	2.5
high density polyethelene (HDPE)	-6840	2.4	-632	1.3	-261	2.2
Polyethelene terephthalate (PET)	-18130	6.3	-2460	5.0	-402	3.3
polypropylene (PP)	-29313	10.1	-1028	2.1	-283	2.4
polyvinyl chloride (PVC)	0	0.0	-1373	2.8	-114	0.9
polystyrene (PS)	0	0.0	-407	0.8	-114	0.9
glass	-16386	5.7	-2174	4.4	-515	4.3
steel cans/tin	-53115	18.4	-6983	14.2	-836	7.0
aluminium cans	0	0.0	-9698	19.7	-5924	49.3
biogenic food waste	-40737	14.1	-7259	14.8	-308	2.6
garden refuse green	0	0.0	-160	0.3	-112	0.9
garden refuse wood	-25984	9.0	-4	0.0	-112	0.9
other	-21696	7.5	-6478	13.2	-588	4.9
Transport Emissions	8826	-3.1	1314	-2.7	193	-1.6
TOTAL	-289359	100.0	-49130	100.0	-12021	100.0

Scenario 4: The use of AD facilities along with recycling and LFGTE in scenario 4 results in the greatest percentage of emission reductions from the highest contributing factor which is biogenic food waste in eThekwini and Msunduzi Municipality. In Newcastle the recycling of aluminium cans could result in the greatest emissions saved.

Table 4.4: Scenario 4 Municipal Comparative Analysis (Reddy, 2016)

	Ethekwini		Msunduzi		Newcastle	
Waste Fraction	Emission (MTCO2EQ)	% Emission contribution	Emission (MTCO2EQ)	% Emission contribution	Emission (MTCO2EQ)	% Emission contribution
newspaper	-15860	4.2	-7247	11.3	-535	4.2
general mixed paper (CWM)	-14467	3.9	-2289	3.6	-1144	9.0
scrap boxes and cardboard (K4)	-38398	10.3	-1417	2.2	-663	5.2
low density polyethylene (LDPE)	-17260	4.6	-836	1.3	-304	2.4
high density polyethelene (HDPE)	-6840	1.8	-632	1.0	-261	2.1
Polyethelene terephthalate (PET)	-18130	4.8	-2460	3.8	-402	3.2
polypropylene (PP)	-29313	7.8	-1028	1.6	-283	2.2
polyvinyl chloride (PVC)	0	0.0	-1373	2.1	-114	0.9
polystyrene (PS)	0	0.0	-407	0.6	-114	0.9
glass	-16386	4.4	-2174	3.4	-515	4.1
steel cans/tin	-53115	14.2	-6983	10.9	-836	6.6
aluminium cans	0	0.0	-9698	15.1	-5924	46.8
biogenic food waste	-122617	32.7	-21850	34.0	-927	7.3
garden refuse green	0	0.0	-160	0.2	-112	0.9
garden refuse wood	-25984	6.9	-4	0.0	-112	0.9
other	-21696	5.8	-6478	10.1	-588	4.6
Transport Emissions	5629	-1.5	799	-1.2	162	-1.3
TOTAL	-374436	100.0	-64236	100.0	-12671	100.0

Scenario 5: In scenario 5 the recycling of steel and aluminium produce the greatest GHG emission reduction across all three case study municipalities. However, there is an increase in emissions contributions due to the composting emission factor.

Table 4.5: Scenario 5 Municipal Comparative Analysis (Reddy, 2016)

	Ethekwini		Msunduzi		Newcastle	
Waste Fraction	Emission (MTCO2EQ)	% Emission contribution	Emission (MTCO2EQ)	% Emission contribution	Emission (MTCO2EQ)	% Emission contribution
newspaper	-15860	11.1	-7247	22.1	-535	4.9
general mixed paper (CWM)	-14467	10.2	-2289	7.0	-1144	10.5
scrap boxes and cardboard (K4)	-38398	27.0	-1417	4.3	-663	6.1
low density polyethylene (LDPE)	-17260	12.1	-836	2.6	-304	2.8
high density polyethelene (HDPE)	-6840	4.8	-632	1.9	-261	2.4
Polyethelene terephthalate (PET)	-18130	12.7	-2460	7.5	-402	3.7
polypropylene (PP)	-29313	20.6	-1028	3.1	-283	2.6
polyvinyl chloride (PVC)	0	0.0	-1373	4.2	-114	1.0
polystyrene (PS)	0	0.0	-407	1.2	-114	1.0
glass	-16386	11.5	-2174	6.6	-515	4.7
steel cans/tin	-53115	37.3	-6983	21.3	-836	7.7
aluminium cans	0	0.0	-9698	29.6	-5924	54.5
biogenic food waste	52154	-36.6	9294	-28.4	394	-3.6
garden refuse green	0	0.0	204	-0.6	143	-1.3
garden refuse wood	33266	-23.4	6	0.0	143	-1.3
other	-21696	15.2	-6478	19.8	-588	5.4
Transport Emissions	3590	-2.5	787	-2.4	139	-1.3
TOTAL	-142454	100.0	-32730	100.0	-10863	100.0

4.8 Landfill Space Savings

In addition to determining the amount of GHG emission reductions that could occur in each scenario, the WROSE model assists in determining the amount of landfill space savings that the municipality can gain from the implementation of alternative waste treatment. This would aid the municipality in extending the current life span of the landfills.

Using the scenarios set in the WROSE model, three of the five scenarios are applicable for the calculation of landfill space saving.

Table 4.6: Landfill diversion rates (Reddy, 2016)

Methodology	Landfill Diversion Rate (%)			
	Scenario 3A	Scenario 3B	Scenario 4	Scenario 5
EThekwini Metro Municipality	10	22	58	68
Msunduzi Local Municipality	4	14	57	49
Newcastle Local Municipality	14	32	46	51

Scenario 3 diverted only recyclables while scenario 4 and 5 diverted recyclables and the biogenic fraction of waste hence the higher rate of waste diversion from landfill.

4.9 Economic Analysis

A detailed economic analysis was conducted for each municipality based on the scenarios available. The outcome of which determined that scenario 3 which includes a MRF is the most economically feasible scenario for the eThekwini municipality. The landfill gas to electricity systems is the most economically feasible for Msunduzi as well as Newcastle Municipality. Due to the outcome of the high capital cost of the implementation of the AD facility it was the least favoured option economically.

It is important to note that this economic analysis was conducted using 2015 Dollar to Rand rates. Recent fluctuations in the exchange rate along with the cost of technologies will affect the cost estimations of each scenario.

4.10 Chapter Summary

In a study conducted by Reddy (2016) the WROSE model was applied on 3 case study municipalities. The outcome of the study was to determine both environmentally and economically the most applicable waste management scenario for each municipality. While environmentally scenarios 3 and 4 provided the greatest GHG reduction and landfill space saving rates, economically scenarios 1 and 3 made the most financially sound options for each municipality. The outcome of the study above will serve as a baseline assessment for the most favoured scenarios in the WROSE model. A comparative analysis will be conducted in the following chapters with the introduction of socio-economic and institutional indicators.

Chapter 5: Results and Discussion

5.1 Introduction

This chapter presents the results of the application of the advancements of the WROSE model on the case study municipalities. The results of the social indicator evaluation are presented as well as the case study results for each of the individual scenarios analysis per municipality.

1. Social Indicator evaluation matrix
2. Application of socio-economic and institutional indicators per municipality
3. Comparative analysis of each scenario based on the baseline case study results and the application of the advanced WROSE model.

The results aim to provide an understanding of the implications of socio-economic and institutional indicators on the decision making process. The discussion aims to note any changes in the outcome of results through the addition of all four sustainability indicators in the decision making process.

5.2 Social Indicator Evaluation Matrix

In previous discussions in the methodology chapter, a social indicator evaluation matrix was developed to determine which social indicators will be included in the advancement of the WROSE model. The indicator evaluation matrix was distributed to specialists in the field of waste management. This included government officials, nationally, provincially and locally, NGO's, industry bodies and researchers in academia and industry. The table below is a representation of the results of the survey conducted.

Table 5.1: Social Indicator Evaluation Results

Social Indicators	**Relevance**	**Transparency/ User friendly**	**Policy relevant**	**Data Availability**	**Data Quality**	**Measurable**	**TOTAL**
Job creation	2.7	2.5	3.0	2.2	2.0	2.6	15
Health risks	2.9	2.7	2.9	2.4	2.3	2.2	15.3
Public acceptance and social perception	2.3	2.4	2.3	2.6	2.3	2.0	13.9
Cleanliness and smell	2.2	2.3	2.8	2.0	1.8	2.4	13.4
Public participation required	2.3	2.7	2.7	2.0	2.0	2.3	14

The indicator with the highest rating is health risks, followed by job creation and public participation. Public acceptance and social perception scored the second lowest with cleanliness and smell scoring the lowest overall. Based on this assessment job creation, health risks and public participation were chosen as the social indicators for this stage of advancement of the WROSE model.

5.3 Application of the advanced WROSE model

In the development and testing of phase 1 the WROSE model, the model was applied on three case study municipalities. The result of this application provided insight on the potential for implementation of alternative waste management strategies to the disposal of waste to landfill as discussed in chapter 4. For the purpose of this study, the introduction of socio-economic and institutional indicators are applied to the same case studies in order to provide a comparative scenario analysis, the outcome of which produced the following results:

5.3.1 eThekwini Municipality

The scenario analysis conducted in the initial application of the WROSE model determined that the disposal of waste to landfill resulted in the highest GHG emission due to the volume and degradation of the biogenic waste fraction for the eThekwini Municipality. The volumes of waste gathered from the waste characterization study explained in the previous chapter was divided into daily quantities and used to determine the job creation potential for each scenario.

It is important to note that in the initial case study application of WROSE, the waste volumes used for the study was the total volume of waste for the entire eThekwini municipality as a whole and not per landfill facility. Therefore, the waste volume per day is higher than anticipated. The total waste volume extracted from the case study is 998987.6 tonnes of waste in the year 2015 as per figure 4.4 in chapter 4. This figure was then divided to provide daily waste volume estimates using the formula below.

$$\frac{998987.6\ tons}{365\ days} = 2736.9\ tons\ of\ waste\ per\ day$$

Equation 1: Calculation of daily waste volumes for the eThekwini Municipality

This figure of 2736.9 tons was then input into the WROSE model to determine the job creation potential for the eThekwini Municipality. The figure below outlines the total percentages of waste per fraction that is used for each scenario.

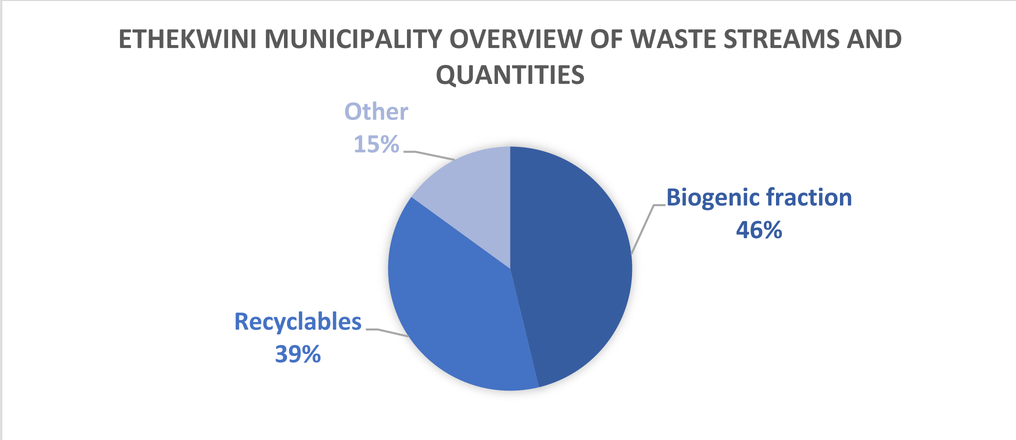


Figure 5.1: eThekwini Municipality overall waste streams and quantities

The overall fraction of recyclables in the eThekwini municipality is 39%. The biogenic fraction of waste is the highest fraction at 46% and the residual fraction as per the waste stream analysis is 15%. The total daily volume of waste is divided into the fractions depicted in the figure above to determine job creation figures. A detailed discussion of the results per scenario are presented below. The results of the application of each of the scenarios will follow a similar process. Figure 5.2 below depicts the application of the phase 1 development process. the outcome of phase 1 will be discussed following which the application of phase 2 will be conducted.

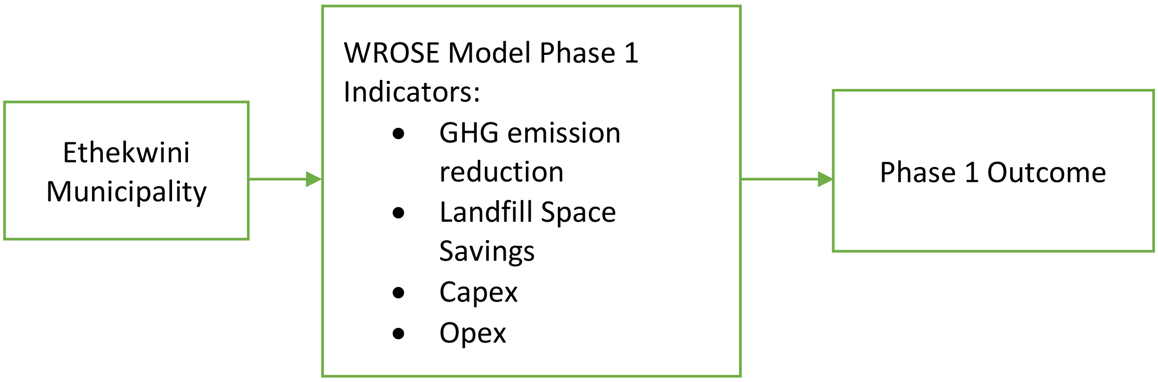


Figure 5.2: Phase 1 of WROSE case study application for eThekwini Municipality

The application of phase 2 of the WROSE model indicators will follow the process in Figure 5.3 below, thereafter a comparative analysis of the results will be conducted.

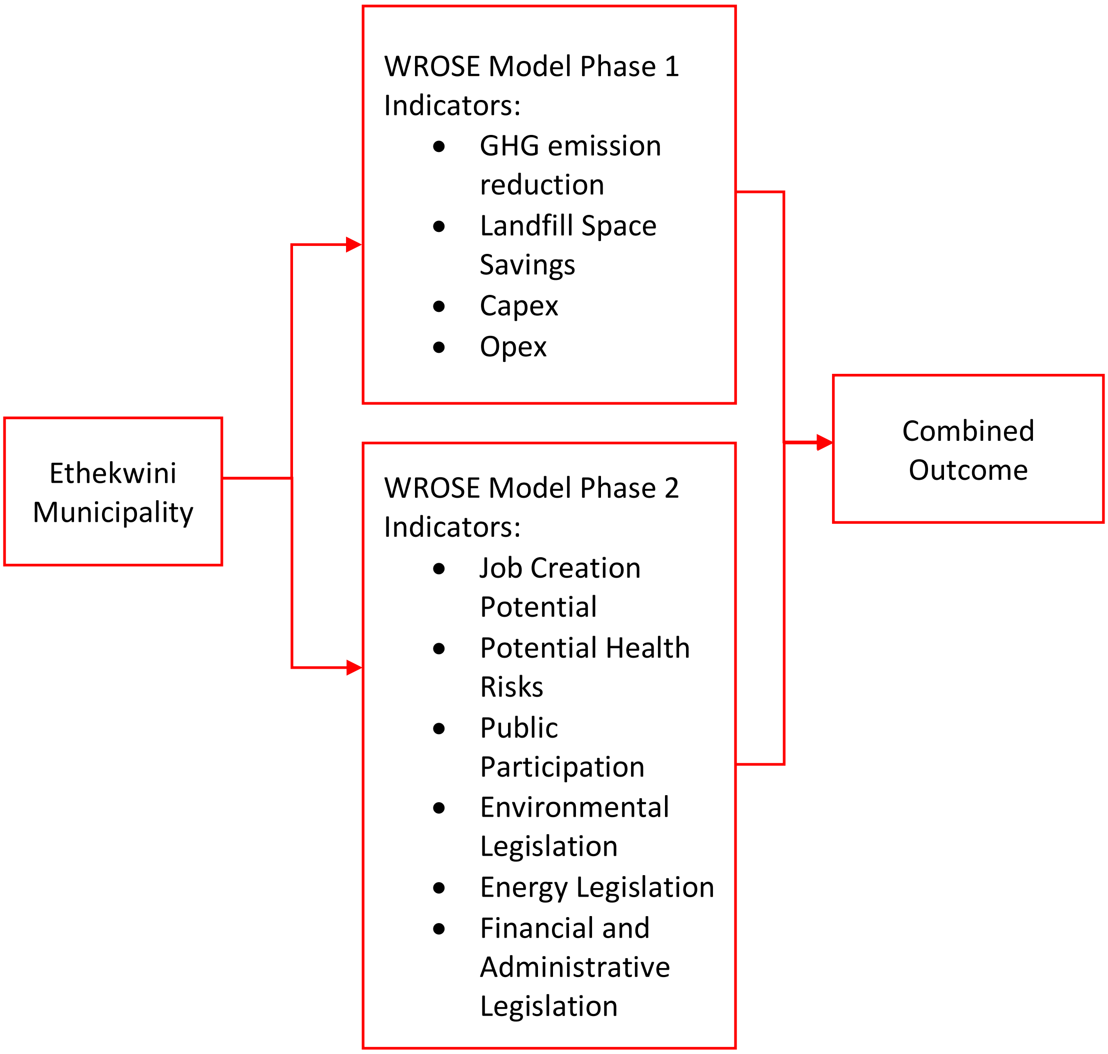


Figure 5.3: Phase 2 of WROSE Model case study application for eThekwini Municipality

5.3.1.1 Scenario 1

Table 5.2 below illustrates the outcome of the application of the socio-economic indicators developed during the phase 2 of the WROSE model. The daily waste volume of 2736.9 tons was extrapolated as depicted in Equation 1. above to determine the job creation potential of scenario 1 on the eThekwini Municipality. In addition to the number of potential jobs to be created through the disposal of waste to landfill, the health risks associated both directly and indirectly are outlined as well as the areas in which public participation will be incorporated

Table 5.2: Scenario 1- Application of socio-economic indicators on eThekwini Municipality

WASTE RESOURCE OPTIMIZATION AND SCENARIO EVALUATION MODEL: SOCIO - ECONOMIC INDICATORS						
	WASTE QUANTITY (tons per day) /MW OF ELECTRICITY	**NO. OF JOBS**	**DIRECT HEALTH RISKS**	**INDIRECT HEALTH RISKS**	**PUBLIC PARTICIPATION IN WASTE MANAGEMENT PROCESS**	**PUBLIC PARTICIPATION IN EIA PROCESS**
SCENARIO 1: LANDFILLING	2736.9	98.5	Respiratory Issues, Fatigue, Headaches, Influenza type Symptoms	Cancer, Low Birth Weight, Birth Defects	No public participation necessary	Public participation process required

Table 5.3 below outlines the institutional implications of scenario 1 of the WROSE model on the eThekwini municipality, taking into consideration licence and regulatory requirements commonly veiwed as barries to project development. In the implementation of scenario 1, all of the legislation outlined below will be triggerred.

Table 5.3: Scenario 1- Application of institutional indicators on eThekwini Municipality

SCENARIOS	WASTE STREAMS	ENVIRONMENTAL LEGISLATION	ENERGY LEGISLATION	FINANCIAL & ADMINISTRATIVE REGULATION	LICENCE REQUIRED	ENVIRONMENTAL AUTHORISATION, EIA or BA REQUIRED	APPROXIMATE COST AND TIME FRAME FOR EIA AND BA
SCENARIO 1: DISPOSAL OF UNSAORTED UNTREATED MSW TO LANDFILL	General MSW	The Constitution	N/A	Occupational Health and Safety Act 1993			BA: >R80 000,00 7-9 Months; EIA: >R150 000,00 9-14 Months
		The Environmental Conservation Act	N/A	Municipal Systems Act 2000		BA listing Notice and triggers	
		National Environmental Management Act	N/A	Municipal Structures Act		EIA listing Notice and triggers	
		National Environmental Management Waste Act	N/A	Municipal Finance Management Act	Atmospheric Emissions Licence		
		National Environmental Management: Air Quality Act	N/A	Supply Chain Management	Waste Licence (For Storage, Treatment, Disposal and Processing of waste)		
		Atmospheric Pollution Prevention Act	N/A	Asset Management			
		National Integrated Coastal Management Act	N/A	Generally Recognised Accounting Practices 17 & 19)			

5.3.1.1 a) Phase 1 Outcome

- Environmental

Based on the initial case study outcome, the GHG emissions of scenario 1 is substantially higher than that of the other scenarios as depicted in figure 4.4 in the previous chapter. In addition, the landfill diversion rate and landfill space savings rates do not apply to this scenario as unsorted, untreated MSW is disposed of into landfill. Economically the application of scenario 1 was the most financially viable for the eThekwini Municipality.

b) WROSE model phase 2 outcome

- Socio-economic Outcome

In the application of scenario 1 of the advanced WROSE model, the results determined that a total of 98 potential jobs will be created across the eThekwini Municipality. This results in an average of 24.6 employees in each of the 4 facility within the municipality. The health risk associated with the disposal of waste to landfill results in poor quality of health for onsite staff workers as direct impacts. These impacts include fatigue, headache and influenza type symptoms. The indirect impacts of air pollution for the local communities include low birth rates, potential birth defects and cancer.
Public participation is required for the EIA process. However due to the WROSE model incorporating the collection and disposal of unsorted, untreated MSW, no public participation is required at a household level.

- Institutional Outcomes

The development and operation of a landfill facility triggers various legislation. At a municipal level a section 78 of the Municipal systems act is triggered along with the need for a Waste licence and an Atmospheric emissions licence. This results the need for a full environmental impact assessment (EIA process).
The application of the institutional advancements in the WROSE model aids the municipality in the planning for additional cost and time factors in the implementation of scenario 1.

5.3.1.2 Scenario 2

Table 5.4 below illustrates the outcome of the application of the socio-economic indicators developed during the phase 2 of the WROSE model. The eThekwini Municipalities landfill gas extraction project is for total of 6MW across the municipality, this figure was extracted from the IWMP for the municipality and input into the WROSE model for determining the job creation potential for scenario 2. In addition to the number of potential jobs to be created through the extraction of landfill gas, the health risks associated both directly and indirectly are outlined as well as the areas in which public participation will be incorporated

Table 5.4: Scenario 2- Application of socio-economic indicators on eThekwini Municipality

WASTE RESOURCE OPTIMIZATION AND SCENARIO EVALUATION MODEL: SOCIO - ECONOMIC INDICATORS						
	WASTE QUANTITY (tons per day) /MW OF ELECTRICITY	**NO. OF JOBS**	**DIRECT HEALTH RISKS**	**INDIRECT HEALTH RISKS**	**PUBLIC PARTICIPATION IN WASTE MANAGEMENT PROCESS**	**PUBLIC PARTICIPATION IN EIA PROCESS**
SCENARIO 2: LANDFILL WITH GAS RECOVERY /ELEC GEN	6	12	Wheezing, nausea, headaches	Asthma, respiratory issues	No public participation necessary	Public participation process required

Table 5.4 below outlines the institutional implications of scenario 2 of the WROSE model on the eThekwini municipality, taking into consideration licence and regulatory requirements commonly veiwed as barriers to project development. In the implementation of scenario 2 for the development of a landfill gas extraction project, all of the legislation outlined below will be triggerred.

Table 5.5: Scenario 2- Application of institutional indicators on eThekwini Municipality

SCENARIOS	WASTE STREAMS	ENVIRONMENTAL LEGISLATION	ENERGY LEGISLATION	FINANCIAL & ADMINISTRATIVE REGULATION	LICENCE REQUIRED	ENVIRONMENTAL AUTHORISATION, EIA or BA REQUIRED	APPROXIMATE COST AND TIME FRAME FOR EIA AND BA
SCENARIO 2: LANDFILL GAS EXTRACTION	General Household Waste, Organics,	The Constitution	National Energy Act	Occupational Health and Safety Act 1993			BA: >R80 000,00 7-9 Months; EIA: >R150 000,00 9-14 Months
		The Environmental Conservation Act	The Gas Act 2001	Municipal Systems Act 2000	Licence to manufacture biofuels	BA listing Notice and triggers	
		National Environmental Management Act	Gas Regulator Levies Act 2002	Municipal Structures Act	Petroleum manufacturing licence (Prerequisite for Licence to manufacture biofuels)	EIA listing Notice and triggers	
		National Environmental Management Waste Act	REIPPP	Municipal Finance Management Act with Particular Reference to:			
		National Environmental Management: Air Quality Act	South African Biofuels Industrial Strategy	Supply Chain Management	Atmospheric Emissions Licence		
		Atmospheric Pollution Prevention Act	White Paper on Renewable Energy	Asset Management	Waste Licence (For Storage, Treatment, Disposal and Processing of waste)		
		National Integrated Coastal Management Act	Electricity Regulation Act 2006	Generally Recognised Accounting Practices 17 & 19)			

5.3.1.2. a) Phase 1 outcome

- Environmental

The initial simulations derived from the WROSE model's development in phase 1 identified significant GHG emission reductions in the implementation of a LFGTE facility. Landfill space savings and landfill diversion rates are not applicable in scenario 2 as waste is directly disposed of into landfill. The implementation of LFGTE requires higher capital and operational costs than that of landfill. Should the municipality use the LFG to generate electricity, there is potential for long term returns on investment through the reduction of electricity costs.

b) WROSE Model Phase 2 Outcome

- Socio-economic

In the implementation of scenario 2, it can be determined that 12 additional jobs will be created when implementing a LFGTE project of up to 6MW. Seeing as the implementation of LFGTE still requires the disposal of unsorted, untreated waste to a landfill facility, the 98 jobs created by the municipality for the disposal of waste to landfill will still be created, in addition to the 12 more jobs when implementing and operating a LFGTE project bringing the total job creation up to 110.

There are some health issues associated with this type of waste treatment, however these are less severe than the impacts created by the disposal of waste to landfill. Health risks directly to the staff involved include issues such as wheezing, nausea and headache. However, the indirect risk are significantly reduced through the implementation of LFGTE projects in which methane is extracted and utilized for the generation of electricity. Indirect impacts on health include asthma and respiratory issues.

A public participation process is required for the EIA process as an EIA report is required for the application of an atmospheric emissions licence and a waste licence. However public participation will not be required for the separation of waste at the source as the models assesses the disposal of unsorted untreated MSW to landfill.

- Institutional Indicators

In implementing scenario 2 the municipality will be required to undergo a section 78 process. A waste licence and an atmospheric emissions licence will also be required. This will require a full EIA process. Should the municipality choose to manufacture biofuels out of the landfill gas extracted then a Petroleum Manufacturing licence will also be required by the municipality.

5.3.1.3 Scenario 3

Table 5.6 below illustrates the outcome of the application of the socio-economic indicators developed during the phase 2 of the WROSE model. The recycling figure of 1061.4 tons was extracted based on the percentage of recyclables identified in the waste stream analysis as seen figure 5.1. In addition to the number of potential jobs to be created through the development of a MRF, the health risks associated both directly and indirectly are outlined as well as the areas in which public participation will be incorporated

Table 5.6: Scenario 3- Application of socio-economic indicators on eThekwini Municipality

WASTE RESOURCE OPTIMIZATION AND SCENARIO EVALUATION MODEL: SOCIO - ECONOMIC INDICATORS						
	WASTE QUANTITY (tons per day) /MW OF ELECTRICITY	**NO. OF JOBS**	**DIRECT HEALTH RISKS**	**INDIRECT HEALTH RISKS**	**PUBLIC PARTICIPATION IN WASTE MANAGEMENT PROCESS**	**PUBLIC PARTICIPATION IN EIA PROCESS**
SCENARIO 3: RECYCLING	1061.4	74.3	Respiratory issues, influenza type symptoms, nausea, headache, tiredness	Asthma, respiratory issues	No public participation necessary due to separation at MRF	Public participation process required

Table 5.7 below outlines the institutional implications of scenario 3 of the WROSE model on the eThekwini municipality, taking into consideration licence and regulatory requirements commonly veiwed as barriers to project development. In the implementation of scenario 3 for the development of a recycling facility, energy leglsation was not considered as waste to energy is not included in scanerio 3, however all other releavant requirements were incorporated.

Table 5.7: Scenario 3- Application of institutional indicators on eThekwini Municipality

SCENARIOS	WASTE STREAMS	ENVIRONMENTAL LEGISLATION	ENERGY LEGISLATION	FINANCIAL & ADMINISTRATIVE REGULATION	LICENCE REQUIRED	ENVIRONMENTAL AUTHORISATION, EIA or BA REQUIRED	APPROXIMATE COST AND TIME FRAME FOR EIA AND BA
SCENARIO 3: RECYCLING	Washing/Chipping/Crushing/Grinding of Recyclable Plastic, Paper, Metals, Glass, Builders Rubble	The Constitution		Occupational Health and Safety Act 1993			BA: >R80 000,00 7-9 Months; EIA: >R150 000,00 9-14 Months
		The Environmental Conservation Act		Municipal Systems Act 2000		BA listing Notice and triggers	
		National Environmental Management Act		Municipal Structures Act		EIA listing Notice and triggers	
		National Environmental Management Waste Act		Municipal Finance Management Act with Particular Reference to:	Waste Licence (For Storage, Treatment, Disposal and Processing of waste)		
		The Water Act		Supply Chain Management			
		Atmospheric Pollution Prevention Act		Asset Management			
		National Integrated Coastal Management Act		Generally Recognised Accounting Practices 17 & 19)			

5.3.1.3 a) Phase 1 Outcome

- Environmental

The outcome of scenario 3 proposes higher GHG emissions reductions as opposed to scenario 1 and 2 as seen in figure 4.4. However as depicted in the case study, biogenic food waste is one of the larger contributors to GHG emissions in the eThekwini Municipality. The diversion of waste from landfill can be achieved using scenario 3 as recyclables are extracted and resold. This ultimately reduces the volume of waste disposed of into landfill thereby extending the lifespan of the landfill facility.

b) WROSE Model Phase 1 Outcome

- Social

Scenario 3 of the WROSE model includes the mechanical pre-treatment of MSW, which involves the extraction of recyclable materials for the purpose of resale. For the purpose of this scenario's application, the recyclable fraction of 39% of the total waste volume as seen in figure 5.1 was used. Upon application of the advancements of the WROSE model indicators, it can be determined that 74.3 jobs will be created in the sorting of MSW. Scenario 3 has the highest socio-economic impact of all other scenarios with the largest number of jobs to be created through the MRF as this method of waste treatment is more labour intensive than the previous 2 scenarios.

In the implementation of scenario 3 there is the risk of both direct and indirect health issues associated with the separation of recyclables at a MRF. Direct health risks for onsite staff include respiratory issues (wheezing and asthma), influenza type symptoms, nausea, headache and tiredness. This is due to direct exposure to airborne pathogens in the separation process, therefore the use of protective face masks, gloves and clothing are required for onsite staff to reduce exposure to associated health risks. Indirect health risks include asthma and respiratory issues that affect the residents and general public in surrounding areas.

Public participation is not required for scenario 3 as waste is not separated at source. Recyclables are extracted via a MRF and sold to recycling companies. However, a public participation process is required for the EIA process when applying for a waste management licence.

- Institutional

The implementation of scenario 3 will require a waste licence for the storage, treatment and disposal of waste. An atmospheric emissions licence may also be required. In order to apply for a waste licence a full EIA is required based on the volume of waste. The average period for conducting a full EIA is 9 to 14 months with potential for delays should the public participation process raise queries. Seeing as scenario 3 does not include ant waste to energy options, no energy legislation is applicable to this scenario.

5.3.1.4 Scenario 4

Table 5.8 below illustrates the outcome of the application of the socio-economic indicators developed during the phase 2 of the WROSE model. The eThekwini Municipality assessed the feasibility of an 8MW AD facility across the municipality this figure was used to calculate the job creation potential of scenario 4. In addition to the number of potential jobs to be created through the development of an AD facility, the health risks associated both directly and indirectly are outlined as well as the areas in which public participation will be incorporated

Table 5.8: Scenario 4- Application of socio-economic indicators on eThekwini Municipality

WASTE RESOURCE OPTIMIZATION AND SCENARIO EVALUATION MODEL: SOCIO - ECONOMIC INDICATORS						
	WASTE QUANTITY (tons per day) /MW OF ELECTRICITY	NO. OF JOBS	DIRECT HEALTH RISKS	INDIRECT HEALTH RISKS	PUBLIC PARTICIPATION IN WASTE MANAGEMENT PROCESS	PUBLIC PARTICIPATION IN EIA PROCESS
SCENARIO 4: ANAEROBIC DIGESTION	8	8	Tiredness, headache, nausea	N/A	No public participation necessary due to separation at MRF	Public participation process required

Table 5.9 below outlines the institutional implications of scenario 4 of the WROSE model on the eThekwini municipality, taking into consideration licence and regulatory requirements commonly veiwed as barries to project development. In the implementation of scenario 4, all of the legislation identified in the table below are applicable in the development of an AD facility.

Table 5.9: Scenario 4- Application of institutional indicators on eThekwini Municipality

SCENARIOS	WASTE STREAMS	ENVIRONMENTAL LEGISLATION	ENERGY LEGISLATION	FINANCIAL & ADMINISTRATIVE REGULATION	LICENCE REQUIRED	ENVIRONMENTAL AUTHORISATION, EIA or BA REQUIRED	APPROXIMATE COST AND TIME FRAME FOR EIA AND BA
SCENARIO 4: ANAEROBIC DIGESTION	Organics, Abattoir Waste, Agricultural Waste, Sewage	occupational Health and Safety Act	National Energy Act	Municipal Structures Act		BA listing Notice and triggers	BA: >R80 000,00 7-9 Months; EIA: >R150 000,00 9-14 Months
		The Environmental Conservation Act	The Gas Act 2001	Occupational Health and Safety Act 1993	Petroleum manufacturing licence (Prerequisite for Licence to manufacture biofuels)	EIA listing Notice and triggers	
		National Environmental Management Act	Gas Regulator Levies Act 2002	Municipal Systems Act 2000			
		National Environmental Management Waste Act	REIPPP	Municipal Finance Management Act with Particular Reference to:			
		National Environmental Management: Air Quality Act	South African Biofuels Industrial Strategy	Supply Chain Management	Atmospheric Emissions License		
		Atmospheric Pollution Prevention Act	White Paper on Renewable Energy	Asset Management			
		National Waste Management Strategy	Electricity Regulation Act 2006	Generally Recognised Accounting Practices 17 & 19)			

5.3.1.4 a) Phase 1 Outcome

- Environmental

The implementation of scenario 4 included the use of mechanical pre-treatment, followed by the sale of recyclables and the transfer of biogenic fraction to an anaerobic digester with electricity production. The results of the implementation of scenario 4 provides the highest environmental benefit as it produces the highest GHG emission reduction potential as opposed to the previously assessed scenarios, along with the diversion of waste from landfill. The residual waste is disposed of into landfill with a LFGTE facility. However, scenario 4 is economically unfeasible due to the high capital and operating costs associated.

b) WROSE Model Phase 2 Outcome

- Social

Based on the application of the advanced WROSE model, the implementation of scenario 4 will result in 8 additional jobs being created at the AD facilities across 3 facilities. These 8 jobs are for a total of 8MW AD facilities across the municipality. This is in conjunction with the existing jobs created at the municipality for the disposal of residual waste to landfill, as well as the jobs created by the operation of the MRF. Therefore, there is potential for a total number of 189 jobs across the eThekwini municipality. Scenario 4 therefore has the capability for the highest socio-economic impact across the eThekwini municipality.

There are minimal direct health impacts in the implementation of the AD facility and scenario 4 as a whole as compared to the health impacts seen in the previous scenarios. These impacts are on the onsite staff operating and monitoring the facility. These impacts include tiredness, nausea and headaches from exposure to pathogens in the biogenic feedstock. Indirect impacts of AD are minimal as GHG emissions are reduced through the conversion of CH_4 to electricity. Therefore, GHG's are not released into the atmosphere as is the case with the disposal of waste to landfill.

Public participation is not required when implementing scenario 4 as there is no separation at source that will occur. Waste will be collected, unsorted and untreated from households and separated at a MRF. Public participation will be required in the EIA process when developing the AD facility.

- Institutional

The implementation of scenario 4 will result in the need for a section 78 process followed by the application for a waste licence and an atmospheric emissions licence. Should the methane extracted be used to produce biofuels, then a petroleum manufacturing licence will be required. In order to apply for a waste licence a full EIA is required based on the volume of waste. The average period for conducting a full EIA is 9 to 14 months with potential for delays should the public participation process raise queries.

5.3.1.5 Scenario 5

Table 5.10 below illustrates the outcome of the application of the socio-economic indicators developed during the phase 2 of the WROSE model. For the application of phase 2 of the model, the biogenic fraction of waste as seen in the waste characterization is considered for this scenario. In addition to the number of potential jobs to be created through the development of a composting facility, the health risks associated both directly and indirectly are outlined as well as the areas in which public participation will be incorporated

Table 5.10: Scenario 5- Application of socio-economic indicators on eThekwini Municipality

WASTE RESOURCE OPTIMIZATION AND SCENARIO EVALUATION MODEL: SOCIO - ECONOMIC INDICATORS						
	WASTE QUANTITY (tons per day) /MW OF ELECTRICITY	NO. OF JOBS	DIRECT HEALTH RISKS	INDIRECT HEALTH RISKS	PUBLIC PARTICIPATION IN WASTE MANAGEMENT PROCESS	PUBLIC PARTICIPATION IN EIA PROCESS
SCENARIO 5: ANAEROBIC COMPOSTING	1264.9	75.894	Fungal spores and bacteria causing Breathing problems, nausea	Fatigue and headaches	No public participation necessary due to separation at MRF	Public participation process required

Table 5.11 below outlines the institutional implications of scenario 5 of the WROSE model on the eThekwini municipality, taking into consideration licence and regulatory requirements that could be seen as barries to project development. In the implementation of scenario 5, all of the legislation identified in the table below are applicable in the development of an composting facility.

Table 5.11: Scenario 5- Application of institutional indicators on eThekwini Municipality

SCENARIOS	WASTE STREAMS	ENVIRONMENTAL LEGISLATION	ENERGY LEGISLATION	FINANCIAL & ADMINISTRATIVE REGULATION	LICENCE REQUIRED	ENVIRONMENTAL AUTHORISATION, EIA or BA REQUIRED	APPROXIMATE COST AND TIME FRAME FOR EIA AND BA
SCENARIO 5: COMPOSTING	Organics, Abattoir Waste, Agricultural Waste, Sewage	National Water Act (No. 36 of 1998)		Occupational Health and Safety Act 1993			BA: >R80 000,00 7-9 Months; EIA: >R150 000,00 9-14 Months
		National Waste Management Strategy		Municipal Systems Act 2000			
		National Waste Information Regulations		Municipal Structures Act		BA listing Notice and triggers	
		National Environmental Management Act		Municipal Finance Management Act with Particular Reference to:		EIA listing Notice and triggers	
		National Environmental Management Waste Act, (No. 59 of 2008)		Supply Chain Management	Waste Licence (For Storage, Treatment, Disposal and Processing of waste)		
		National Environmental Management: Air Quality Act		Asset Management			
		The Fertilizers, Farm Feeds, Agricultural Remedies and Stock Remedies Act		Generally Recognised Accounting Practices 17 & 19)			

5.3.1.5 a) Phase 1 Outcome

- Environmental

The outcome of scenario 5 of the WROSE model depicted significant GHG emission reduction as well as high rates of diversion of waste from landfill due to the extraction of the biogenic fraction. However, despite the high rate of GHG emissions reduction and landfill diversion, the GHG emission reduction is still lower than that of scenario 4. Due to lower technological requirements, scenario 5 was more economically viable than that of scenario 4, yet still more expensive than scenario 1.

b) WROSE Model Phase 2 Outcome

- Social

Upon application of the advanced WROSE model to scenario 5 using the volumes of the biogenic fraction of waste from figure 5.1, an additional 78.5 jobs will be created across the eThekwini municipality. This is due to the aerobic composting process being highly labour intensive. The total number of jobs created include the number of jobs in the disposal of residual waste to landfill, the additional jobs the LFGTE facility creates as well as the jobs created in the MRF. This bring the total jobs created in the eThekwini municipality up to 260.6. Therefore scenario 5 has the potential for creating the most employment when compared to scenarios 1 to 4.

There are various direct health risks associated with the aerobic composting of waste as opposed to the minimal risks associated in scenario 4, this includes exposure to fungal spores and bacteria that could result in respiratory disorders. Indirect effects of composting also exist such as the emissions of GHG's that could cause fatigue and headaches to nearby residents.

Due to there being no separation of waste at the source, no public participation is required for the extraction of recyclables from the biogenic fraction. A public participation process is required during the EIA process which will be used for the licence application process

- Institutional

In implementing scenario 5, no energy legislation is triggered. A section 78 process of the Municipal Finance Management Act is required as the first internal step for a Municipality, following the outcome of which may require municipal procurement and tender processes to then be carried out to appoint a service provider. An EIA process will be required for the application of a waste licence, due to the transportation, storage and handling of waste above a certain threshold. An atmospheric emissions licence may also be required during this process. The EIA process could cause project delays as the entire process spans from approximately 18 – 24 months.

5.3.1.6 eThekwini Municipality Summary

The eThekwini Municipality was initially evaluated in accordance with environmental, technical and economic indicators. The outcome of the model depicted that scenario 1 which is the disposal of unsorted, untreated MSW to landfill produces the highest GHG emissions into the atmosphere and is the most economically viable waste management option for the municipality Reddy (2016). The implementation of scenario 4 had the highest environmental benefit through the largest volume of GHG emission reduction overall as well as landfill diversion rates. However, the implementation of scenario 4 requires large upfront capital due to the implementation of the AD facility. Scenario 4, although the most environmentally beneficial is not economically viable for the eThekwini Municipality.

Upon application of the advancements of the WROSE model on the eThekwini Municipality the results depict that scenario 1 has the potential for the lease amount of jobs that could be created in the municipality. Scenario 1 also poses significant health risks to onsite staff as well as surrounding areas. Scenario 5 has the highest socio-economic benefit regarding job creation potential. In addition to the socio-economic benefits, as per the initial case study application, scenario 5 is also economically feasible for the municipality to implement with significant GHG emission reduction potential. Furthermore, no energy legislation is applicable to scenario 5 reducing the red tape that results in project delays over all. The figure below summarises the job creation potential across all 5 scenarios.

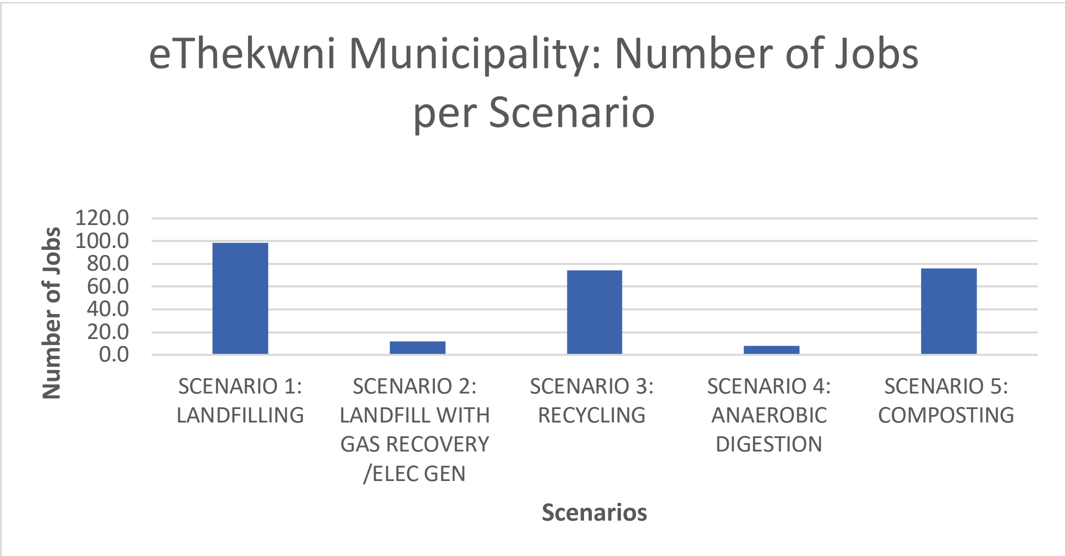


Figure 5.4: Summary of job creation potential per scenario for eThekwini Municipality

Figure 5.5 below outlines the statistical significance of Figure 5.4. The statistical analysis conducted was for job creation potential over a five year period. The maximum number of job creation potential is 98. The minimum number of jobs is 8, with a median of 74.

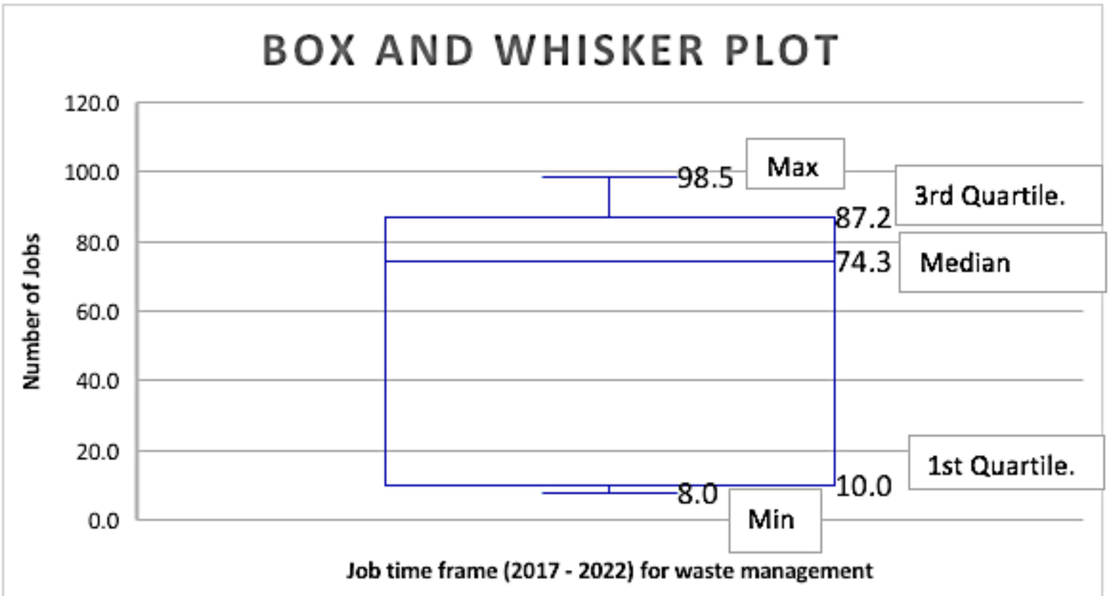


Figure 5.5: Statistical significance using the box and whisker plot

5.3.2 Msunduzi Municipality

The Msuduzi Municipality was the second case study municipality for which a scenario analysis was conducted using the WROSE model. Msunduzi Municipality is local municipality located west of Durban. As a typically South African local municipality the waste volume generated are significantly lower than that of a metropolitan municipality like eThekwini. The results produced by the scenario analysis depicted similar results to that of the eThekwini Municipality. Scenario 1, the disposal of waste to landfill produced the highest GHG emissions into the atmosphere whereas scenario 4 which included the mechanical pre-treatment of waste produced the highest GHG emission reduction potential.

The volume of waste for Msunduzi Municipality used in the initial application of the WROSE model is the total value of waste disposed of in the year 2015. In order to determine the job creation potential of the Msunduzi Municipality per scenario, a waste volume per day is required. Using the equation below, daily waste volumes were established.

$$\frac{149332\ tons\ of\ waste}{365\ days} = 409.1\ tons\ per\ day$$

Equation 2: Calculation of daily waste volumes for the Msunduzi Municipality

The total waste volume was extracted from figure 4.5 in the previous chapter was 149332 tons of waste with was in put into the equation above to determine daily waste volumes. The figure above of 409.1 tons was then input into the advanced WROSE model to determine the number of jobs per scenario. The figure below depicts the total waste volume in general fractions applicable to specific scenarios.

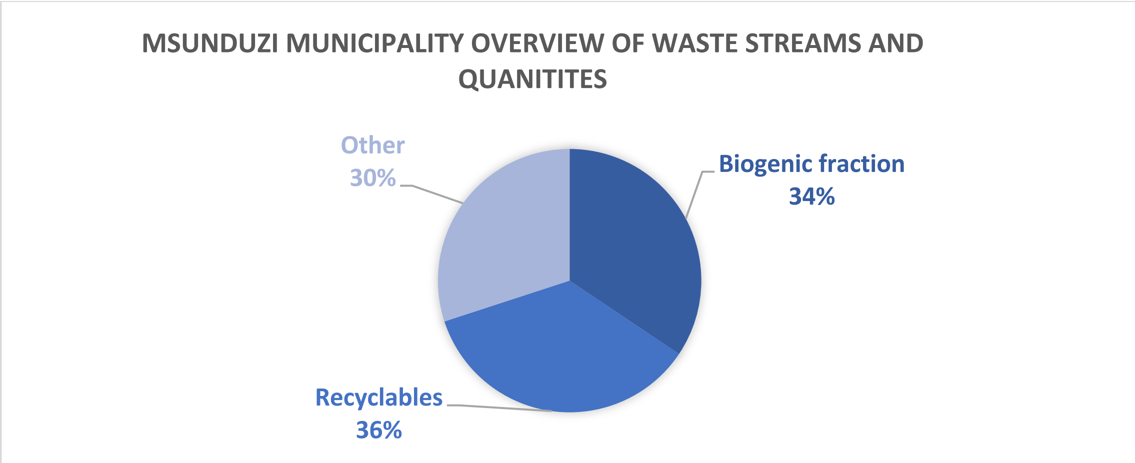


Figure 5.6: Msunduzi Municipality overall waste streams and quantities

Within the Msunduzi Municipality, the recyclable fraction of waste is 36%, the biogenic fraction is 34% and the residual fraction of waste is at 30%. The total daily volume of waste is divided into the fractions depicted in the figure above to determine job creation figures. A detailed discussion of the results per scenario are presented below. The results of the application of each of the scenarios will follow a similar process. Figure 5.6 below depicts the application of the phase 1 development process on the Msunduzi Municipality. The outcome of phase 1 will be discussed following which the application of phase 2 will be conducted.

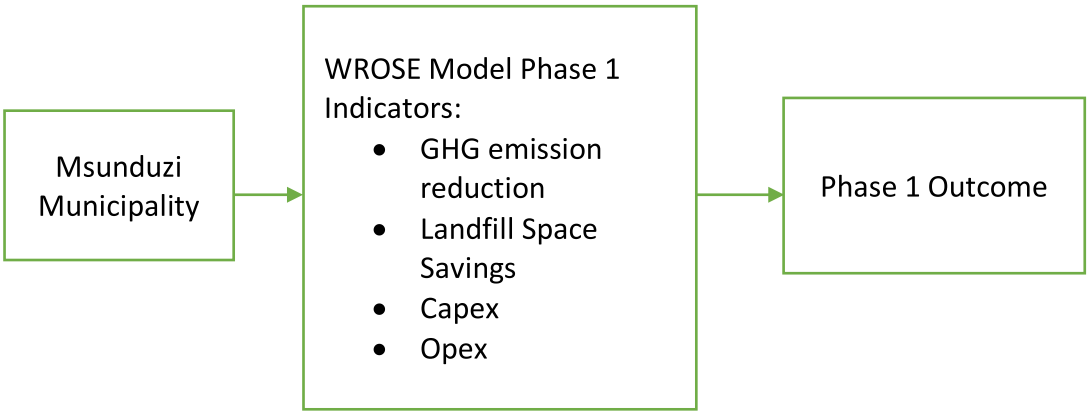


Figure 5.7: Phase 1 of WROSE case study application Msunduzi Municipality

The application of phase 2 of the WROSE model indicators will follow the process in Figure 5.7 below, thereafter a comparative analysis of the results will be conducted between the outcome of phase 1 and the results of phase 2.

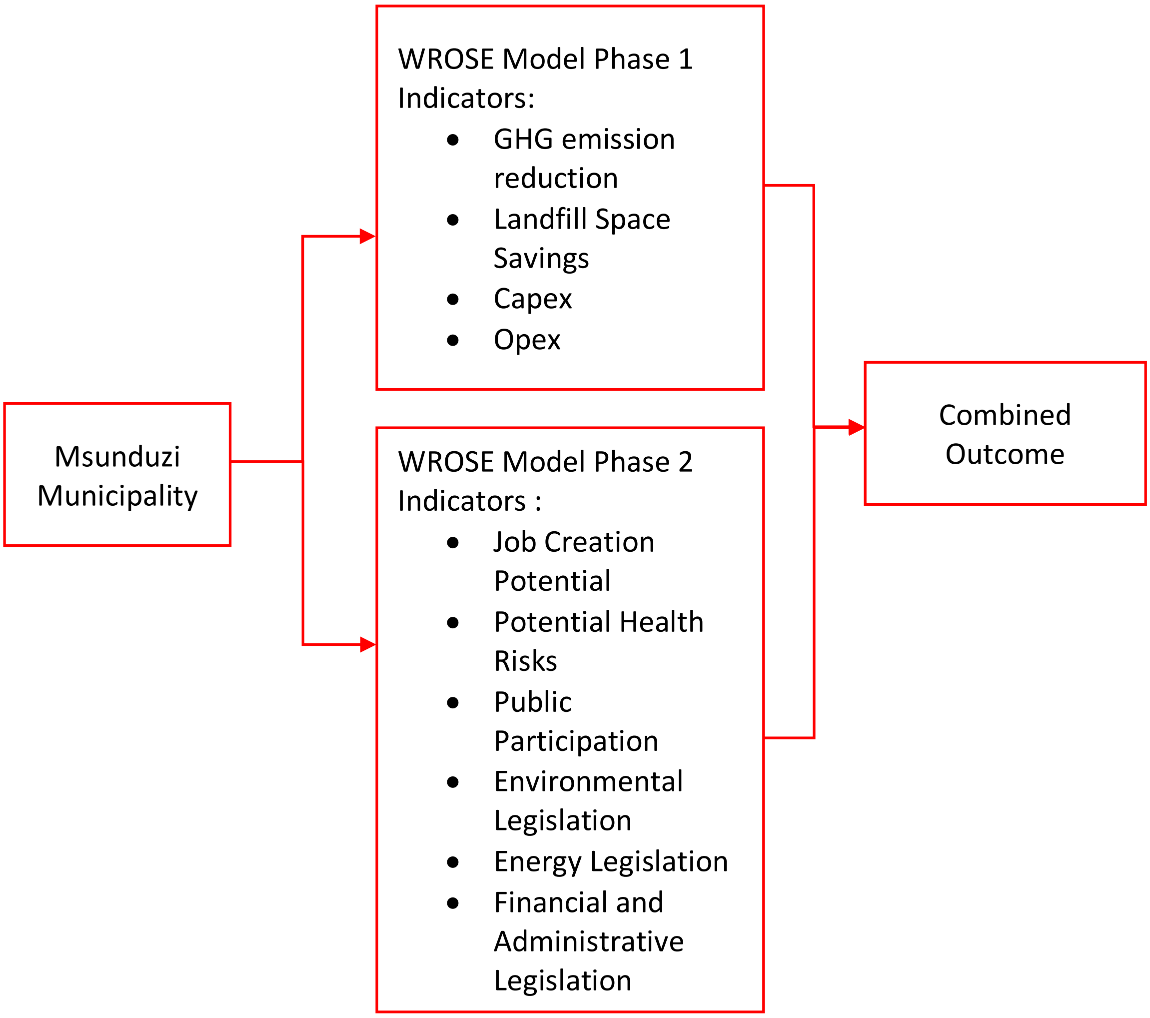


Figure 5.8: Phase 2 of WROSE Model case study application

5.3.2.1 Scenario 1

Table 5.12 below illustrates the outcome of the application of the socio-economic indicators developed during the phase 2 of the WROSE model. The daily waste volume of 409.1 tons was extrapolated as depicted in Equation 2. above to determine the job creation potential of scenario 1 on the Msunduzi Municipality. In addition to the number of potential jobs to be created through the disposal of waste to landfill, the health risks associated both directly and indirectly are outlined as well as the areas in which public participation will be incorporated

Table 5.12: Scenario 1- Application of socio-economic indicators on Msunduzi Municipality

WASTE RESOURCE OPTIMIZATION AND SCENARIO EVALUATION MODEL: SOCIO - ECONOMIC INDICATORS						
	WASTE QUANTITY (tons per day) /MW OF ELECTRICITY	**NO. OF JOBS**	**DIRECT HEALTH RISKS**	**INDIRECT HEALTH RISKS**	**PUBLIC PARTICIPATION IN WASTE MANAGEMENT PROCESS**	**PUBLIC PARTICIPATION IN EIA PROCESS**
SCENARIO 1: LANDFILLING	409.1	14.7	Respiratory Issues, Fatigue, Headaches, Influenza type Symptoms	Cancer, Low Birth Weight, Birth Defects	No public participation necessary	Public participation process required

Table 5.13 below outlines the institutional implications of scenario 1 of the WROSE model on the Msunduzi municipality, taking into consideration licence and regulatory requirements commonly veiwed as barries to project development. In the implementation of scenario 1, all of the legislation outlined below will be triggerred for the development of a landfill facility.

Table 5.13: Scenario 1- Application of institutional indicators on Msunduzi Municipality

SCENARIOS	WASTE STREAMS	ENVIRONMENTAL LEGISLATION	ENERGY LEGISLATION	FINANCIAL & ADMINISTRATIVE REGULATION	LICENCE REQUIRED	ENVIRONMENTAL AUTHORISATION, EIA or BA REQUIRED	APPROXIMATE COST AND TIME FRAME FOR EIA AND BA
SCENARIO 1: DISPOSAL OF UNSAORTED UNTREATED MSW TO LANDFILL	General MSW	The Constitution	N/A	Occupational Health and Safety Act 1993			BA: >R80 000,00 7-9 Months; EIA: >R150 000,00 9-14 Months
		The Environmental Conservation Act	N/A	Municipal Systems Act 2000		BA listing Notice and triggers	
		National Environmental Management Act	N/A	Municipal Structures Act		EIA listing Notice and triggers	
		National Environmental Management Waste Act	N/A	Municipal Finance Management Act	Atmospheric Emissions Licence		
		National Environmental Management: Air Quality Act	N/A	Supply Chain Management	Waste Licence (For Storage, Treatment, Disposal and Processing of waste)		
		Atmospheric Pollution Prevention Act	N/A	Asset Management			
		National Integrated Coastal Management Act	N/A	Generally Recognised Accounting Practices 17 & 19)			

5.3.2.1 a) Phase 1 Outcome

- Environmental

Upon conducting the scenario analysis on the Msunduzi Municipality, the results determined that the disposal of unsorted, untreated MSW to landfill resulted in the high GHG emissions into the atmosphere as seen in figure 4.5. No landfill diversion strategies and GHG emission reduction strategies result in scenario 1 being the least environmentally viable option. However, scenario 1 is the most economically viable option which also the currently used waste management in the Msunduzi Municipality.

b) WROSE Model Phase 2 Outcome

- *Social*

The application of the advanced WROSE model through the input of the daily waste volumes as shown in the figure above estimates the creation of 14.7 jobs at the landfill facility.

Various health risks are associated with the disposal of waste to landfill, both direct and indirect impacts are predicted for this scenario. Scenario 1 poses the risk of respiratory issues, fatigue and influenza type symptoms for onsite staff. Indirect health risks due to airborne pollutants results in cancer, low birth weight in infants and potential birth defects.

Due to there being no separation at source required, no public participation is required in this scenario. However, a public participation process will be required for the EIA process, should a new landfill facility be developed.

- Institutional

Various legislative requirements are triggered in the development phase of a landfill facility. A section 78 process of the Municipal Finance Management Act is required as the first internal step for a Municipality, following the outcome of which municipal procurement and tender processes must then be carried out to appoint a service provider. The service provider will then be required to conduct an EIA process in order to apply for the necessary waste and atmospheric emissions licence. No energy legislation is triggered as scenario 1 does not include waste to energy strategies.

5.3.2.2 Scenario 2

Table 5.14 below illustrates the outcome of the application of the socio-economic indicators developed during the phase 2 of the WROSE model. The Msunduzi Municipalities conducted a feasibility study for a landfill gas extraction project for the total of 1.5MW across the municipality, this figure was extracted from the IWMP for the municipality and input into the WROSE model for determining the job creation potential for scenario 2. In addition to the number of potential jobs to be created through the extraction of landfill gas, the health risks associated both directly and indirectly are outlined as well as the areas in which public participation will be incorporated

Table 5.14: Scenario 2- Application of socio-economic indicators on Msunduzi Municipality

WASTE RESOURCE OPTIMIZATION AND SCENARIO EVALUATION MODEL: SOCIO - ECONOMIC INDICATORS						
	WASTE QUANTITY (tons per day) /MW OF ELECTRICITY	NO. OF JOBS	DIRECT HEALTH RISKS	INDIRECT HEALTH RISKS	PUBLIC PARTICIPATION IN WASTE MANAGEMENT PROCESS	PUBLIC PARTICIPATION IN EIA PROCESS
SCENARIO 2: LANDFILL WITH GAS RECOVERY /ELEC GEN	1.5	3	Wheezing, nausea, headaches	Asthma, respiratory issues	No public participation necessary	Public participation process required

Table 5.15 below outlines the institutional implications of scenario 2 of the WROSE model on the Msunduzi Municipality, taking into consideration licence and regulatory requirements commonly veiwed as barries to project development. In the implementation of scenario 2, the disposal of waste to landfill with the extraction of landfill gas , all of the legislation outlined below will be triggerred.

Table 5.15: Scenario 2- Application of institutional indicators on Msunduzi Municipality

SCENARIOS	WASTE STREAMS	ENVIRONMENTAL LEGISLATION	ENERGY LEGISLATION	FINANCIAL & ADMINISTRATIVE REGULATION	LICENCE REQUIRED	ENVIRONMENTAL AUTHORISATION, EIA or BA REQUIRED	APPROXIMATE COST AND TIME FRAME FOR EIA AND BA
SCENARIO 2: LANDFILL GAS EXTRACTION	General Household Waste, Organics,	The Constitution	National Energy Act	Occupational Health and Safety Act 1993			BA: >R80 000,00 7-9 Months; EIA: >R150 000,00 9-14 Months
		The Environmental Conservation Act	The Gas Act 2001	Municipal Systems Act 2000	Licence to manufacture biofuels	BA listing Notice and triggers	
		National Environmental Management Act	Gas Regulator Levies Act 2002	Municipal Structures Act	Petroleum manufacturing licence (Prerequisite for Licence to manufacture biofuels)	EIA listing Notice and triggers	
		National Environmental Management Waste Act	REIPPP	Municipal Finance Management Act with Particular Reference to:			
		National Environmental Management: Air Quality Act	South African Biofuels Industrial Strategy	Supply Chain Management	Atmospheric Emissions Licence		
		Atmospheric Pollution Prevention Act	White Paper on Renewable Energy	Asset Management	Waste Licence (For Storage, Treatment, Disposal and Processing of waste)		
		National Integrated Coastal Management Act	Electricity Regulation Act 2006	Generally Recognised Accounting Practices 17 & 19)			

5.3.2.2 a) Phase 1Outcome

- Environmental

The results produced by the scenario analysis conducted on the Msunduzi municipality showed that the implementation of scenario 2 which is the LFGTE system could result in significant GHG emission reductions as opposed to the disposal of waste to landfill. Landfill space savings and landfill diversion rates are not applicable in scenario 2 as waste is directly disposed of into landfill. The implementation of LFGTE requires higher capital and operational costs than that of the disposal of waste to landfill.

b) WROSE Model Advancement Outcome

- Social

The Msunduzi Municipality conducted a feasibility study for the implementation of a landfill gas to energy project with a potential to generate up to 1.5MW of electricity. This figure was then input into the advanced WROSE model which resulted in the potential for the creation of 3 jobs. This is in addition to the number of jobs created by the operation of the landfill.

The health risks of scenario 2 are also reduced as the volume of GHG released into the atmosphere is significantly lower than that of the disposal of waste with no landfill gas recovery system. Some of the direct health risks include wheezing, nausea and headache to onsite staff. Indirect symptoms include but are not limited to asthma and respiratory issues.

Due to the collection of unsorted, untreated MSW, no public participation is required in this scenario. A public participation process is required during the EIA process.

- Institutional

In the development of a LFGTE project various legislations apply, these include the need for section 78 internal municipal process, waste licence and an atmospheric emissions licence. Should the gas extracted be used to produce biofuels, then a licence to manufacture biofuels is required. An EIA process will also be conducted in order to apply for the licences required.

5.3.2.3 Scenario 3

Table 5.16 below illustrates the outcome of the application of the socio-economic indicators developed during the phase 2 of the WROSE model. The recycling figure of 145.5 tons was extracted based on the percentage of recyclables identified in the waste stream analysis as seen figure 5.5. In addition to the number of potential jobs to be created through the development of a MRF, the health risks associated both directly and indirectly are outlined as well as the areas in which public participation will be incorporated.

Table 5.16: Scenario 3- Application of socio-economic indicators on Msunduzi Municipality

WASTE RESOURCE OPTIMIZATION AND SCENARIO EVALUATION MODEL : SOCIO - ECONOMIC INDICATORS						
	WASTE QUANTITY (tons per day) /MW OF ELECTRICITY	NO. OF JOBS	DIRECT HEALTH RISKS	INDIRECT HEALTH RISKS	PUBLIC PARTICIPATION IN WASTE MANAGEMENT PROCESS	PUBLIC PARTICIPATION IN EIA PROCESS
SCENARIO 3: RECYCLING	145.5	10.2	Respiratory issues, influenza type symptoms, nausea, headache, tiredness	Asthma, respiratory issues	No public participation necessary due to separation at MRF	Public participation process required

Table 5.17 below outlines the institutional implications of scenario 3 of the WROSE model on the Msunduzi Municipality, taking into consideration licence and regulatory requirements commonly veiwed as barries to project development. In the implementation of scenario 3 for the development of a recycling facility, energy leglsation was not considered as waste to energy is not included in scanerio 3, however all other releavant requirements were incorporated.

Table 5.17: Scenario 3- Application of institutional indicators on Msunduzi Municipality

SCENARIOS	WASTE STREAMS	ENVIRONMENTAL LEGISLATION	ENERGY LEGISLATION	FINANCIAL & ADMINISTRATIVE REGULATION	LICENCE REQUIRED	ENVIRONMENTAL AUTHORISATION, EIA or BA REQUIRED	APPROXIMATE COST AND TIME FRAME FOR EIA AND BA
SCENARIO 3: RECYCLING	Washing/Chipping/Crushing/Grinding of Recyclable Plastic, Paper, Metals, Glass, Builders Rubble	The Constitution		Occupational Health and Safety Act 1993			BA: >R80 000,00 7-9 Months; EIA: >R150 000,00 9-14 Months
		The Environmental Conservation Act		Municipal Systems Act 2000		BA listing Notice and triggers	
		National Environmental Management Act		Municipal Structures Act		EIA listing Notice and triggers	
		National Environmental Management Waste Act		Municipal Finance Management Act with Particular Reference to:	Waste Licence (For Storage, Treatment, Disposal and Processing of waste)		
		The Water Act		Supply Chain Management			
		Atmospheric Pollution Prevention Act		Asset Management			
		National Integrated Coastal Management Act		Generally Recognised Accounting Practices 17 & 19)			

5.3.2.3 a) Phase 1 Outcome

- Environmental

The initial scenario analysis conducted on the Msunduzi Municipality determined that scenario 3 of the WROSE model would result in higher GHG emission reduction than that of scenario 1 and 2. Further to the reduction of GHG emissions with scenario 3 is also the diversion of waste from landfill which results in extending the lifespan of existing landfills with the landfill space savings potential.

b) WROSE Model Phase 2 Outcome

- Social

Taking into consideration the recyclable fraction of the waste stream which was 35.58% of the total volume of waste per day and inputting this figure into the advanced WROSE model resulted in an estimated of 10.2 jobs that will be created. This is in addition to the number of jobs created by the operation of the landfill facility.

Various direct health risks are associated with scenario 3. This include, but are not limited to respiratory issues, influenza type symptoms, nausea, tiredness and headache from exposure to airborne pathogens that could affect the onsite staff. Indirect health risks to residents in surrounding areas are asthma and respiratory issues. These health risks are less harmful than those of scenario 1.

Due to the mechanical pre-treatment of waste via a MRF no public participation is required for the separation of waste at the source. However, a public participation process is required during the EIA process.

- Institutional

A waste licence is required for the development of a MRF as waste in large volumes will be transported and stored. In order to obtain a waste licence, an EIA process is required. No waste to energy projects are implemented in scenario 3 therefore no energy legislation is triggered.

5.3.2.4 Scenario 4

Table 5.18 below illustrates the outcome of the application of the socio-economic indicators developed during the phase 2 of the WROSE model. The Msunduzi Municipality assessed the feasibility of a 2MW AD facility across the municipality this figure was used to calculate the job creation potential of scenario 4. In addition to the number of potential jobs to be created through the development of an AD facility, the health risks associated both directly and indirectly are outlined as well as the areas in which public participation will be incorporated

Table 5.18: Scenario 4- Application of socio-economic indicators on Msunduzi Municipality

WASTE RESOURCE OPTIMIZATION AND SCENARIO EVALUATION MODEL: SOCIO - ECONOMIC INDICATORS						
	WASTE QUANTITY (tons per day) /MW OF ELECTRICITY	**NO. OF JOBS**	**DIRECT HEALTH RISKS**	**INDIRECT HEALTH RISKS**	**PUBLIC PARTICIPATION IN WASTE MANAGEMENT PROCESS**	**PUBLIC PARTICIPATION IN EIA PROCESS**
SCENARIO 4: ANAEROBIC DIGESTION	2	2	Tiredness, headache, nausea	N/A	No public participation necessary due to separation at MRF	Public participation process required

Table 5.19 below outlines the institutional implications of scenario 4 of the WROSE model on the Msunduzi municipality, taking into consideration licence and regulatory requirements commonly veiwed as barries to project development. In the implementation of scenario 4, all of the legislation identified in the table below are applicable in the development of an AD facility.

Table 5.19: Scenario 4- Application of institutional indicators on Msunduzi Municipality

SCENARIOS	WASTE STREAMS	ENVIRONMENTAL LEGISLATION	ENERGY LEGISLATION	FINANCIAL & ADMINISTRATIVE REGULATION	LICENCE REQUIRED	ENVIRONMENTAL AUTHORISATION, EIA or BA REQUIRED	APPROXIMATE COST AND TIME FRAME FOR EIA AND BA
SCENARIO 4: ANAEROBIC DIGESTION	Organics, Abattoir Waste, Agricultural Waste, Sewage	occupational Health and Safety Act	National Energy Act	Municipal Structures Act		BA listing Notice and triggers	BA: >R80 000,00 7-9 Months; EIA: >R150 000,00 9-14 Months
		The Environmental Conservation Act	The Gas Act 2001	Occupational Health and Safety Act 1993	Petroleum manufacturing licence (Prerequisite for Licence to manufacture biofuels)	EIA listing Notice and triggers	
		National Environmental Management Act	Gas Regulator Levies Act 2002	Municipal Systems Act 2000			
		National Environmental Management Waste Act	REIPPP	Municipal Finance Management Act with Particular Reference to:			
		National Environmental Management: Air Quality Act	South African Biofuels Industrial Strategy	Supply Chain Management	Atmospheric Emissions License		
		Atmospheric Pollution Prevention Act	White Paper on Renewable Energy	Asset Management			
		National Waste Management Strategy	Electricity Regulation Act 2006	Generally Recognised Accounting Practices 17 & 19)			

5.3.2.4 a) Phase 1 Outcome

- Environmental

The outcome of scenario 4 much like that of the eThekwini Municipality has the potential for the highest GHG emission reduction. Scenario 4 with the use of an AD facility and the diversion of waste from landfill produces the highest environmental benefit overall. The implementation of the AD facility however requires high capital investment making it an economically unfeasible option for small South African municipalities with limited budget.

b) WROSE Model Phase 2 Outcome

- Social

As part of the Msunduzi Municipalities IWMP a climate change strategy was considered in which a 2MW AD facility has been considered. The facility has the potential to create 2 extra jobs in the municipality. These jobs are created in conjunction with the jobs created through the MRF, as well as the jobs created through the operation of the landfill facility. Therefore scenario 4 has the potential to create 30 jobs in total which is higher than those of the previous scenarios.

Minimal health risks are associated with scenario 4 as this aims to promote zero waste and thereby minimizing the impacts on health and the environment. Direct health risks are headaches, nausea and tiredness. There are no indirect health risks associated with scenario 4 as methane is extracted via the LFGTE facility as well as the AD facility. Public participation is not required when implementing scenario 4 as there is no separation at source that will occur. Waste will be collected, unsorted and untreated from households and separated at a MRF. Public participation will be required in the EIA process when developing the AD facility.

- Institutional

In the implementation of scenario 4 various legislative requirements are triggered. Along with the need for an initial MSA S78 process, a waste licence and an atmospheric emissions licence is required as well as respective energy legislation. An EIA process will also be required for this process with could result in extended project development delays of up to two years. Should the methane extracted be used to produce biofuels, then a petroleum manufacturing licence will also be require

5.3.2.5 Scenario 5

Table 5.20 below illustrates the outcome of the application of the socio-economic indicators developed during the phase 2 of the WROSE model. For the application of phase 2 of the model, the biogenic fraction of waste as seen in the waste characterization is considered for this scenario. In addition to the number of potential jobs to be created through the development of a composting facility, the health risks associated both directly and indirectly are outlined as well as the areas in which public participation will be incorporated.

Table 5.20: Scenario 5- Application of socio-economic indicators on Msunduzi Municipality

WASTE RESOURCE OPTIMIZATION AND SCENARIO EVALUATION MODEL: SOCIO - ECONOMIC INDICATORS						
	WASTE QUANTITY (tons per day) /MW OF ELECTRICITY	**NO. OF JOBS**	**DIRECT HEALTH RISKS**	**INDIRECT HEALTH RISKS**	**PUBLIC PARTICIPATION IN WASTE MANAGEMENT PROCESS**	**PUBLIC PARTICIPATION IN EIA PROCESS**
SCENARIO 5: ANAEROBIC COMPOSTING	140.7	8.442	Fungal spores and bacteria causing Breathing problems, nausea	Fatigue and headaches	No public participation necessary due to separation at MRF	Public participation process required

Table 5.21 below outlines the institutional implications of scenario 5 of the WROSE model on the Msunduzi Municipality, taking into consideration licence and regulatory requirements that could be seen as barries to project development. In the implementation of scenario 5, all of the legislation identified in the table below are applicable in the development of an composting facility.

Table 5.21: Scenario 5- Application of institutional indicators on Msunduzi Municipality

SCENARIOS	WASTE STREAMS	ENVIRONMENTAL LEGISLATION	ENERGY LEGISLATION	FINANCIAL & ADMINISTRATIVE REGULATION	LICENCE REQUIRED	ENVIRONMENTAL AUTHORISATION, EIA or BA REQUIRED	APPROXIMATE COST AND TIME FRAME FOR EIA AND BA
SCENARIO 5: COMPOSTING	Organics, Abattoir Waste, Agricultural Waste, Sewage	National Water Act (No. 36 of 1998)		Occupational Health and Safety Act 1993			BA: >R80 000,00 7-9 Months; EIA: >R150 000,00 9-14 Months
		National Waste Management Strategy		Municipal Systems Act 2000			
		National Waste Information Regulations		Municipal Structures Act		BA listing Notice and triggers	
		National Environmental Management Act		Municipal Finance Management Act with Particular Reference to:		EIA listing Notice and triggers	
		National Environmental Management Waste Act, (No. 59 of 2008)		Supply Chain Management	Waste Licence (For Storage, Treatment, Disposal and Processing of waste)		
		National Environmental Management: Air Quality Act		Asset Management			
		The Fertilizers, Farm Feeds, Agricultural Remedies and Stock Remedies Act		Generally Recognised Accounting Practices 17 & 19)			

5.3.2.5 a) Phase 1 Outcome

- Environmental

The GHG emission reduction potential of scenario 5 is lower than that of scenario 4 however scenario 4 still has high potential for diversion of waste from landfill due to the extraction of the recyclables and biogenic fraction. Due to the absence of an AD facility and the use of aerobic composting, scenario 5 is more economically feasible. High capital investment costs such as those required for scenario 4 are not required for this scenario.

b) WROSE Model Phase 2 Outcome

- Social

The application of the figures for the biogenic fraction of the waste which is 34% of the daily waste volume at the Msunduzi Municipality into the advanced WROSE model determined the job creation potential of 8 additional jobs in scenario 5. These are jobs created in addition to the jobs created by running the existing landfill facility with LFGTE and the MRF. This brings the total job creation figure up to 36 potential jobs. This is due to MRF and composting facilities being more labour intensive than other technological applications.

The direct health risks associated with scenario 5 include respiratory issues from inhaling fungal spores from the composting facility, along with nausea and headache. Indirect health risks are higher than that of an AD facility, resulting in fatigue and headaches to surrounding residents.

No level of public participation is required in the implementation of scenario 5 as no separation of waste at the source is required. A public participation process will be required in the planning phase, as implementation of scenario 5 requires a full EIA process.

- Institutional

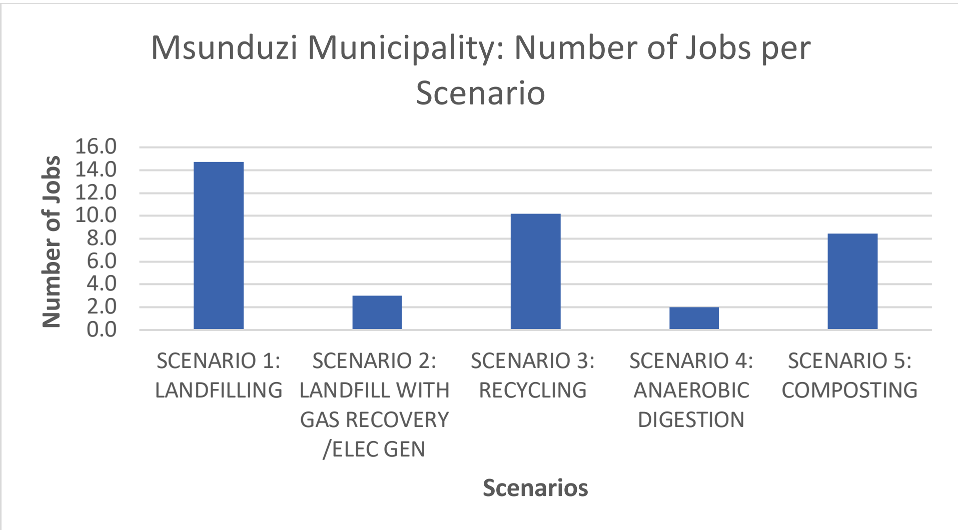
In the application of scenario 5 of the WROSE model, a waste licence is required for the volume of waste collected, stored and transported. An atmospheric emissions licence is also required for this process. No energy legislation is triggered in scenario 5. A full EIA process is required

5.3.2.6 Summary of Msunduzi Municipality

The Msunduzi case study is based on a district municipality, this is still however smaller than a metropolitan municipality such as eThekwini, but it includes multiple local municipalities. The outcome of the application of the advanced WROSE model on the Msunduzi Municipality produced results similar to that of the eThekwini Municipality. At present the disposal of unsorted, untreated MSW is the most economically viable option for a typical South African Municipality such as Msunduzi. However, when Msunduzi Municipality was evaluated against environmental indicators such as GHG emission reduction potential, the results determined that scenario 4 was the most environmentally viable solution.

Upon application of the advanced WROSE model with socio-economic and institutional indicators included, the outcome differed to that of the original results produced. The results show that the currently applied scenario 1 at the municipality has the lowest job creation potential, yet still is subjected to legislative requirements which cost the municipality large volumes of money and result in project delays. Scenario 5 has the potential for the creation of 36 jobs along the overall waste process which is higher than the 14 jobs created simply by the disposal of waste to landfill. Furthermore, similar legislative requirements are applicable to scenario 5 as is the case in scenario 1, yet less capital cost is required than that of scenario 4. Therefore scenario 5 is the most sustainable zero waste solution for the Msunduzi Municipality having taken into consideration all four pillars of sustainability.

Figure 5.9: Summary of job creation potential per scenario for Msunduzi Municipality



5.3.3 Newcastle Municipality

The Newcastle Municipality is the final case study municipality selected for the WROSE model analysis. A scenario analysis was conducted on the Newcastle Municipality, the results of the scenario analysis showed a slight difference in the results than that of the eThekwini Municipality and the Msunduzi Municipality. This is due to the waste volumes per fraction being different than that of the previous municipalities. Furthermore, Newcastle Municipality is a much smaller than that of a large metropolitan municipality such as eThekwini. There is therefore a much smaller overall population and in turn significantly lower waste volumes.

The scenario analysis of Newcastle Municipality showed that scenario 1, much like the other two municipalities produces the largest amount of GHG emissions into the atmosphere. Scenario 4 has the potential for the highest GHG emission reduction, while scenario 3 depicts the potential for equally as high GHG emission reduction potential should Newcastle Municipality utilise a MRF. Scenario 5 has the potential for the highest landfill space saving amongst all scenarios as more waste will be diverted into recycling and composting facilities.

In order to determine the job creation potential of Newcastle Municipality, the total waste volumes extracted were divided into daily quantities. The volumes of waste per day are then input into the advanced WROSE model to determine number of jobs per scenario.

$$\frac{19366\ tons\ of\ waste}{365\ days} = 53.1\ tons\ per\ day$$

Equation 3: Calculation of daily waste volumes for the Newcastle Municipality

The figure above is daily waste fraction of waste received by the Newcastle municipality. Based on the waste characterization study the waste volumes per fraction are depicted in the figure below. The tons per day as indicated by the equation above will be divided per fraction of waste as depicted below. The volume of waste per fraction will be used to conduct a scenario analysis for the Newcastle Municipality.

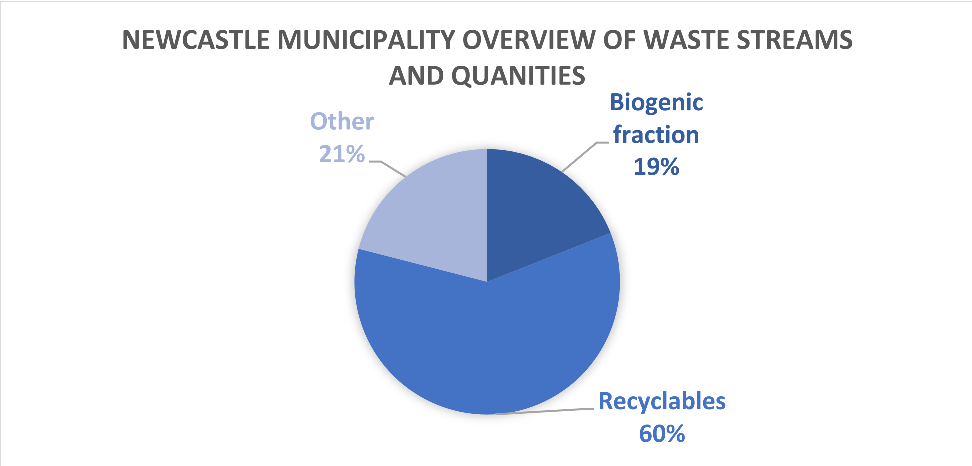


Figure 5.10: Newcastle Municipality overall waste streams and quantities

As seen in the figure above, the total fraction of recyclable waste is the largest volume disposed of at the Newcastle Municipality which is 60% of the total daily volume. The biogenic fraction, unlike that of the eThekwini Municipality is the lowest volume of 19% per day. The residual fraction of waste characterised as other is 21% of the total waste stream. The results of the application of each of the scenarios will follow a similar process. Figure 5.10 below depicts the application of the phase 1 development process on the Newcastle Municipality. The outcome of phase 1 will be discussed following which the application of phase 2 will be conducted.

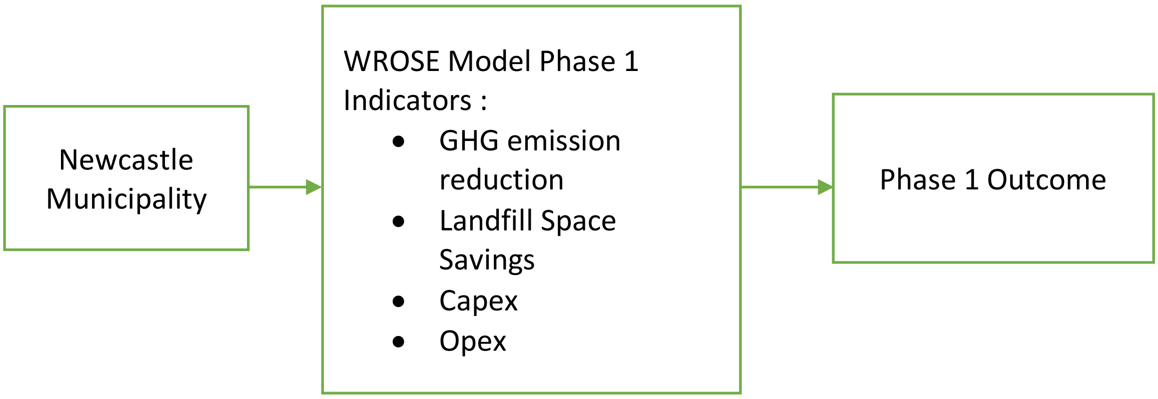


Figure 5.11: Phase 1 of WROSE case study application

The application of phase 2 of the WROSE model indicators will follow the process in Figure 5.7 below, thereafter a comparative analysis of the results will be conducted between the outcome of phase 1 and the results of phase 2.

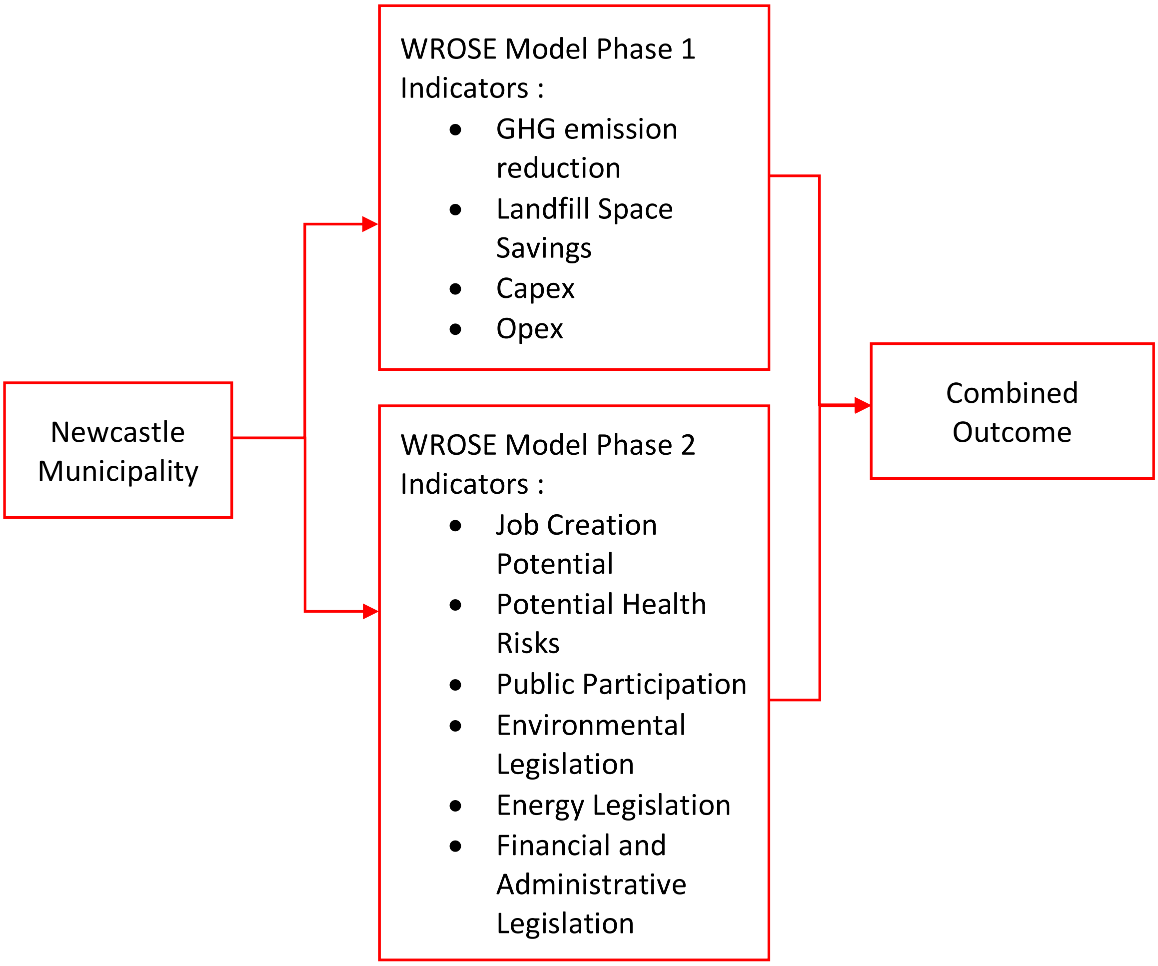


Figure 5.12: Phase 2 of WROSE Model case study application

5.3.3.1 Scenario 1

Table 5.22 below illustrates the outcome of the application of the socio-economic indicators developed during the phase 2 of the WROSE model. The daily waste volume of 53.1 tons was extrapolated as depicted in Equation 3. above to determine the job creation potential of scenario 1 on the Newcastle Municipality. In addition to the number of potential jobs to be created through the disposal of waste to landfill, the health risks associated both directly and indirectly are outlined as well as the areas in which public participation will be incorporated

Table 5.22: Scenario 1- Application of socio-economic indicators on Newcastle Municipality

WASTE RESOURCE OPTIMIZATION AND SCENARIO EVALUATION MODEL: SOCIO - ECONOMIC INDICATORS						
	WASTE QUANTITY (tons per day) /MW OF ELECTRICITY	**NO. OF JOBS**	**DIRECT HEALTH RISKS**	**INDIRECT HEALTH RISKS**	**PUBLIC PARTICIPATION IN WASTE MANAGEMENT PROCESS**	**PUBLIC PARTICIPATION IN EIA PROCESS**
SCENARIO 1: LANDFILLING	53.1	1.9	Respiratory Issues, Fatigue, Headaches, Influenza type Symptoms	Cancer, Low Birth Weight, Birth Defects	No public participation necessary	Public participation process required

Table 5.23 below outlines the institutional implications of scenario 1 of the WROSE model on Newcastel Municipality, taking into consideration licence and regulatory requirements commonly veiwed as barries to project development. In the implementation of scenario 1, all of the legislation outlined below will be triggerred for the development of a landfill facility.

Table 5.23: Scenario 1- Application of institutional indicators on Newcastel Municipality

SCENARIOS	WASTE STREAMS	ENVIRONMENTAL LEGISLATION	ENERGY LEGISLATION	FINANCIAL & ADMINISTRATIVE REGULATION	LICENCE REQUIRED	ENVIRONMENTAL AUTHORISATION, EIA or BA REQUIRED	APPROXIMATE COST AND TIME FRAME FOR EIA AND BA
SCENARIO 1: DISPOSAL OF UNSAORTED UNTREATED MSW TO LANDFILL	General MSW	The Constitution	N/A	Occupational Health and Safety Act 1993			BA: >R80 000,00 7-9 Months; EIA: >R150 000,00 9-14 Months
		The Environmental Conservation Act	N/A	Municipal Systems Act 2000		BA listing Notice and triggers	
		National Environmental Management Act	N/A	Municipal Structures Act		EIA listing Notice and triggers	
		National Environmental Management Waste Act	N/A	Municipal Finance Management Act	Atmospheric Emissions Licence		
		National Environmental Management: Air Quality Act	N/A	Supply Chain Management	Waste Licence (For Storage, Treatment, Disposal and Processing of waste)		
		Atmospheric Pollution Prevention Act	N/A	Asset Management			
		National Integrated Coastal Management Act	N/A	Generally Recognised Accounting Practices 17 & 19)			

5.3.3.1 a) Phase 1 Outcome

- Environmental

The Newcastle Municipality produced similar results to that of eThekwini Municipality and Msunduzi Municipality in scenario 1 when applied to the initial WROSE model. Scenario 1 assesses the GHG emission potential for the disposal of unsorted, untreated MSW into landfill, the outcome of scenario 1 depicted the highest volume of GHG emissions into the atmosphere. Despite being the least environmentally favourable scenario, scenario 1 is also the most economically viable option for a small South African municipality.

b) WROSE Model Phase 2 Outcome

- Social

The daily waste volume of 53.1 tons of waste per day were input into the advanced WROSE model which includes socio-economic and institutional indicators. The outcome of the of the job creation potential for Newcastle Municipality is significantly lower than eThekwini and Msunduzi due to the lower volumes of waste per day. A total of two potential jobs are estimated by the model for the disposal of unsorted, untreated waste to landfill.

The disposal of unsorted, intreated MSW into landfill gives rise to various potential health risks. Direst risks to the onsite staff include respiratory issues, fatigue and influenza type symptoms, while potential indirect risks to nearby residents and business are cancer, low birth weight and birth defects in infants due to the air emissions.

No public participation is required as the separation of waste at the source is not included in this type of model. A public participation process will be required for the EIA process in the landfill development stage.

- Institutional

Scenario 1 involves the disposal of unsorted, untreated MSW to landfill, therefore no energy legislation is triggered. Various legislative requirements are triggered in the development phase of a landfill facility. A section 78 process of the Municipal Finance Management Act is required as the first internal step for a municipality. A waste licence is required for the disposal of waste to landfill along with an atmospheric emissions licence. In order to obtain these a full EIA process is to be followed, this could result in development delays of up to two years.

5.3.3.2 Scenario 2

Table 5.24 below illustrates the outcome of the application of the socio-economic indicators developed during the phase 2 of the WROSE model. The Newcastle Municipalities conducted a feasibility study for a landfill gas extraction project for the total of 0.12MW across the municipality, this figure was extracted from the IWMP for the municipality and input into the WROSE model for determining the job creation potential for scenario 2. In addition to the number of potential jobs to be created through the extraction of landfill gas, the health risks associated both directly and indirectly are outlined as well as the areas in which public participation will be incorporated

Table 5.24: Scenario 2- Application of socio-economic indicators on Newcastle Municipality

WASTE RESOURCE OPTIMIZATION AND SCENARIO EVALUATION MODEL: SOCIO - ECONOMIC INDICATORS						
	WASTE QUANTITY (tons per day) /MW OF ELECTRICITY	NO. OF JOBS	DIRECT HEALTH RISKS	INDIRECT HEALTH RISKS	PUBLIC PARTICIPATION IN WASTE MANAGEMENT PROCESS	PUBLIC PARTICIPATION IN EIA PROCESS
SCENARIO 2: LANDFILL WITH GAS RECOVERY /ELEC GEN	0.12	0.24	Wheezing, nausea, headaches	Asthma, respiratory issues	No public participation necessary	Public participation process required

Table 5.25 below outlines the institutional implications of scenario 2 of the WROSE model on Newcastle Municipality, taking into consideration licence and regulatory requirements commonly veiwed as barries to project development. In the implementation of scenario 2, the disposal of waste to landfill with the extraction of landfill gas , all of the legislation outlined below will be triggerred.

Table 5.25: Scenario 2- Application of institutional indicators on Newcastle Municipality

SCENARIOS	WASTE STREAMS	ENVIRONMENTAL LEGISLATION	ENERGY LEGISLATION	FINANCIAL & ADMINISTRATIVE REGULATION	LICENCE REQUIRED	ENVIRONMENTAL AUTHORISATION, EIA or BA REQUIRED	APPROXIMATE COST AND TIME FRAME FOR EIA AND BA
SCENARIO 2: LANDFILL GAS EXTRACTION	General Household Waste, Organics,	The Constitution	National Energy Act	Occupational Health and Safety Act 1993			BA: >R80 000,00 7-9 Months; EIA: >R150 000,00 9-14 Months
		The Environmental Conservation Act	The Gas Act 2001	Municipal Systems Act 2000	Licence to manufacture biofuels	BA listing Notice and triggers	
		National Environmental Management Act	Gas Regulator Levies Act 2002	Municipal Structures Act	Petroleum manufacturing licence (Prerequisite for Licence to manufacture biofuels)	EIA listing Notice and triggers	
		National Environmental Management Waste Act	REIPPP	Municipal Finance Management Act with Particular Reference to:			
		National Environmental Management: Air Quality Act	South African Biofuels Industrial Strategy	Supply Chain Management	Atmospheric Emissions Licence		
		Atmospheric Pollution Prevention Act	White Paper on Renewable Energy	Asset Management	Waste Licence (For Storage, Treatment, Disposal and Processing of waste)		
		National Integrated Coastal Management Act	Electricity Regulation Act 2006	Generally Recognised Accounting Practices 17 & 19)			

5.3.3.2 a) Phase 1 Outcome

- Environmental

The initial application of scenario 2 of the WROSE model on Newcastle Municipality showed the potential for significant GHG emission reduction as opposed to that of scenario 1. Scenario 2 much like scenario 1 involves the disposal of unsorted, untreated MSW to landfill, scenario 2 however, includes a landfill gas recovery system. The inclusion of a landfill gas recovery system significantly reduces the volume of GHG emitted into the atmosphere. Scenario 2 is therefore more favoured than scenario 1. Landfill space savings and landfill diversion rates are not applicable in scenario 2 as waste is directly disposed of into landfill. The implementation of LFGTE requires higher capital and operational costs than that of landfill.

b) WROSE Model Phase 2 Outcome

- Social

Due to the lower volumes of waste generated by Newcastle Municipality there is the potential for a 0.12MW landfill gas recovery plant. Newcastle also has a significantly lower biogenic waste fraction than the previous 2 case studies, therefore the methane generation potential is lower. This facility will create less than 1 job in total over and above the jobs created through the operation of the landfill facility

The direct health impacts of scenario 2 are less severe than that of scenario 1. Health risks include wheezing, nausea and headaches. Indirect health impacts of scenario 2 are asthma and respiratory issues associated with some level of atmospheric emission, however these impacts on health are significantly lower than those of disposal of waste to landfill.

No public participation is required as the separation of waste at the source is not included in this type of model. A public participation process will be required for the EIA process in the development stages of the project.

- Institutional

The implementation of scenario 2 triggers various legislative requirements, a section 78 process of the Municipal Finance Management Act is required as the first internal step for a Municipality thereafter the need for a waste licence as waste is still disposed of into landfill. An atmospheric emissions licence will also be required for the landfill facility, these licences require a full EIA process to be conducted. The EIA process takes on average 18-24 months for completion which could result in significant project development delays. Should the landfill gas extracted be used for the manufacture of biofuels, then a licence to manufacture biofuels is required.

5.3.3.3 Scenario 3

Table 5.26 below illustrates the outcome of the application of the socio-economic indicators developed during the phase 2 of the WROSE model. The recycling figure of 31.8 tons was extracted based on the percentage of recyclables identified in the waste stream analysis as seen figure 5.9. In addition to the number of potential jobs to be created through the development of a MRF, the health risks associated both directly and indirectly are outlined as well as the areas in which public participation will be incorporated.

Table 5.26: Scenario 3- Application of socio-economic indicators on Newcastle Municipality

WASTE RESOURCE OPTIMIZATION AND SCENARIO EVALUATION MODEL: SOCIO - ECONOMIC INDICATORS						
	WASTE QUANTITY (tons per day) /MW OF ELECTRICITY	NO. OF JOBS	DIRECT HEALTH RISKS	INDIRECT HEALTH RISKS	PUBLIC PARTICIPATION IN WASTE MANAGEMENT PROCESS	PUBLIC PARTICIPATION IN EIA PROCESS
SCENARIO 3: RECYCLING	31.8	2.2	Respiratory issues, influenza type symptoms, nausea, headache, tiredness	Asthma, respiratory issues	No public participation necessary due to separation at MRF	Public participation process required

Table 5.27 below outlines the institutional implications of scenario 3 of the WROSE model on the Newcastle Municipality, taking into consideration licence and regulatory requirements commonly veiwed as barries to project development. In the implementation of scenario 3 for the development of a recycling facility, energy leglsation was not considered as waste to energy is not included in scanerio 3, however all other releavant requirements were incorporated.

Table 5.27: Scenario 3- Application of institutional indicators on Newcastle Municipality

SCENARIOS	WASTE STREAMS	ENVIRONMENTAL LEGISLATION	ENERGY LEGISLATION	FINANCIAL & ADMINISTRATIVE REGULATION	LICENCE REQUIRED	ENVIRONMENTAL AUTHORISATION, EIA or BA REQUIRED	APPROXIMATE COST AND TIME FRAME FOR EIA AND BA
SCENARIO 3: RECYCLING	Washing/Chipping/Crushing/Grinding of Recyclable Plastic, Paper, Metals, Glass, Builders Rubble	The Constitution		Occupational Health and Safety Act 1993			BA: >R80 000,00 7-9 Months; EIA: >R150 000,00 9-14 Months
		The Environmental Conservation Act		Municipal Systems Act 2000		BA listing Notice and triggers	
		National Environmental Management Act		Municipal Structures Act		EIA listing Notice and triggers	
		National Environmental Management Waste Act		Municipal Finance Management Act with Particular Reference to:	Waste Licence (For Storage, Treatment, Disposal and Processing of waste)		
		The Water Act		Supply Chain Management			
		Atmospheric Pollution Prevention Act		Asset Management			
		National Integrated Coastal Management Act		Generally Recognised Accounting Practices 17 & 19)			

5.3.3.3 a) Phase 1 Outcome

- Environmental

The analysis of scenario 3 presented the potential for significantly higher GHG emission reductions than that of scenarios 1 and 2. Scenario 3 includes the use of a MRF to remove recyclables from the waste that is to be disposed of into landfill. Along with the reduction of GHG emissions into the atmosphere, landfill airspace can also be saved as a lower volume of will be disposed of into landfills. Scenario 3 is therefore more favourable than scenario 1 and 2.

b) WROSE Model Phase 2 Outcome

- Social

The application of the advanced WROSE model on the daily recyclable volume of 31.8 tons per day shows the potential for the creation of 2 jobs along with the jobs created through the landfill operation process. The recyclable fraction is 60% of the total waste volume per day therefore the separation of waste in a MRF has the potential for the creation of additional jobs.

There are various direct health risks associated with scenario 2 as it involves the manual sorting of waste in a MRF. Symptoms of direct health related issues are headache, influenza type symptoms, tiredness and respiratory issues that could affect the onsite staff. Indirect health risks include asthma and respiratory issues.

No public participation is required as the separation of waste at the source is not included in this type of model. A public participation process will be required for the EIA process in the development stages of the project

- Institutional

The institutional indicators associated with scenario 3 do not include energy legislation. This is due to no inclusion of AD or LFGTE projects within scenario 3. Various legislative requirements are triggered, a section 78 process of the Municipal Finance Management Act is required as the first internal step for a municipality. A waste licence is still required for the transportation and storage of waste, in addition an atmospheric emissions licence is also required. In order to obtain both licences, a full EIA process is required.

5.3.3.4 Scenario 4

Table 5.28 below illustrates the outcome of the application of the socio-economic indicators developed during the phase 2 of the WROSE model. The Newcastle Municipality assessed the feasibility of a 0.2MW AD facility across the municipality this figure was used to calculate the job creation potential of scenario 4. In addition to the number of potential jobs to be created through the development of an AD facility, the health risks associated both directly and indirectly are outlined as well as the areas in which public participation will be incorporated

Table 5.28: Scenario 4- Application of socio-economic indicators on Newcastle Municipality

WASTE RESOURCE OPTIMIZATION AND SCENARIO EVALUATION MODEL: SOCIO - ECONOMIC INDICATORS						
	WASTE QUANTITY (tons per day) /MW OF ELECTRICITY	**NO. OF JOBS**	**DIRECT HEALTH RISKS**	**INDIRECT HEALTH RISKS**	**PUBLIC PARTICIPATION IN WASTE MANAGEMENT PROCESS**	**PUBLIC PARTICIPATION IN EIA PROCESS**
SCENARIO 4: ANAEROBIC DIGESTION	0.2	.02	Tiredness, headache, nausea	N/A	No public participation necessary due to separation at MRF	Public participation process required

Table 5.29 below outlines the institutional implications of scenario 4 of the WROSE model on the Newcastle municipality, taking into consideration licence and regulatory requirements commonly veiwed as barries to project development. In the implementation of scenario 4, all of the legislation identified in the table below are applicable in the development of an AD facility.

Table 5.29: Scenario 4- Application of institutional indicators on Newcastle Municipality

SCENARIOS	WASTE STREAMS	ENVIRONMENTAL LEGISLATION	ENERGY LEGISLATION	FINANCIAL & ADMINISTRATIVE REGULATION	LICENCE REQUIRED	ENVIRONMENTAL AUTHORISATION, EIA or BA REQUIRED	APPROXIMATE COST AND TIME FRAME FOR EIA AND BA
SCENARIO 4: ANAEROBIC DIGESTION	Organics, Abattoir Waste, Agricultural Waste, Sewage	occupational Health and Safety Act	National Energy Act	Municipal Structures Act		BA listing Notice and triggers	BA: >R80 000,00 7-9 Months; EIA: >R150 000,00 9-14 Months
		The Environmental Conservation Act	The Gas Act 2001	Occupational Health and Safety Act 1993	Petroleum manufacturing licence (Prerequisite for Licence to manufacture biofuels)	EIA listing Notice and triggers	
		National Environmental Management Act	Gas Regulator Levies Act 2002	Municipal Systems Act 2000			
		National Environmental Management Waste Act	REIPPP	Municipal Finance Management Act with Particular Reference to:			
		National Environmental Management: Air Quality Act	South African Biofuels Industrial Strategy	Supply Chain Management	Atmospheric Emissions License		
		Atmospheric Pollution Prevention Act	White Paper on Renewable Energy	Asset Management			
		National Waste Management Strategy	Electricity Regulation Act 2006	Generally Recognised Accounting Practices 17 & 19)			

5.3.3.4 a) Phase 1 Outcome

- Environmental

The application of the waste data on scenario 4 of the WROSE model which consists of anaerobic digestion, produces the largest volume of GHG emission reductions than that of the previous 3 scenarios. Scenario 4 is therefore the most environmentally viable waste management option. In addition, higher landfill diversion is achieved than scenario 3. However, the high capital investment required for the implementation of scenario 4 makes the project not economically feasible for a small South African Municipality.

b) WROSE Model Phase 2 Outcome

- Social

The application of scenario 4 of the advanced WROSE on the Newcastle Municipality allows for the creation of less than additional one job. The volume of biogenic waste is significantly lower in Newcastle Municipality as opposed to the two previous case study Municipalities. Therefore, only a small-scale bio digester is suitable for this type of municipality.

Minimal direct health impacts are associated with the application of scenario 4 in comparison to the other scenarios, these impacts include tiredness, headache and nausea. There are no indirect health impacts making scenario 4 more socially acceptable.

No public participation is required as the separation of waste at the source is not included in this type of model. A public participation process will be required for the EIA process in the development stages of the project

- Institutional

Scenario 4 triggers various legislative requirements similar to that of scenario 2, such as a section 78 process of the Municipal Finance Management Act is required as the first step thereafter the need for a waste licence as waste is still disposed of into landfill. An atmospheric emissions licence will also be required as some flaring may occur, these licences require a full EIA process to be conducted. The EIA process takes on average 18-24 months for completion which could result in significant project development delays. Should the landfill gas extracted be used for the manufacture of biofuels, then a licence to manufacture biofuels is required

5.3.3.5 Scenario 5

Table 5.30 below illustrates the outcome of the application of the socio-economic indicators developed during the phase 2 of the WROSE model. For the application of phase 2 of the model, the biogenic fraction of waste as seen in the waste characterization is considered for this scenario. In addition to the number of potential jobs to be created through the development of a composting facility, the health risks associated both directly and indirectly are outlined as well as the areas in which public participation will be incorporated.

Table 5.30: Scenario 5- Application of socio-economic indicators on Newcastle Municipality

WASTE RESOURCE OPTIMIZATION AND SCENARIO EVALUATION MODEL: SOCIO - ECONOMIC INDICATORS						
	WASTE QUANTITY (tons per day) /MW OF ELECTRICITY	**NO. OF JOBS**	**DIRECT HEALTH RISKS**	**INDIRECT HEALTH RISKS**	**PUBLIC PARTICIPATION IN WASTE MANAGEMENT PROCESS**	**PUBLIC PARTICIPATION IN EIA PROCESS**
SCENARIO 5: ANAEROBIC COMPOSTING	10.1	0.606	Fungal spores and bacteria causing Breathing problems, nausea	Fatigue and headaches	No public participation necessary due to separation at MRF	Public participation process required

Table 5.31 below outlines the institutional implications of scenario 5 of the WROSE model on the Newcastle Municipality, taking into consideration licence and regulatory requirements that could be seen as barries to project development. In the implementation of scenario 5, all of the legislation identified in the table below are applicable in the development of an composting facility.

Table 5.31: Scenario 5- Application of institutional indicators on Newcastle Municipality

SCENARIOS	WASTE STREAMS	ENVIRONMENTAL LEGISLATION	ENERGY LEGISLATION	FINANCIAL & ADMINISTRATIVE REGULATION	LICENCE REQUIRED	ENVIRONMENTAL AUTHORISATION, EIA or BA REQUIRED	APPROXIMATE COST AND TIME FRAME FOR EIA AND BA
SCENARIO 5: COMPOSTING	Organics, Abattoir Waste, Agricultural Waste, Sewage	National Water Act (No. 36 of 1998)		Occupational Health and Safety Act 1993			BA: >R80 000,00 7-9 Months; EIA: >R150 000,00 9-14 Months
		National Waste Management Strategy		Municipal Systems Act 2000			
		National Waste Information Regulations		Municipal Structures Act		BA listing Notice and triggers	
		National Environmental Management Act		Municipal Finance Management Act with Particular Reference to:		EIA listing Notice and triggers	
		National Environmental Management Waste Act, (No. 59 of 2008)		Supply Chain Management	Waste Licence (For Storage, Treatment, Disposal and Processing of waste)		
		National Environmental Management: Air Quality Act		Asset Management			
		The Fertilizers, Farm Feeds, Agricultural Remedies and Stock Remedies Act		Generally Recognised Accounting Practices 17 & 19)			

5.3.3.5 a) Phase 1 Outcome

- Environmental

Scenario 5 has the potential for lower GHG emission reductions than that of scenario 3 and 4. However the GHG emission reduction potential of scenario 5 is still higher than that of scenario 1 and 2. The landfill space saving potential of scenario 5 is higher than the other scenarios. Furthermore, the capital cost required for the implementation of scenario 5 is lower than that of the implementation of the AD facility in scenario 5.

b) WROSE Model Phase 2 Outcome

- Social

As seen in the previous 5 scenarios, due to the Newcastle Municipality being significantly smaller with a lower population density, the overall waste volumes are lower than that of a metropolitan municipality such as eThekwini Municipality. The biogenic waste fraction is also lower than in the previous 2 case study municipalities, therefore the job creation figures are lower. The implementation of scenario 5 which includes composting will result in the creation of less than 1 additional job, over and above the jobs created at the landfill facility and MRF.

The direct health risks associated with a composting facility includes the inhalation of fungal spores and bacteria that result in respiratory issues and nausea to the onsite staff. The indirect health risks to surrounding residents and businesses fatigue and headaches.

No public participation process is required as no separation of waste at the source in included in this scenario. A public participation process is required for the EIA process. This is essential for the licence application requirements.

- Institutional

The implementation of scenario 5 triggers various legislative requirements, such as the need for a section 78 process of the Municipal Finance Management Act, a waste licence for the transportation and storage of waste and an atmospheric emissions licence will also be required for the landfill facility, MRF and composting facility emissions, these licences require a full EIA process to be conducted. The EIA process takes on average 18-24 months for completion which could result in significant project development delays. No energy legislation is triggered in scenario 5.

5.3.3.6 Summary of Newcastle Municipality

The Newcastle Municipality is a local municipality, this is typically representative of smaller non-metropolitan South African Municipality such as eThekwini and is part of a larger district Municipality similar to that of Msunduzi. Therefore there is small waste generation figures. The results of the scenario analysis of Newcastle Municipality differ from that of eThekwini and Msunduzi Municipality. Upon application of the advanced WROSE model with socio-economic and institutional indicators included, the outcome differed to that of the original results produced. Scenario 1 has a high job creation potential, however, due to the large volume of recyclables in Newcastle Municipality scenario 2 has the highest job creation potential within the Municipality.

The results of scenario 5 includes the jobs created in landfilling with gas extraction, recycling and composting as all 3 components are included in this scenario. Therefore, from a job creation perspective scenario 5 is the most favourable with the highest job creation potential. Furthermore, the institutional implications and legislative requirements are similar to those of the implementation of scenario 1 minimizing the red tape associated with other technologies. The figure below is a comparative summary of the job creation potential of all 5 scenarios.

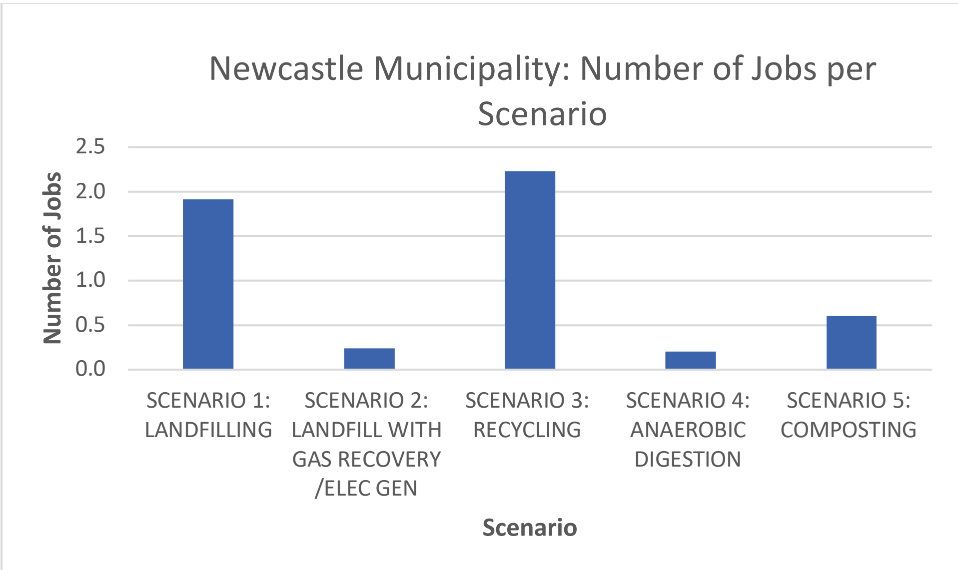


Figure 5.13: Summary of job creation potential per scenario for Newcastle Municipality

Chapter Summary

Each of the selected case study municipalities, eThekwini, Msunduzi and Newcastle were initially evaluated against environmental and economic indicators. The outcome of which generally favoured the use of AD or scenario 4 as a preferred technology for GHG emissions reductions across all municipalities. Scenarios 4 and 5 were preferred for landfill space savings

The economic outcome of the initial study determined that scenario 3 was the most feasible for a large municipality such as eThekwini, however for smaller municipalities such as Msunduzi and Newcastle, landfill gas recovery was the most economical.

As seen in the figure below, the application of the advanced WROSE model on each municipality depicts that from a job creation perspective, scenarios 1, 3 and 5 are most preferable as these scenarios are more labour intensive than scenarios 2 and 4.

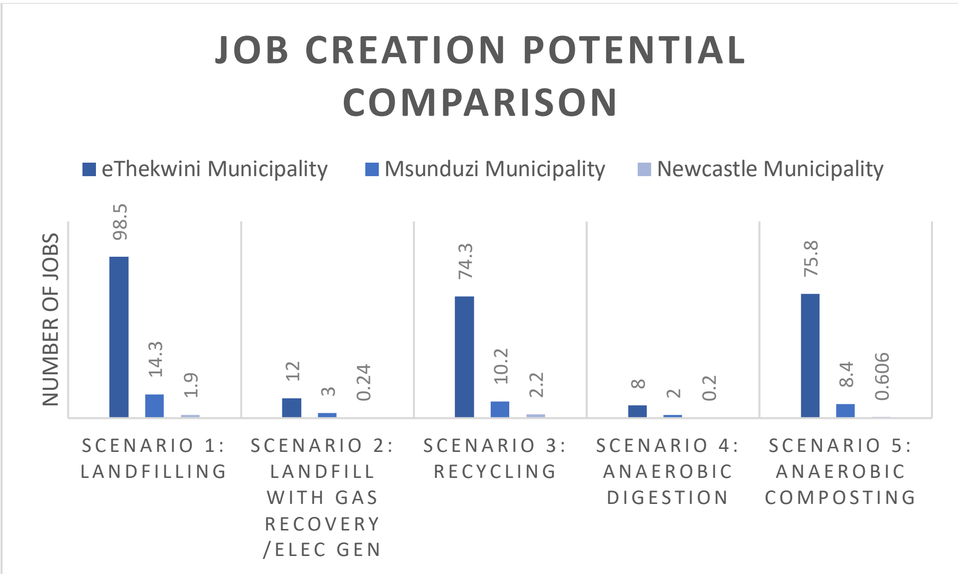


Figure 5.14: Comparison of job creation potential across all case study municipalities

The impacts of scenario 1 on health was the highest both directly and indirectly. Scenario 4 has the least direct impact on health and the no indirect impacts.

All 5 scenarios trigger various institutional indicators and will require specific licence requirements and rigorous EIA processes which need to be considered in the project planning phase. These allow for better time management and to foresee any potential project delays that may occur.

The figure below is the comparison of existing jobs within eThekwini Municipality and Msunduzi municipality as per figures extracted from the respective IWMPs. The Msunduzi Municipality's existing human resources figure was undisclosed and therefore this could not be included in the comparison

Figure 5.14: Existing Municipal Jobs vs WROSE Jobs per Scenario

As seen in figure 5.14 above the current jobs at the eThekwini Municipality and the job creation potential of the baseline scenario are both at the 100 job mark. The current employment figure at the Newcastle Municipality is significantly higher than that depicted by the baseline scenario.

Chapter 6: Conclusion and Recommendations

6.1 Introduction

The purpose of this study was to further develop and enhance the WROSE model to serve as a comprehensive zero waste model which encompasses all four pillars of sustainability. The study provides a system whereby municipal decision and policy makers are able to make well informed decisions. The WROSE model has the potential to contribute towards the development of municipal integrated waste management plans and overall waste minimization strategies. The initial development stage of the WROSE model included the quantification of GHG emissions, economic and technical feasibility as its main indicators. The advancement of the model allowed for the inclusion of socio-economic and institutional indicators. The selection of socio-economic and institutional indicators was conducted by a systematic, detailed literature review process. The socio-economic and institutional indicators were then developed into an excel platform to keep in line with the scenarios in the existing WROSE model. Each of the abovementioned indicators were developed on a scenario basis assessing the socio-economic implications of each waste management strategy as well as the institutional implication of each technology type.

A scenario analysis was then conducted on three case study municipalities, these are eThekwini, Msunduzi and Newcastle Municipality. The analysis included the comparison of the results generated from the initial development of the WROSE model and the results generated from the application of the advanced indicators developed.

6.2 Summary of results

The outcome of the social indicator evaluation matrix resulted in the selection of job creation potential, health risks and public participation as the indicators that was used for this study. The institutional indicators were organised into three broad categories which are, environmental, energy and financial and administrative legislation applicable to each of the respective scenarios within the WROSE model.

The outcome of the scenario analysis conducted for all three case studies produced different results than that of the initial WROSE scenario analysis. The initial outcome of the scenario analysis determined that scenario 4, the use of AD, recycling and LFGTE has the potential for highest GHG emissions reduction. This is due to the high volumes of biogenic waste fractions in each municipality. Scenario 4, however results in high capital and operational expenditure, therefore is not economically viable for the municipalities in question.

Upon application of the advanced WROSE model, taking into consideration all four sustainability indicators, scenario 5 emerged as the most suitable in terms of best environmental benefits, lower costs, higher job creation potential and minimal health risks and institutional red tape. This is due to scenario 5 creating the highest number of jobs as all avenues of waste management within each scenario are highly labour intensive. In addition to the job creation potential, the health risks associated with scenario 5 are lower than that of scenarios 1, 2 and 3, with no public participation necessary. Lastly the legislative requirements for scenario 5 are less tedious than that of technologies that require energy production and connection to the grid. As seen in the initial development of WROSE, scenario 5 is also has the second highest GHG emission reduction potential and is more cost effective than the AD facility. Therefore, taking into consideration all areas of sustainability scenario 5 is the most viable for the case study municipalities discussed.

6.3 Challenges

South African municipalities vary in size, seasonality, geography and population such as upper, middle and lower income households. This ultimately impacts the waste streams, quality and quantity. Furthermore, up to date waste characterization data is essential for determining more precise outcomes using the WROSE model. Outdated municipal IWMP's and lack of current job creation figures leads to the extrapolation of data and projection of expected job creation figures.

Each of the municipalities addressed in this study differ in accordance to the factors identified above. Therefore, there is no one size fits all application for waste management strategies.

6.4 Recommendations

Following the outcome of the study, recommendations can be made to:

- Update the GHG emission factors with more recent figures

- Municipalities to conduct detailed waste stream analysis for up to date data
- Upgrade of economic indicators with recent rand/dollar exchange rates
- Roll out WROSE model to other case study municipalities

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APPENDICES

APPENDIX A: Social Indicator Evaluation Matrix

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YAKWAZULU-NATALI

Sameera Kissoon
MSc Researcher
University of KwaZulu Natal
Civil Engineering
Howard College Campus

MASTERS RESEARCH SURVEY

SCHOOL OF ENGINEERING

Dear Sir/Madam

My name is Sameera Kissoon, I am a Masters student at the University of KwaZulu-Natal, School of Engineering. I am conducting my postgraduate studies under the supervision of Prof. Cristina Trois. My area of focus is Environmental Engineering and in particular waste management.

The UKZN research group CRECHE (Centre for Research in Environmental, Coastal and Hydrological Engineering) has developed the WROSE (Waste Resource Optimization and Scenario Evaluation) model. WROSE is a zero waste model developed to achieve the objectives set out by the Polokwane Declaration to achieve waste diversion and ultimately zero waste.

At present the WROSE model serves as decision support tool for municipalities by providing them with the best possible technologies or waste management solutions suitable for their municipality. In addition the model provides the user with information such as GHG emission reduction potential, landfill space savings and capital and operational expenditure.

The purpose of my research is to advance the WROSE model into a sustainable zero waste model through the inclusion of social indicators. This will allow factors such as job creation potential to be included in the decision making process for municipalities looking to implement alternative waste treatment technologies.

In understanding the needs of society from the perspective of waste management experts please take a few minutes to rate the matrix below.

Return email: sameerakissoon@gmail.com

Kind Regards

Sameera

Please Note: For ethical purposes all respondent information will be regarded as confidential and will not be disclosed

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Founding Campuses:

- Edgewood
- Howard College
- Medical School
- Pietermaritzburg

Social Indicator Evaluation Criteria

The following social indicators were identified through previous studies as relevant to the implementation of waste management strategies. The purpose of this survey is to determine which of the identified social indicators will be used for inclusion in the advancement of the Waste Resource Optimization and Scenario Evaluation (WROSE) model developed by the University of KwaZulu-Natal's CRECHE research group.

Rating Scale:

1. Unimportant	2. Neutral	3. Important

Please respond by rating the following from 1 to 3 using the rating scale represented above. *For example if you feel like job creation is an important indicator for policy relevance rate 3 in block below. Explanation of criteria is given on the following page.*

Social Indicators	**Policy relevant**	**Transparency/User friendly**	**Relevant social indicator**	**Data Availability**	**Data Quality**	**Measurable**
Job creation						
Health Risks						
Public acceptance and social perception						
Cleanliness and smell						
Social participation required						

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Characteristics defined	
Policy relevant	Is the indicator relevant to policy and do you think that is an important or unimportant factor
Transparency/User friendly	Is the indicator an important factor for consideration and should this information be transparent and user friendly for the decision making process
Relevant social indicator	Is the indicator a relevant social indicator to take into consideration
Data Availability	Is the data for this indicator readily available
Data Quality	Is the data of good sound quality for accurate results to aid in the decision making
Measurable	Is this indicator measurable

Appendix B: Sardinia Symposium 2017

ADVANCEMENT OF THE WASTE RESOURCE OPTIMIZATION AND SCENARIO EVALUATION (W.R.O.S.E) MODEL TO INCLUDE SOCIAL INDICATORS FOR WASTE MANAGEMENT DECISION MAKING IN DEVELOPING COUNTRIES

S. KISSOON*, C. TROIS*

** School of Engineering, CRECHE, Centre for Research in Environmental, Coastal and Hydrological Engineering, University of KwaZulu-Natal, Durban, South Africa.*

SUMMARY: Municipal solid waste management activities contribute to greenhouse gas (GHG) emissions into the atmosphere, and in South Africa, these are on the rise due to rapid urbanization and an increased amount of waste generated. Mitigation measures to reduce the impacts of global warming and the emission of greenhouse gases are underway globally. However, in developing countries like South Africa, waste management activities are not viewed as high priority issues. In addition, the disposal of waste to landfill is still the most affordable waste management method in the country. The Waste Resource Optimization and Scenario Evaluation (W.R.O.S.E) model was developed to evaluate the most economically viable and environmentally sustainable alternative waste management solutions. This is done on a scenario basis, which includes the disposal of waste to landfill, landfill gas to energy, recycling, anaerobic digestion and composting. The WROSE model has been tested on various case study municipalities, the outcome of which determined that alternative waste management scenarios have the potential to reduce GHG emissions and landfill airspace, however may require high capital costs.

The large capital and operational costs required for the implementation of alternative waste management technology in South Africa renders such projects unfeasible. Therefore, socio-economic factors must be taken into consideration; this includes: benefits such as job creation potential and public perception of alternative waste treatment projects. This will be achieved through the development of a framework for the quantification of social indicators, which will then be used to assist in the decision-making process when implementing alternative waste management strategies. This multi-phased approach requires a step by step process within which each indicator will be selected and quantified. The overall purpose of the project is the optimization of the WROSE model to include and validate social indicators as a factor for consideration for waste management decision-making for municipalities in developing countries.

1. INTRODUCTION

The changes in the waste sector across the world have given rise to strategies, policies and laws to improve waste management practices. Waste management models are also identified as municipal decision support tools for the implementation of sustainable waste management practices. Morrissey and Browne (2004), conducted an assessment of waste management models and established that no model considered all three pillars of sustainability and included a multi-criteria analysis of environmental, economic and social indicators. The increasing awareness of the impacts of the disposal of waste to landfill is the primary driver for the need for alternative waste management options. The implementation of alternative waste management solutions has high associated capital and operational costs. These costs are unaffordable by most South African Municipalities, which results in alternative waste management options being the least favourable to the disposal of waste to landfill (Trois & Jagath, 2011b).

In the context of developing countries, municipal waste management as a service is irregular, not all households receive waste collection services (Matete & Trois 2008). In addition, landfills in South Africa, are under pressure to divert waste from landfill and aim for the targets set in the Polokwane Declaration in 2001. These are, the reduction of waste generated by 50% and the reduction of waste disposal by 25%, by the year 2012, furthermore is the target set for achieving zero waste by 2022. The Waste Resource Optimization and Scenario Evaluation (WROSE) model is a zero-waste decision support tool designed to assist municipal officials and private sector players in waste management make informed decisions when determining the best alternative waste treatment technology. The WROSE model was developed by the University of Kwa-Zulu Natal as a means to optimize municipal waste management systems and strategies (Jagath 2010). The WROSE model is a multi-criteria analysis model, which considers all four levels of sustainability (environmental, social, economic and institutional) as criteria for evaluation of waste management scenarios and technologies. The WROSE model is designed to evaluate combinations of waste management scenarios such as, for example:

Scenario 1: landfill disposal of unsorted, untreated MSW (Baseline)

Scenario 2: landfill disposal of unsorted, untreated MSW with landfill gas recovery

Scenario 3: Mechanical pre-treatment of MSW, recovery of recyclable fraction through a Material Recovery Facility (MRF) with landfill gas recovery

Scenario 4: MBT (MPT, recovery of recyclables through MRF and anaerobic digestion of biogenic food waste with landfill gas recovery)

Scenario 5: MBT (MPT, recovery of recyclables through MRF and composting of biogenic food-waste with landfill gas recovery)

At present, the model provides the user with information such as landfill space savings and GHG emission reduction figures as well as basic economic viability of alternative waste treatment technologies present in each scenario (Trois & Jagath, 2011). For the WROSE model to function as a sustainable zero waste model, social indicators need to be included.

However, quantifying social indicators is a complex process. Therefore, the purpose of this study is to optimize the WROSE model by determining a methodology to include social indicators into the model before validating them with application on specific case studies.

Based on existing studies, relevant social indicators have been selected that are in line with waste management strategy implementation. The indicators are required to have specific characteristics most in line with the social issues associated with alternative waste treatment technologies. However, determining which of the social indicators are most relevant, is established using a multi criteria decision analysis framework. Thereafter, each of the indicators selected through the use of the framework is quantified using unique quantification methods.

The use of mixed methods research design incorporates both the qualitative and quantitative aspects of data collection and analysis. Godfrey *et al* (2012) expanded significantly on the use and importance of qualitative data methodology in determining the relationship between data and behaviour. Using a structured framework for the collection and analysis of qualitative data, a similar approach will be used for the development of the framework.

In developing a scientifically sound methodology for inclusion of social indicators into the WROSE model, a multi phased framework approach is required. The initial steps in developing the framework included a systematic literature review and identifying what social indicators are particularly relevant to the subject matter. The first phase of the framework involved designing a multi criteria decision matrix to establish which of the social indicators identified in the literature review was most relevant to waste management strategies in South Africa and applicable to other similar developing countries. Due to the complexity of each indicator, individual data collection and analysis methods needed to be established.

2. FRAMEWORK DEVELOPMENT

The purpose of a framework is to have a structure by which a study should be carried out to ensure maximum output. The need for such a framework is for the user to ensure that all pillars of sustainability are included adequately. The framework had been developed to act as a precondition by which social indicators can be measured. The figure below demonstrates the suggested framework for the inclusion of social indicators as a factor for decision-making in the WROSE model.

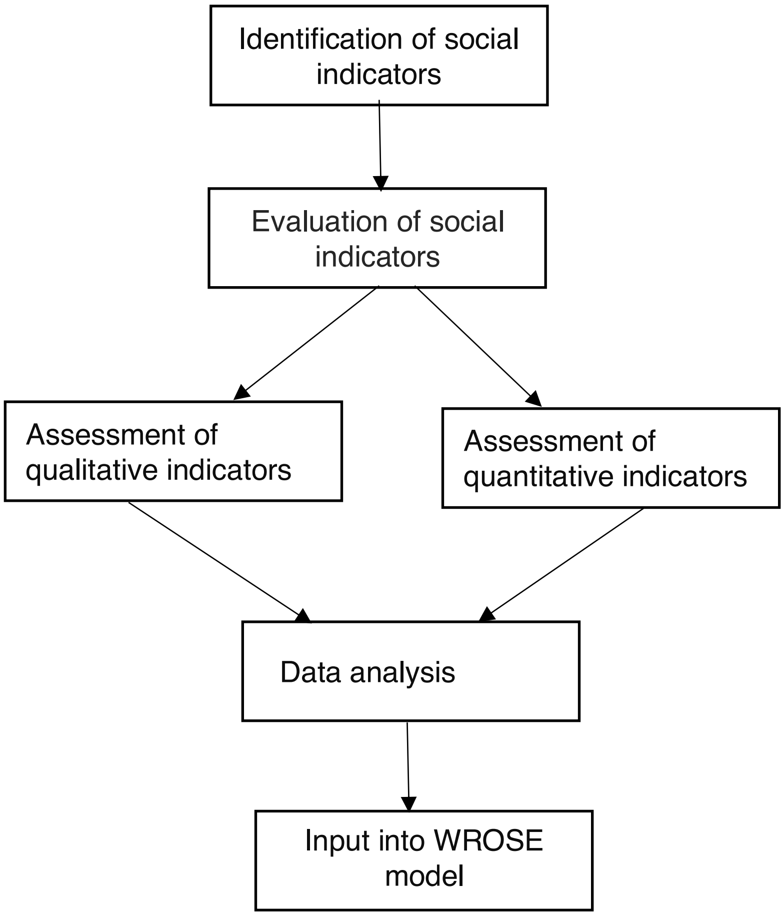

Figure 1. Proposed framework for the quantification of social indicators for input into the WROSE model

2.1 Indicators Identification and Criteria Evaluation

Indicators are numerical measures that describe the satisfaction of individuals or communities and/or statistical measures that describe social trends and conditions impacting on human well-being. These indicators provide information for decision making, monitoring and evaluating policy (Atkinson *et al,* 2002). The social indicators were identified through an in-depth literature review of the WROSE model, sustainability indicators and waste management indicators. Based on previous studies on waste management strategies by Armijo, 2011; Couth and Trois 2012 and Jagath, 2010, a total of five social indicators were identified for the purpose of this study.

These indicators are:

- Job creation potential
- Health Risks
- Public acceptance and social perception
- Cleanliness and smell
- Social participation required

In order to determine which of the abovementioned indicators will be selected for use in the optimization of the WROSE model, an indicator evaluation analysis needed to be developed. This led to the formulation of a multi criteria evaluation matrix in the table below. The evaluation criteria for sustainability indicators are based on existing studies and literature. Important characteristics of sustainability indicators based on the Regions for Sustainable Change (RSC) tool kit include:

- Simple
- Representative
- Scientifically grounded
- Measurable
- Comparable
- Policy relevant
- Timely
- Results oriented

Taking the abovementioned characteristics into consideration the following evaluation criteria matrix was developed. This would be used to rank each indicator according to its related characteristic using a semantic differential scale. The scale ranges from 1 to 3, with 1 being unimportant to 3 being important. Based on this scale, a sample population consisting of waste experts in government, academia and the private sector will be selected to rate the indicators below. Based on the responses received the highest scoring indicators will then be selected for inclusion into the WROSE model.

Table 1. Indicators evaluation matrix.

Social Indicators	**Relevance**	**Transparency/User friendly**	**Policy relevant**	**Data Availability**	**Data Quality**	**Measurable**
Job creation						
Health risks						
Public acceptance and social perception						
Cleanliness and smell						
Social participation required						

3. SOCIAL INDICATORS QUANTIFICATION METHODOLOGY

Due to the nature and dimensions of the research, the process to quantify each social indicator differs. In order to quantify each indicator, data collection methods and sample population will differ, for example job creation figures would require obtaining municipal/landfill weighbridge data whereas an indicator like health risks would require an open-ended survey or health statistics gained from local residents.

3.1. Quantitative indicators

In order to quantify job creation potential of alternative waste management strategies, a methodology was developed to calculate the job creation potential of each scenario ranging from processes such as collection and disposal to more complex scenarios such as material recovery facilities to anaerobic digestion facilities. Due to each component in each scenario of the WROSE model being a full process, the methodology for job creation differed from one context to the next. Based on studies of job creation figures in waste management strategies globally various methods of quantification exist.

Table 2 below breaks down the methodologies used to quantify job creation figures as per the five scenarios within the WROSE model detailed above. This methodology will be applied to 5 case study municipalities to generate figures to optimize and modify the WROSE model.

Table 2. Methodology for the quantification of job creation potential of waste management strategies in accordance with the scenarios of the WROSE model.

WROSE SCENARIO	PROCESS WITHIN SCENARIOS	JOB CREATION POTENTIAL METHODOLOGY
Scenario 1	Landfill disposal of unsorted, untreated MSW.	1) Number of jobs per ton of waste
Scenario 2	Landfill disposal of unsorted, untreated MSW with landfill gas recovery.	1) Number of jobs per ton of waste 2) Number of jobs per MW of electricity generated from landfill gas
Scenario 3	Mechanical pre-treatment of MSW, recovery of recyclable fraction through a Material Recovery Facility (MRF) with landfill gas recovery	1) Number of jobs per ton of waste processed 2) Number of jobs per MW of electricity generated from landfill gas
Scenario 4	MBT (MPT, recovery of recyclables through MRF and anaerobic digestion of biogenic food waste with landfill gas recovery).	1) Number of jobs per ton of waste processed 2) Number of jobs per MW of electricity generated from AD and LFGE
Scenario 5	MBT (MPT, recovery of recyclables through MRF and composting of biogenic food waste with landfill gas recovery).	1) Number of jobs per ton of waste processed 2) Number of jobs per ton of waste composted

3.2 Qualitative indicators

Issues such as, cleanliness, smell, social perception and public participation cannot be measured without the use of a systematic literature review of impacts, surveys and key informant interviews. Data collection methods for such qualitative information requires a specific sample population relevant to its outcome. In the instance of issues such as social perception and public participation, local residents impacted on by nearby facilities will be surveyed. These surveys will aim to explore in depth, the issues faced by the general public regarding existing waste management strategies and the implementation of new strategies. In addition, it will serve as an assessment strategy to establish the depth of knowledge of the general public on issues pertaining to waste management strategies.

The data collected from the surveys will be analysed and input into the WROSE model to inform decision making on multiple levels. In addition to determining the overall perception of the general public, the inclusion of such indicators can serve as a guide to the overall understanding of people regarding waste management strategies.

5. CONCLUSIONS

The inclusion of social indicators as a factor for decision making is a multifaceted process. Therefore, the development of a framework is necessary, this framework forms the basis of ensuring the accuracy of the methodology for the inclusion of social indicators into the WROSE model. It requires a step by step procedure and the compartmentalization of each step as an individual set of processes. The designed methodology can form the basis for the inclusion of social and thereafter institutional indicators into a comprehensive sustainable zero waste, decision support model. Various data collection methods must be administered for this particular type of research, both qualitative and quantitative data collection and in-depth analysis is required. Using the abovementioned methodologies and detailed analysis of the data collected, various social indicators will be included into the WROSE model to assist in the decision-making process. In addition, this will serve as an awareness exercise and an assessment of the general public understanding of waste management strategies. With this information at hand, not only will job creation potential be realised but also awareness campaigns can be established to inform public perception and social participation to make project implementation smoother.

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Appendix C: WasteCon 2018 Conference Paper

ADVANCEMENT OF THE WASTE RESOURCE OPTIMIZATION AND SCENARIO EVALUATION (WROSE) MODEL TO INCLUDE SOCIO-ECONOMIC AND INSTITUTIONAL INDICATORS.

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ABSTRACT

Waste management activities produce approximately 4.3% of the total methane emissions in South Africa (Nahman, *et al.*, 2012). If GHG emissions continue to increase without constraint to the year 2030, CO_2 equivalent emissions would likely be more than double the 2010 value. With landfilling being the primary waste disposal strategy employed by South African municipalities the need arises for economically viable waste diversion strategies to be evaluated in the South African context.

The Waste Resource Optimisation and Scenario Evaluation (WROSE) model is a decision support tool developed by the University of KwaZulu-Natal to assist municipalities in determining the most appropriate waste management strategy for their particular needs. Previous studies on the WROSE model assessed various waste management strategies that included landfilling, landfill gas with electricity generation/flaring, recycling, anaerobic digestion and composting through the case study evaluation of typical municipalities in South Africa. Each strategy was evaluated through the implementation of the WROSE model via the use of waste management indicators of sustainability and feasibility such as the potential for greenhouse gases emissions reduction, landfill space savings, landfill diversion rate and several economic indicators.

The study found that high capital and operating costs of diversion strategies were the main barrier to implementation in these municipalities. Therefore, following the initial evaluation of the WROSE model, further investigations were carried out to determine what impact socio-economic and institutional indicators of sustainability will have on the decision making process. A matrix for the evaluation of socio-economic indicators were developed along with an institutional indicator assessment sheet relevant to each of the diversion scenarios based on the model.

The purpose of these are to determine the legal and socio-economic implications of diversion strategies. The outcome of such an exercise is to further develop WROSE into a sustainable decision support tool that will ultimately result in sound, well rounded decision making for municipalities and industry alike.

KEYWORDS

Waste Resource Optimisation and Scenario Evaluation (WROSE), socio-economic, institutional indicators, waste diversion strategies

INTRODUCTION

The introduction of the waste hierarchy in the National Environmental Waste Management Act puts the disposal of waste to landfill as an end of life solution for waste management. This gives rise to the need for implementing alternative strategies such as recycling and the reuse of waste as a resource. However local municipalities lack the required human and financial resources to implement such new systems. Up to 40% of the South African population receives little or no waste services (DEA, 2010) The high associated costs and complex municipal supply chain processes make alternative systems difficult to obtain. To date landfilling in South Africa is still the cheapest and therefore preferred waste management option for majority of the municipalities in the country. However, the disposal of waste to landfill although the most cost effective poses many disadvantages among which are soil, water and air pollution. Alternative waste management solutions can provide communities with services such as waste management, access to renewable energy, organic fertilizer for farming and overall improvement of life.

Landfills in South Africa, are under pressure to divert waste from landfill and aim for the targets set in the Polokwane Declaration in 2001. These are, the reduction of waste generated by 50% and the reduction of waste disposal by 25%, by the year 2012, furthermore is the target set for achieving zero waste by 2022. The Waste Resource Optimization and Scenario Evaluation (WROSE) model is a zero-waste decision support tool designed to assist municipal officials and private sector players in waste management make informed decisions when determining the best alternative waste management strategies. The WROSE model was developed by the University of Kwa-Zulu Natal as a means to optimize municipal waste management systems and strategies (Jagath 2010). The WROSE model is a multicriteria analysis model, which considers all four levels of sustainability (environmental, social, economic and institutional) as criteria for evaluation of waste management scenarios and technologies. The WROSE model is designed to evaluate combinations of waste management scenarios for example:

Scenario 1: landfill disposal of unsorted, untreated MSW (Baseline)

Scenario 2: landfill disposal of unsorted, untreated MSW with landfill gas recovery

Scenario 3: Mechanical pre-treatment of MSW, recovery of recyclable fraction through a Material Recovery Facility (MRF) with landfill gas recovery

Scenario 4: MBT (MPT, recovery of recyclables through MRF and anaerobic digestion of biogenic food waste with landfill gas recovery)

Scenario 5: MBT (MPT, recovery of recyclables through MRF and composting of biogenic food-waste with landfill gas recovery)

At present, the model provides the user with information such as landfill space savings and GHG emission reduction figures as well as basic economic viability of alternative waste treatment technologies present in each scenario (Trois & Jagath, 2011). For the WROSE model to function as a sustainable zero waste model, social and institutional indicators need to be included. Therefore, the purpose of this study is to optimize the WROSE model by determining a methodology to include social and institutional indicators into the model before validating them with application on specific case studies.

INDICATOR EVALUATION

Social Indicators

Social indicators were identified through an in-depth literature review of the WROSE model, sustainability indicators and waste management indicators. Based on previous studies on waste management strategies by Armijo, 2011; Couth and Trois 2012 and Jagath, 2010, a total of five social indicators were identified for the purpose of this study. These indicators are:

- Job creation potential
- Health Risks
- Public acceptance and social perception
- Cleanliness and smell
- Social participation required

In order to determine which of the abovementioned indicators were to be selected for use in the optimization of the WROSE model, an indicator evaluation matrix needed to be developed. This led to the formulation of a multi criteria evaluation matrix in the table below. The evaluation criteria for sustainability indicators are based on existing studies and literature. Important characteristics of sustainability indicators based on the Regions for Sustainable Change (RSC) tool kit include:

- Simple
- Representative
- Scientifically grounded
- Measurable
- Comparable
- Policy relevant
- Timely
- Results oriented

Taking the abovementioned characteristics into consideration the following evaluation criteria matrix was developed. This would be used to rank each indicator according to its related characteristic using a semantic differential scale. The scale ranges from 1 to 3, with 1 being unimportant to 3 being important. Based on this scale, a sample population consisting of waste experts in government, academia, NGO's and the private sector were selected to rate the indicators.

Table1: Indicator evaluation matrix

Social Indicators	**Relevance**	**Transparency/User friendly**	**Policy relevant**	**Data Availability**	**Data Quality**	**Measurable**
Job creation						
Health risks						
Public acceptance and social perception						
Cleanliness and smell						
Public participation required						

Based on the results of the indicator evaluation survey three social indicators were selected for use in the optimization of the WROSE model. The selected indicators were, job creation potential, health risks and public participation.

Job creation potential

The job creation potential for each of the waste management scenario identified above were calculated by averaging data from existing facilities across South Africa. In order to determine the job creation potential for each scenario, a detailed literature review was conducted on various existing and operational facilities across all five scenarios. The formula below depicts how the job creation figures were estimated.

$$\frac{Tons\ of\ waste\ per\ day}{Number\ of\ employees} = x\ tons\ of\ waste\ per\ job$$

This process was carried out for multiple landfills, material recovery facilities (MRF's) and composting facilities and the final figures were averaged out and input into the WROSE model. A similar process was carried out for the scenarios that include electricity generation such as anaerobic digestion (AD) and landfill gas to electricity (LFGTE).

$$\frac{Megawatts\ of\ electricity}{Number\ of\ employees} = x\ MW\ of\ electricity\ per\ job$$

It is important to note that the job creation figures were calculated based on the volumes of waste per day and not annually to get a clear indication of daily staff requirements per scenario. Therefore, figures identified in the case study will be divided into daily volumes for the estimation of job creation potential. Furthermore, the figures input into the advanced model were divided according to the percentages of waste fractions identified in the waste characterization study.

Health risks

The health risks of each of the identified waste management scenarios were established by conducting a detailed literature review and determining the most common risk factors associated with each technology type. Although health risks differ between each type of technology, they do not differ per municipality.

Public participation

The need for public participation per scenario were also assessed. Public participation was looked at from public involvement in the waste separation at source point of view as well as the participation of the public in the EIA process. The table below is an example of the collated information for the selected socio-economic indicators.

Table 2: Socio-economic indicators in WROSE model

WASTE RESOURCE OPTIMIZATION AND SCENARIO EVALUATION MODEL : SOCIO - ECONOMIC INDICATORS						
	WASTE QUANTITY (tons per day) /MW OF ELECTRICITY	NO. OF JOBS	DIRECT HEALTH RISKS	INDIRECT HEALTH RISKS	PUBLIC PARTICIPATION IN WASTE MANAGEMENT PROCESS	PUBLIC PARTICIPATION IN EIA PROCESS
SCENARIO 1: LANDFILLING	0	0.0	Respiratory Issues, , Fatigue, Headaches, Influenza type Symptoms	Cancer, Low Birth Weight, Birth Defects	No public participation necessary	Public participation process required
SCENARIO 2: LANDFILL WITH GAS RECOVERY /ELEC GEN	0	0	Wheezing, nausea, headaches	Asthma, respiratory issues	No public participation necessary	Public participation process required
SCENARIO 3: RECYCLING	0	0.0	Respiratory issues, influenza type symptoms, nausea, headache, tiredness	Asthma, respiratory issues	No public participation necessary due to separation at MRF	Public participation process required
SCENARIO 4: ANAEROBIC DIGESTION	0	0	Tiredness, headache, nausea	N/A	No public participation necessary due to separation at MRF	Public participation process required
SCENARIO 5: ANAEROBIC COMPOSTING	0	0	Fungal spores and bacteria causing Breathing problems, nausea	Fatigue and headaches	No public participation necessary due to separation at MRF	Public participation process required

Institutional Indicators

Regulatory barriers to the implementation of alternative waste management solutions is a common cause for delays to the development and implementation of projects across the country. Institutional indicators include the legal requirements and/or implications of the scenarios identified in the WROSE model which will assist the user to determine legal requirements of suggested solutions and estimate appropriate cost and time frames.

These institutional indicators were identified based on the relevant technologies identified in each scenario. The legislation applicable to each scenario was separated into three categories, environmental, energy and financial and administrative. Institutional requirements differ in each scenario, however the same legislative requirements are applicable to all municipalities across the country. Prior to any external feasibility studies, all municipalities must first conduct as section 78 process of the Municipal Systems Act. In doing so, the municipality assesses their inhouse capabilities in implementing and managing waste management projects. Should the municipality not possess the resources to conduct the project inhouse, external mechanisms must then be assessed. This process has the potential to add considerable delays to project implementation time frames. It is therefore important for municipal officials to understand what processes are required in advance and allocate realistic time frames for project planning. This will also reduce unforeseen red tape that usually result in project delays. The table below is an example of the data collated for scenario 1 of the WROSE model and what legislative requirements are triggered.

Table 3: Institutional indicators per sceanrio

SCENARIOS	WASTE STREAMS	ENVIRONMENTAL LEGISLATION	ENERGY LEGISLATION	FINANCIAL & ADMINISTRATIVE REGULATION	LICENCE REQUIRED
SCENARIO 1: DISPOSAL OF UNSAORTED UNTREATED MSW TO LANDFILL	General MSW	The Constitution	N/A	Occupational Health and Safety Act 1993	
		The Environmental Conservation Act	N/A	Municipal Systems Act 2000	
		National Environmental Management Act	N/A	Municipal Structures Act	
		National Environmental Management Waste Act	N/A	Municipal Finance Management Act	Atmospheric Emissions Licence
		National Environmental Management: Air Quality Act	N/A	Supply Chain Management	Waste Licence (For Storage, Treatment, Disposal and Processing of waste)
		Atmospheric Pollution Prevention Act	N/A	Asset Management	
		National Integrated Coastal Management Act	N/A	Generally Recognised Accounting Practices 17 & 19)	

CONCLUSION

The methodology adopted for this study comprised of both quantitative and qualitative researched methods. The quantitative analysis was used for the evaluation of social indicators as well as determining the job creation potential of each scenario. The qualitative aspects of the research involved the literature review required in identifying potential health risks as well as legislative requirements of each scenario in the WROSE model. Both indicators that were developed into an Excel model were added into the pre-existing WROSE model. Three South African case study municipalities have been identified for the testing of the newly updated model. A comparative analysis will be carried out, using the results collected in the initial testing of the WROSE model in previous studies and the results obtained with the advancements of all four pillars of sustainability.

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