EXAMINER'S COPY

AN INVESTIGATION INTO THE REDUCTION OF GREENHOUSE GASES ASSOCIATED WITH THE DISPOSAL OF MUNICIPAL SOLID WASTE FOR THE DEVELOPMENT OF AN INSTITUTIONAL FRAMEWORK IN DEVELOPING COUNTRIES

By

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As the candidate's supervisor, I have approved this thesis for submission.

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Preface

The work described in this thesis was carried out through the School of Engineering, University of KwaZulu-Natal, Durban, from June 2011 to June 2015, under the supervision of Professor Cristina Trois.

These studies represent original work by the author and have not otherwise been submitted in any form for any degree or diploma to any tertiary institution. Where use has been made of the work of others it is duly acknowledged in the text.

FACULTY OF ENGINEERING

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Acknowledgements:

First and above all I would like to thank God for showering me with wisdom and blessings for the completion of my doctorate.

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My friends, Ishara and Rekha who kept me sane during my research.

All those not mentioned here who helped and motivated me during my doctoral studies.

Dedication: To my children

Abstract

Municipal solid waste in landfills releases the greenhouse gas (GHG), methane. This study aimed to develop an institutional framework that could assist municipalities in developing countries to adopt an integrated waste management strategy to maximise the reduction of GHG emissions using appropriate technologies. The results of key informant interviews and a systematic literature review informed the selection of the case studies.

The case studies involved a waste stream analysis in two developing countries in order to determine the level of the waste diverted from landfills and the most appropriate treatment technologies. These included a waste stream analysis of the Deonar landfill site in the Municipal Corporation of Greater Mumbai (MCGM) which receives waste volumes of 6 800 tonnes per day and the Newcastle landfill site, a medium-sized landfill in South Africa.

The findings of the case study in Newcastle Municipality provide the basis for recommendations to municipal managers on potential alternatives processes for polyethylene terephthalate (PET) diverted from municipal solid waste. It focuses on the importance of Separation at Source including the effect of zero PET into landfills and their contribution to GHG reductions for the production of hollow woven fibre.

Finally, an integrated waste management system is presented which sets out an institutional framework that illustrates the interrelationship between waste and energy, best practices and bottlenecks to guide municipalities in their efforts to utilize appropriate technologies. South Africa is challenged to find sustainable solutions that are aligned with government objectives in identifying appropriate technologies for prevailing waste streams. The institutional framework is based on the planning process, risks and learning curves associated with the uncertainty of landfill gas to energy technologies.

The reduction of GHG emissions in municipal solid waste is of concern due to the pressure of non-renewable energy. GHG emitted due to waste management in developing countries' cities creates problems in accounting and reporting these gases. Reducing the volumes of waste landfilled will also reduce methane emissions and other environmental impacts associated with landfills that will in turn contribute positively to climate impacts and the national carbon footprint.

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List of Abbreviations

AD	Anaerobic Digestion
BaU	Business as Usual
CDM	Clean Development Mechanism
CERs	Carbon Emissions Reductions
CH_4	Methane
CO_2	Carbon dioxide
CRs	Carbon Sequestration Requirement
DAT	Dome Aeration Technology
DEA	National Department of Environmental Affairs
EIA	Environmental Impact Assessment
EPA	Environmental Protection Agency
ER	Emissions Reduction
EU	European Union
GHG	Greenhouse gas
HDPE	High density polyethylene
IPCC	Intergovernmental Panel on Climate Change
ISO	International Standards of Organisations
IVC’s	In-vessel composters
LDPE	Low density polyethylene
LFG	Landfill gas
LFGTE	Landfill gas to energy
MBT	Mechanical Biological Treatment
MCGM	Municipal Corporation of Greater Mumbai
MRF	Materials Recovery Facility

MSA	Municipal Systems Act
MSW	Municipal Solid Waste
$MtCO_2eq$	Metric tons of carbon dioxide equivalent
NEMA	National Environment Management Act
NLM	Newcastle Local Municipality
NWMS	National Waste Management Strategy
O&M	Operation and Maintenance
PCF	Prototype Carbon Fund
PET	Polyethylene terephatelate
POP	Persistent Organic Pollutants
PP	Polypropylene
PPP	Public Private Partnership
PS	Polystyrene
PVC	Polyvinylchloride
RDF	Refuse Derived Fuels
RPF	Refuse Plastic Fuels
SA	South Africa
SWM	Solid Waste Management
SAWIS	South African Waste Information System
UNEP	United Nations Environment Program
UNFCCC	United Nations Framework Convention on Climate Change
WSA	Waste Stream Analysis
WTE	Waste to Energy

1. INTRODUCTION

1.1 Rationale

Integrated Solid Waste Management illustrates how waste should be managed, taking into account the various laws and strategies designed to protect the environment from improper management of solid and hazardous waste.

Municipal compliance with the National Environmental (Waste) Act 2008 and the Municipal Systems Act 32 of 2000 are the basis for assessing current municipal institutional performance.

With regard to the Waste Act, municipalities are required to adopt a hierarchical approach to implement integrated waste management systems that result in waste avoidance, reduction, re-use, recycling, recovery, treatment and finally the disposal of waste.

Worldwide, methane (CH_4) from landfilling of MSW accounted for over 730 million metric tonnes of carbon dioxide equivalent ($MtCO_2eq$) in 2000 and represented over 12% of total global CH_4 emissions (Shukla, 2008).

The Intergovernmental Panel on Climate Change (IPCC) notes that there is now indisputable evidence of the warming of climate systems demonstrated increases in global average air and ocean temperatures, extensive melting of snow and ice and a rising global average sea level (IPCC, 2007). Warming is expected to be the strongest in the Arctic, with the ongoing retreat of glaciers, permafrost and sea ice. Climate change is the most talked about environmental problem facing the world today. Urgent action is required to achieve global commitment to limit future warming to below 2^0C above pre-industrial levels In addressing climate change counties need prioritise their developmental efforts to reduce pressure on resources, energy and carbon intensity. South Africa (SA) hosted the 17^{th} Conference of Parties (COP 17) of the United Nations Framework Convention on Climate Change (UNFCCC, 2011).

Table 1.1 shows that SA is categorised among the top 21 countries measured by absolute carbon dioxide (CO_2) emissions on a worldwide table, with emissions per capita in the region of 10 metric tonnes per annum. India is ranked among the top three countries measured by absolute CO_2 emissions.

Table 1- 1 A worldwide table of GHG Emissions in M-tonnes in 2009 (Source: DEAT 2009)

GHG Emission M-tonnes- 2009			
Rank	**Country**	**M-tonnes**	**%**
1	China	7711	25.4
2	United States	5425	17.8
3	India	1602	5.3
4	Russia	1572	5.2
5	Japan	1098	3.6
6	Germany	766	2.5
7	Canada	541	1.8
8	Korea, South	528	1.7
9	Iran	527	1.7
10	United Kingdom	520	1.7
11	Saudi Arabia	470	1.5
12	South Africa	450	1.5
13	Mexico	444	1.5
14	Brazil	420	1.4
15	Australia	418	1.4
16	Indonesia	413	1.4
17	Italy	408	1.3
18	France	397	1.3
19	Spain	330	1.1
20	Taiwan	291	1.0
21	Poland	286	0.9

Research across Africa has established that the most sustainable way to manage waste in the majority of urban communities is to remove dry recyclables by hand-picking, and through door to door collection, and/or a dirty materials recovery facility (MRF) (Couth and Trois, 2012). This research found that composting/ green waste projects are the most sustainable and that if biogenic waste fraction is removed landfills should not require biogas extraction systems as they will comprise mainly inert and fossil carbon wastes.

Landfills release methane gas into the atmosphere, which has global warming potential of more than 20 times that of CO_2 (EPA, 2011). In SA the waste sector contributes around 4.3% to total GHG emissions (Nahman et al., 2012). Landfilling is amid the biggest producers of GHGs and it continues to produce amounts of GHGs for decades (Harley, 2010). The waste sector contributes approximately 3% of global methane emissions (Bogner et al., 2008). As illustrated in Table 1-1, in SA, the waste sector contributes 1.5 % of total GHG emissions, with waste management activities contributing 12% of total methane emissions (DEAT, 2009b).

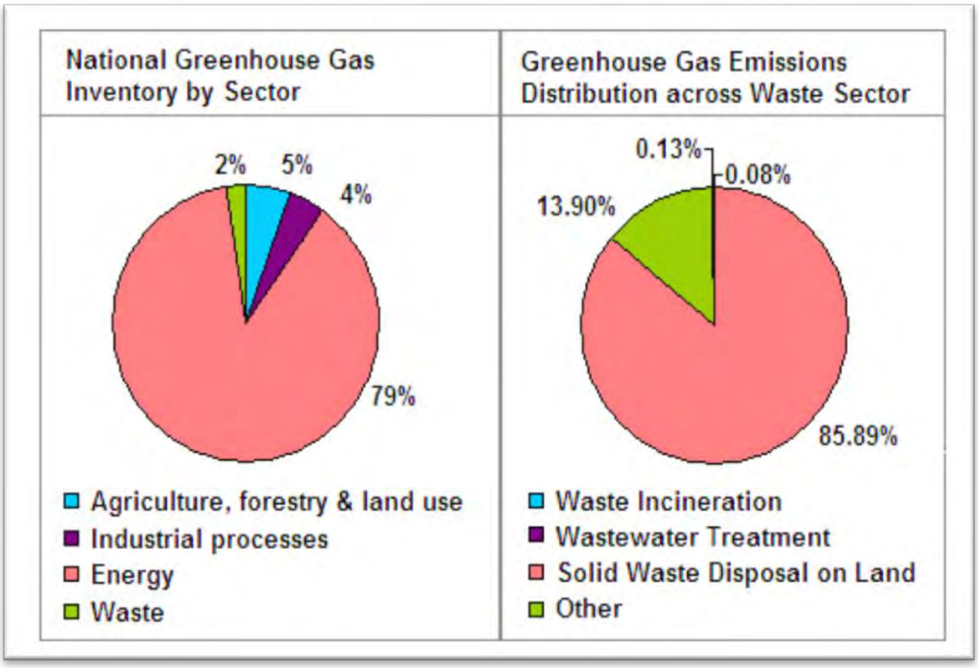

Figure 1- 1 National GHG emissions Source: Jagath and Trois (2011)

In Figure 1-1 illustrates the National GHG by the Inventory by Sector and of which waste only contributes 2%. IN the GHG emission distribution across the waste sector, solid waste disposal on land is 85.89%. The GHGs which have the greatest climate change impacts are CO_2, CH_4 and nitrous oxide (N_2O), all of which emanate from the landfilling of MSW (Smith et al., 2001). The rapid increase in waste generation and limited landfill space, this requires improved MSW management methods and technologies for sustainable and efficient waste management. As shown in Table 1-2, total methane emissions in South Africa increased by 76.5% from 1990 to 2000.

The significance of this increase resides in the fact that methane is far more powerful GHG than CO_2, with a global warming potential of 21 times greater (Smith et al., 2001). Friedrich and Trois (2010) note that there is some uncertainty regarding these statistics as different GHG accounting methodologies were used between 1990 and 2000, specifically, the 1996 IPCC guidelines for both the 1990 and 1994 national inventories and the 2006 IPCC guidelines for the 2000 inventory.

Table 1- 2 GHG emission trends in SA (Source: DEAT, 2009b)

GHG	**YEAR**			**% increase from 1999 to 2000**
	1990	**1994**	**2000**	
CO_2	280,932	315,957	353,643	18.60%
CH_4	2,053	2,057	3,624	76.50%
N_2O	75	67	76.7	2.70 %
CF_6			0.303	
C_2F_6			0.021	

In the circumstance of a middle-income developing country like SA, municipal solid waste management (MSWM) is an ever-increasing challenge. Zero waste is a concept that major South African municipalities are starting to include at an urban policy and planning level. The Polokwane Declaration objectives to develop a zero waste plan by 2022, which will lead to an effective and sustainable waste management system for the country (DEAT, 2001)

Many studies have suggested that zero waste and waste diversion strategies could result in significant GHG/carbon reductions (Smith et al., 2001; Mohareb et al., 2008; Couth and Trois, 2010). These studies identify waste strategies which can be applied at municipal level in developing countries like SA and India and assess their potential for MSW diversion and strategies for GHG emission reduction. Table 1-2 above showed GHG trends in SA. Table 1 -3 outlines the national GHG trends in India from 2000 to 2008.

Table 1- 3 National GHG trends in India (Source: Courtesy of MCGM, 2011)

GHG	2000	2008
CO_2	1,186,000	1,639,029
CH_4	20,800	23,228
N_2O	260	395
HFC	5	18
CF_6	7	10
C_2F_6	0.1	12

A detailed waste stream analysis of characteristics and quantities provides a thorough description of municipal waste composition. Municipal solid waste is composed of an organic (wet waste) and inorganic (dry waste) fraction. It consists mainly of household industrial and commercial waste to be disposed of by the local authority (FFF, 2008-2010). The carbon content in MSW can be divided into two main groups, biogenic carbons and fossil carbons. Fossils carbons are found in products such as synthetic fabrics and plastic and are largely non-degradable. Biogenic carbons are degradable carbons from food waste and paper (Couth and Trois, 2010).

Municipal Corporation of Greater Mumbai (MCGM) and Newcastle Local Municpality (NLM) were selected as representative municipalities in developing countries in terms of their socio-economic parameters and MSW management systems. The Deonar landfill site was selected from four landfill sites due to the potential of projects that can be implemented on site. Newcastle Local Municipality is an emerging municipality that was selected as a case study to benchmark waste management practices across municipalities of different sizes in SA and to determine an appropriate waste management technology for each municipality. In Figure 1-2 is a map of South Africa showing the geographical location of Newcastle. In Figure 1-3 is a map of India showing the geographical location of Mumbai.

Figure 1- 2 Map of Newcastle in South Africa. Source: Courtesy of Newcastle Municipality - Road Traffic Plan (2013)

Figure 1- 3 Map of Mumbai in India. Source: (Courtesy of Municipal Corporation of Greater Mumbai 2013)

1.2 Research Background

Currently, the municipal practice is to collect, transport and dispose of solid waste at a disposal facility. Municipal treatment of waste is non-existent in most municipalities, especially in developing countries. The literature review discusses global waste management practices, especially in terms of recycling, composting and waste diversion to landfills and highlights the current state of waste management in developing countries. It is clear that developing countries require an institutional framework that will enable solid waste professionals to understand that the issues related to the management of solid waste should be addressed using a holistic approach. The National Department of Environmental Affairs has developed a National Waste Management Strategy in an effort to effectively manage waste. The aim of developing an institutional framework is to assist waste professionals in their decision making by ensuring that they adopt the strategies that are most environmentally acceptable. The National Waste Management Strategy outlines a hierarchy of the most to least desirable solid waste management strategies as follows: reducing the quantity of waste generated, reusing the materials, recycling and recovering materials, energy recovery and landfilling.

This research aimed to provide municipal waste managers with data and information on alternative strategies before landfill disposal of MSW in developing countries. Tchobanoglous (1993) describes MSW as all the waste that is generated through municipal activities or sources for which municipalities are responsible in terms of collection, treatment or disposal. The MSW stream in Figure 1.4 comprises of a dry and wet fraction (Matete and Trois, 2008; Couth and Trois, 2010).

The dry fraction contains recyclable waste and other inert residual waste, while the wet fraction contains biogenic waste which is inclusive of food and garden refuse. Both the recyclable and biogenic fractions of the waste stream can be recovered, recycled or treated to produce new energy products (Ostem, 2004; Matete, 2009). Other products can be produced from recyclable and biogenic fractions such as fertilizer from compost or bottles from waste glass.

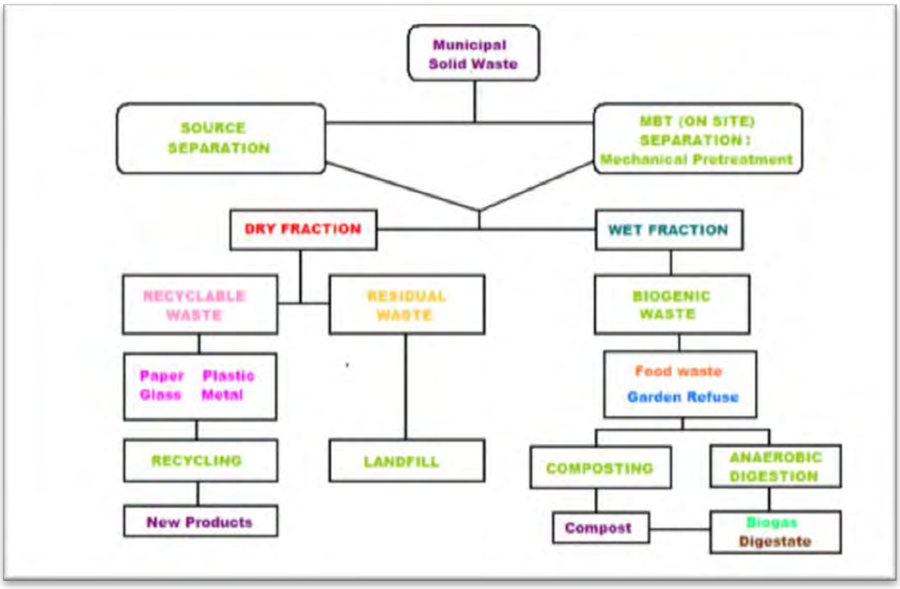

Figure 1- 4 Waste Diversion Model (Source: Couth and Trois, 2012)

Waste treatment technologies were investigated to identify the most appropriate and suitable application to maximise GHG reductions. While a number of zero waste models have been developed, the objective was to identify the most practical model that municipalities in developing countries could apply, taking into consideration the economic viability besides techinical feasibility and environmental benefits.

Major GHG emissions associated to plastic waste recycling were assessed with respect to three management alternatives: recycling clean, single type plastic; recycling mixed/contaminated plastic; and the use of plastic waste as fuel in industrial processes. Source separated plastic waste was received at an MRF and processed for granulation and a following downstream use. In the three alternatives, plastic was assumed to substitute virgin plastics in new products, wood in low-strength products (outdoor furniture, fences, etc.), and coal or fuel oil in the case of energy application. Greenhouse gas accounting was structured in terms of indirect upstream emissions (e.g., provision of energy, fuels and materials), direct emissions at the MRF (e.g., fuel combustion) (Astrup, Fruergaard and Christensen, 2009; Friedrich and Trois, 2011).

PET is not a global commodity unlike metals and paper are, primarily due to the material's (and other plastics) value/ density equation which creates challenges for entrepreneurial-driven collection. Because of this, it is not that PET would be collected in most parts of the world without publicly-initiated programmes. Strong anti-litter campaigns and overflowing landfills motivated public programmes and were an essential step in the development of PET recycling. Today, a combination of climate change, resource responsibility, waste and recycling, and related energy issues resonate more strongly with the public, captured in the concept of sustainability. The first characteristic of sustainability is its ability to fulfil its primary function which is to recycle (Friedrich and Trois, 2011).

Research across Africa has resolved that the most sustainable way to manage waste in large urban communities is to remove dry recyclables by hand picking, and through door to door collection, and/or a dirty MRF (Couth and Trois, 2012). Studies have shown that, in many African countries, composting projects are the most sustainable and if biogenic waste is removed, landfills should not require biogas extraction systems as they will mainly comprise inert and fossil carbon wastes.

Many studies have suggested that zero waste and waste diversion strategies could result in significant GHG/carbon reductions (Smith et al., 2001; Mohareb et al., 2008; Couth and Trois, 2010). This study seeks to identify waste strategies that could be applied at municipal level in developing countries like SA and India and assess their potential for MSW diversion and strategies for GHG emission reduction.

In the context of a middle-income developing country like SA, MSWM is an escalating challenge. Major South African municipalities are starting to engage with zero waste as a concept at an urban policy and planning level. The Polokwane Declaration aims to develop a zero waste plan by 2022, which will lead to an efficient and sustainable waste management system for the country (DEAT, 2001)

This research study aimed to provide data and information on the impact of PET not being landfilled and its potential for GHG reduction. Tchobanoglous (1993) describes MSW as all the waste that is generated through municipal activities or sources for which municipalities are responsible in terms of collection, treatment or disposal. The MSW stream comprises of a dry and wet fraction (Matete and Trois, 2008; Couth and Trois, 2010).

1.3 Motivation and objectives

The motivation and objectives of this research study stem from several factors and legislative developments, including the increasing emphasis on GHG mitigation (DEAT, 2009a), waste diversion, landfill space shortages, and the zero waste goals of the Polokwane Declaration (DEAT, 2001); as well as the increased attention on waste to energy technology implemented under the CDM or similar schemes (Couth et al., 2010).

There is a paucity of data on waste management activities in South Africa. Godfrey's (2008) survey of South African municipalities found that only 68.9% collected some data on waste management, and that the type and quality of these data varied considerably.

1.4 Research Questions, Aim and Objectives

1.4.1 Research Questions

1.4.1.1 What fraction of the waste stream can be diverted from landfills and what treatment options are available?

1.4.1.2 Which waste management strategies have the most potential to maximise GHG savings (from an economic, social and technical point of view)?

1.4. 1.3 How should local authorities assess different solid waste treatment options and how can municipalities be supported in their decisions on waste management strategies?

1.4.2 Aim and Objectives

Aim

To develop an institutional framework that could assist municipalities in South Africa and other developing countries to adopt a waste management strategy to maximise the reduction of GHG emissions using appropriate technologies.

Objectives

- To analyse waste management in Mumbai, India and characterise the waste stream inclusive of sources and quantities.
- To comprehensively assess waste management in Newcastle, South Africa and conduct a waste stream analysis, highlighting unique aspects of waste management (PET recycling).
- To develop an institutional framework as a decision making tool to support municipalities and their various stakeholders in implementing waste management strategies.

1.5. Field Work

The external collaborators involved in this research project were the MCGM and NLM. With input from these sources, a detailed waste stream analysis was to determine the amount of waste that contributes to GHG emissions. Data on the tonnage of organic, inorganic, combustible, non-combustible waste in the waste stream was collected from these entities through examination and statistical analysis of data records, an investigation of trends in waste generation and physical waste assessment using representative sampling, collection and sorting methods.

1.5.1 Statistical Analysis: The data attained were used to maximise the reduction of GHG emissions through a comparative analysis of recycling/waste minimisation strategies in developed countries and their potential for implementation in developing countries.

1.6 Critical Review

The outcomes of the statistical analysis are critically reviewed. The development of an institutional framework could assist local municipalities in developing countries like SA and India to determine the best management strategy to maximise the reduction of GHG emissions from waste. The study assesses best waste management practices as a mitigating tool in comparison with current/alternative methods.

1.7 Structure of the Thesis

This thesis is structured into seven chapters.

Chapter one provides an overall introduction to the study.

Chapter 2 presents a literature review that outlines the context for the study. Available waste treatment technologies are investigated as well as the waste policy and status quo of waste management in SA and India. South Africa's legislative framework is discussed, as well as the National Environmental Management Strategy. GHG emissions from the individual waste management procedures which make up a municipal waste management system are summarized and compared, with an emphasis on developing countries, especially India and SA. This is the initial step in developing an all-inclusive GHG accounting for municipalities.

Chapter 3 discusses the research methodology adopted for this study, including the key informants that were interviewed for the case studies and the questionnaires administered to households. It also discusses the methodology employed to conduct the waste stream analysis of the selected sites.

Chapter 4 presents a case study on waste management in India, including the collection, transportation and disposal of MSW with a focus on waste entering the Deonar Landfill Site in Mumbai.

Chapter 5 present a case study on waste management in Newcastle, South Africa. The first part of this chapter discusses the collection, transportation and disposal of MSW, while the second focuses on an alternative technology that is utilised in Newcastle to divert plastic (PET) from the landfill to a process plant.

Chapter 6 presents an institutional framework as a decision making tool for municipal waste management strategies based on the experiences of Newcastle Municipality.

Chapter 7 summarises the study's key findings, presents final conclusions and offers recommendations for further research.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

This chapter outlines the context for the study. Available waste treatment technologies are considered as well as the waste policy and status quo of waste management in SA and India. An objective of this research is to determine the potential greenhouse gas reductions from using waste diversion strategies in developing countries' municipalities, especially with regard to India and South Africa. In general, majority of the studies investigate greenhouse gas emission from waste focussed on waste disposal through landfilling, and rarely includes other processes; in particular waste minimisation. Developing countries have population sizes which contribute significantly as generators to municipal solid waste which have been less researched than developing countries. This chapter also provides an overview of current practices, waste treatment and waste to energy technologies.

The Waste-to-Energy Research and Technology Council concluded, that, there are more than 700 WTE projects in over 37 countries worldwide (WTERT, 2010). It is important to state that not all technologies are suitable for there are different types of municipalities; it will vary according to the size and charateristics of that municipality. All countries involved in sustainable waste management strategies have similar waste diversion to landfill characteristics. These include the expansion of recycling and composting and the minimisation of waste disposal to landfill. The Earth Engineering Centre analysed the extent of recycling, landfilling and creating energy from waste in European countries. Figure 2.1 depicts that developed countries have been most successful in minimising the use of landfills in their waste management strategies.

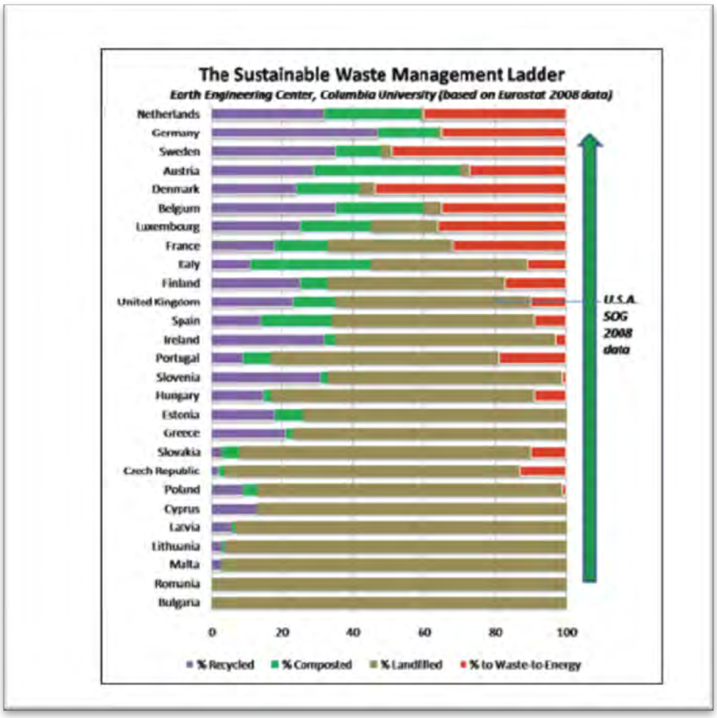

Figure 2- 1 Waste management practices in the European Union (WTERT, 2010)

The Netherlands and Germany have attained zero waste to landfill, while Denmark and Sweden lead the European Union (EU) in treating their MSW with WTE technologies.

2.2. Legislation and Policy Air Quality Policies, Legislation and Regulations - LFG

In most jurisdictions in South Africa and India, air quality policies and regulations are in their infancy and are still being developed. One important principle that seems to be disregarded in Landfill gas (LFG) projects is that the net total emissions before, and after, a project should be considered in assessing the merits of a specific project or candidate site. In some jurisdictions, it has been problematic to meet emission reduction targets as a result of combustion products other than methane. It is recommended that the net impact and benefits of all emissions reductions be considered when evaluating the merits and benefits of a prospective project. With most LFG management, Carbon Emission Reductions (CERs) offer immense benefits. There is also a very significant benefit in reducing the emissions of volatile organic compounds, as they are contributors to both GHG and toxic gas emissions. There is typically a slight increase in NOx and SOx emissions from LFG management projects but the overall air quality benefits far exceed the implications of these minor increases. South Africa's extensive use of coal and petroleum fuels has significant adverse impacts on both the local and global environment.

For example, most of the methane released from the country's energy sector is the result of coal mining. Land scarring is caused by pit digging and discard dumping. The extraction of large quantities of coal leads to noticeable environmental impacts and 'upstream' emissions.

South Africa is presently drafting stringent air quality standards. The country is a signatory to the United Nations Framework Convention on Climate Change (UNFCCC); at the same time, it is Africa's highest emitter of GHGs. It is very likely that targets will be obligatory on South Africa as soon as these are applied to developing countries. Complying with such obligations, both local and global, will be expensive. To ensure sustainable development, this should not be done at the expense of the country's socio-economic development.

2.2.1 Policies, Legislation and Regulations on Landfill Gas Management Projects

One of the most important factors that must always be recognized in LFG management projects is that they are associated with landfill sites. This means that the performance of some of the aspects of landfill design, operations and maintenance other than LFG management itself can be relevant to the stable, long term performance of an LFG system. LFG systems generate a substance known as waste liquid that must be collected and disposed of. The quantities are generally quite immaterial relative to the volumes of leachate that are generated in a landfill. However, care should be taken to not impose any cost prohibitive restrictions on condensate management and disposal. Condensate should be treated in a similar manner to the leachate generated in the landfill.

Regulation dictating the daily operations of the landfill has the capacity to affect the generation of LFG if there are requirements for the construction or operations of the landfill. For example, there could be a requirement for the use of a low permeable daily cover, which would impede the potential to collect LFG and impact on the initial rate of LFG generation. There are many impediments to the use of techniques such as moisture addition to the waste, as used in bioreactor landfills.

Legislation affecting the type of waste permitted in a landfill can have a negative effect on an LFG management project if there is an emphasis on removing the organic material from the waste stream. This is for the reason that LFG is generated by the biogenic fraction of the decomposing waste. Future projections of waste filling are a significant component of LFG generation projection and are therefore directly related to the value of the resource and the economic justification for such a project.

It is important to not only have a good understanding of the current regulations and policies governing the design and operations of the landfill, but also take cognizance of any upcoming legislation that could affect the viability of the LFG management project. The general life of these projects, especially LFGTE projects, makes them vulnerable to the introduction of future legislation, especially voluntary GHG emission reductions.

The DEA will approve suitable emissions factors and procedures, consistent with international information published by Intergovernmental Panel and Climate Change (IPCC). According to the 2011 White Paper, the DEA will introduce mandatory reporting of GHG emissions for entities, companies and installations that release in excess of 100 000 tonnes of GHGs annually, or consume electricity that results in more than 100 000 tonnes of emissions from the electricity sector.

The sources of GHG emissions are diverse and include direct emissions from sources that are owned or controlled by an entity; indirect emissions resulting from the generation of electricity, heating and cooling, or steam generated off site but purchased by the entity; and indirect GHG emissions from sources not owned or directly controlled by the entity but related to its activities.

From most perspectives, the most important component of LFG is methane, which constitutes approximately 50% of the LFG volume produced. Methane is a potential hazard since it is combustible and explosive at concentrations between 5% and 15% in air. LFG can migrate below ground surface in the unsaturated soil zones, especially during winter and spring when the ground is frozen or saturated with moisture at the surface. LFG can then accumulate in the enclosed structure, posing a potential hazard. Methane has no odour and is therefore impossible to detect without proper instrumentation.

Methane released from landfill has been known as a significant contributor to GHG emissions, which contribute to global warming. Over a 100-year time horizon, in comparison with CO_2, methane is considered to be 21 times more efficient at trapping heat within the atmosphere (IPCC, 1995).
Presently under review and could be revised upwards in the future, in addition increasing the incentive for LFG management projects. Methane generated from solid waste and wastewater through AD represents about 20% of human-induced methane emissions (IPCC, 1999).

The EPA uses the waste generation reference point to measure GHG emissions (GHG emissions are accounted for at the point of waste generation). All subsequent emissions and sinks from waste management practices are counted. Changes in emissions and sinks from raw material acquisition and manufacturing processes are captured to the extent that source reduction and recycling affect these processes. Negative emission factors indicate that, from a waste generation reference point, a given management practice for a particular material type results in emission reductions. However, it is important to note that none of the management-specific emission factors should be used on their own as it is the difference between two competing management practices that matters.

2.3.1 South African Policies and Legislation

2.3.1.1 National Environmental Management Act

The National Environmental Management Act (NEMA), Act 107 of 1998 is the framework legislation for environmental protection in SA. The environmental management principles set in this Act are the basis for dealing with environmental issues. The concepts of sustainable development and equity support these principles. The specific principles outlining waste management are:

- "*Polluter pays"* – those liable for environmental damage must pay both to repair the damage to the environment and human health as well as the costs associated with preventative measures to reduce or prevent further pollution or environmental damage.
- *"Cradle-to-grave"* – responsibility for the environmental health and safety consequences of a policy, program, project, product, process, service or activity exists throughout its lifecycle. It starts with conceptualisation and planning and runs through all the stages of implementation to re-use, recycling and ultimate disposal of the product and waste or the decommissioning of installations.
- *"Precautionary principle"* - government will apply a risk averse and cautious approach that identifies the limits of current knowledge about the environmental consequences of decisions or actions.
- *"Waste avoidance and minimization"* – waste management must reduce and avoid the creation of waste at source, especially in the case of toxic and hazardous waste. Government must encourage waste recycling, separation at source and safe disposal of unavoidable waste.

2.3.1.2 National Environmental Management Act: Waste Act

The National Environmental Management: Waste Act, 2008 (Act No. 59 of 2008), the "Waste Act", gives legislative effect to the constitutional imperatives in relation to waste management. The objectives of the Waste Act are structured around the guidelines in the waste management hierarchy, which is the overall approach that informs waste management in SA. The various instruments set out in this Act give effect to the duty of care, including norms and standards, integrated waste management plans, industry waste management plans, extended producer responsibility, and priority waste.

2.3.1.3 The National Waste Management Strategy (NWMS)

The overall objective of the NWMS is to minimise the generation of waste and the environmental impact of all forms of waste, thereby ensuring sound socio-economic development, a healthy population and that the quality of our environmental resources are no longer adversely affected by uncontrolled and uncoordinated waste management. The internationally accepted waste hierarchy approach to waste avoidance, reduction, re-use, recycle, recovery, treatment and disposal informs the strategy

The NWMS provides the framework within which the actions of different stakeholders are located. This includes stakeholders in all spheres of government, industry, labour unions, community-based and non-governmental organisations, and the public at large. It outlines the different roles and responsibilities of each stakeholder and level of government.

The NWMS establishes goals that are directly relevant to waste management and recycling infrastructure, including:

1. Promotion of waste minimization, re-use, recycling and recovery of waste;
2. Efficient and effective delivery of waste services;
3. Increasing the contribution of the waste sector to the green economy;
4. Achieving integrated waste management planning;
5. Thorough budgeting and financial management for waste services; and
6. Effective compliance with and enforcement of the Waste Act.

These goals should inform best practice approaches to the management of waste and recycling infrastructure.

2.3.1.4 National government

The National Department of Environmental Affairs (DEA) and its provincial counterparts are responsible for the overall implementation of the Waste Act. The Act outlines mandatory provisions that the DEA must address, which include:

- Establishing the National Waste Management Strategy;
- Set national norms and standards;
- Establishing and maintaining a National Contaminated Land Register;
- Establishing and maintaining a National Waste Information System; and
- Preparing and implementing a National Integrated Waste Management Plan.

2.3.1.5 Provincial government

Provincial government is the primary regulatory authority for waste activities, except for activities for which the Minister is the authority. It must encourage and ensure the implementation of the NWMS and national norms and standards. Provinces have a number of discretionary powers in terms of the Waste Act. To ensure a consistent regulatory environment for waste management, provinces are only permitted to exercise these discretionary powers where clear and compelling reasons exist, after consultation with the DEA.

2.3.1.6 Local government

Local government must make available waste management services, which include waste removal, storage and disposal services, as per Schedule 5B of the Constitution. Municipalities must work with industry and other stakeholders to extend recycling at municipal level. They must provide additional bins for separation at-source, and are responsible for diverting organic waste from landfill and composting it. Municipalities must facilitate local solutions for the establishment of Buy Back Centres and Material Recovery Facilities rather than providing the entire recycling infrastructure themselves. They must designate a waste management officer in their administration to co-ordinate waste management matters.

In its 2011 National Waste Management Strategy (NWMS), the DEA recognized the pressures experienced by waste management facilities, including:

- Increasing volumes as the population increases and the economy grows;
- The increased complexity of waste streams due to urbanization and new industrial processes;
- Limited understanding of waste flows as the submission of waste data is not mandatory;
- A policy and regulatory environment that does not actively encourage the waste management hierarchy; and
- Growing pressure on outdated waste management infrastructure, with decreasing levels of capital investment and maintenance.

The Waste Act (2008), which informs waste management practices in the country, defines the waste management hierarchy in downward order of priority as waste avoidance and reduction, re-use and recycling, recovery and treatment and disposal as the last option.

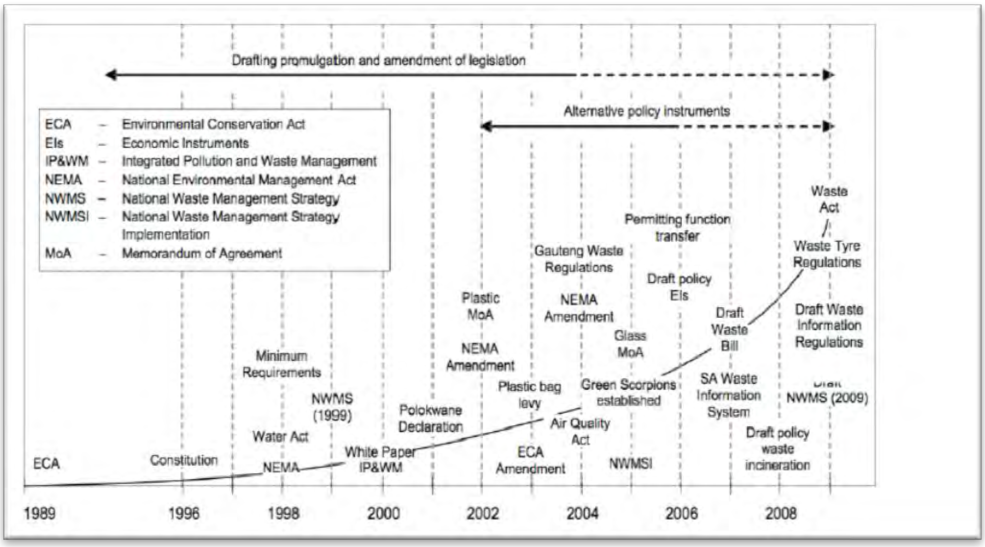

Figure 2- 2 Development of Waste Policies in SA; (Source: Godfrey and Nahman, 2008)

The purpose of the NWMS, which is a legislative requirement of the Waste Act (2008), is to achieve the objectives of the Act. The NWMS must be reviewed every five years. It must outline an action plan that specifies how the three spheres of government and industry will give effect to the NWMS. The current NWMS recognises the need for energy recovery for waste types that cannot be re-used or recovered.

The treatment of waste is defined by the Waste Act of 2008 as:

"any method, technique or process that is designed to-

(a) change the physical, biological or chemical character or composition of a waste; or

(b) remove, separate, concentrate or recover a hazardous or toxic component of a waste; or

(c) destroy or reduce the toxicity of a waste,

in order to minimise the impact of waste on the environment prior to further use or disposal" (DEA, 2008).

2.3.1.7 Municipal Systems Act

The Municipal Systems Act No 32 of 2000 is a significant piece of legislation as it relates to the planning and undertaking of municipal service delivery and development. Amongst others, the objectives of the Act are to provide for the core principles, mechanisms and processes that are essential to enable municipalities to move progressively towards the social and economic upliftment of local communities, and ensure universal access to essential services that are affordable to all; to provide for community participation; to create a simple and enabling framework for the core processes of planning, performance management and resource management and to provide for legal matters pertaining to local government.

Section 77 of the Act sets out the times when municipalities must both review and decide on a mechanism to provide municipal services, including when:

- preparing or reviewing its Integrated Development Plan;
- a new municipal service is to be significantly upgraded, extended or improved;
- Instructed to do so by the provincial executive acting in terms of section 139 (1) (a) of the Constitution.

The establishment of certain types of recycling services or facilities may trigger the first two items listed above. In such a case, Section 78 of the Act sets out the criteria and process for deciding on mechanism to provide municipal services. The municipality must first assess:

- the indirect and direct cost and benefits related with the project if the service is provided by the municipality through an internal mechanism, including the expected effect on the environment and on human health, well-being and safety;
- the municipality's capacity and potential future capacity to provide the skills, expertise and resources essential for the provision of the service through an internal mechanism;
- the degree to which the re-organization of its administration and the development of human resource capacity within that administration could be utilized to provide a service through an internal mechanism;

- the potential economic impact on development, job creation and employment patterns in the municipality;
- and, perception of organized labour.

Having undertaken the above assessment, a municipality may:

- decide on a suitable internal mechanism to provide the service; or
- before it takes a decision on an appropriate mechanism, explore the possibility of providing the service through an external mechanism.

If a municipality decides to investigate the possibility of providing a service through an external mechanism it must:

- give notice to the local community of its intention to investigate the provision of the service through an external mechanism; and
- assess the different service delivery options, taking into account:
- the anticipated benefit of any service delivery mechanism on the environment and on human health, well-being and safety.
- the capacity and potential future capacity of potential service providers to furnish the skills, expertise and resources necessary for the provision of the service;
- the opinions of the local community;
- the probable impact on development and employment patterns in the municipality;
- the views of organized labour.

2.3.2 Solid Waste Policies in India

Solid waste policy in India specifies the duties and responsibilities for hygienic waste management for cities and citizens of India. The policy was framed in September 2000. They also serve as a guide on how to comply with the MSW rules. Both the report and the rules are based on the principle that the best way to keep streets clean is not to dirty them in the first place. So a city without streetbins will ultimately become clean and stay clean. They advocate daily doorstep collection of “wet” (food) waste for composting, which is the best option for India. This is not only because composting is cost-effective process practiced in old times, but also because India’s soils need organic manures to prevent loss of fertility through unbalanced use of chemical fertlizers. (Wikipedia.org.solid waste policy in India)

2.3.2.1 Municipal Solid Waste Rules

To stop the present unplanned open dumping of waste outside city limits, the MSW rules have laid down strict timetable for compliance, improvement of existing landfill sites by the end of year 2001. Identification of landfill sites for long-term future use and making them ready for operation by end of year 2002 setting up waste-processing and disposal facilities by end 2003 and provision of a buffer zone around such sites. Biodegrable waste should be processed by composting, vemicomposting etc. and landfilling shall be restricted to non-biodegrable inert waste and compost rejects.

The rules also require municipalties to ensure community participation in waste segregation (by not mixing “wet”food waste with “dry” recyclables like paper, glass, metal etc) and to promote recycling or reuse of segregated materials. Garbage and dry leaves are not allowed to be burnt. Biomedical wastes and industrial wastes are not allowed to be mixed with municipal waste. Route use of pesticides on garbage has been banned by the Supreme Court on 28.7.1997. (Wikipedia.org.solid waste policy in India)

Littering and throwing of garbage on roads os prohibited. Citizens should keep their wet (food) waste and dry (recyclable) waste within their premises until collected and must ensure delivery of wastes as per the collection and segregation system of the city, prefably by house-to-house collectin at fixed times in multi-container handcarts or tricyles (to avoid manual handling of waste) or directly into trucks stopping at street corners at regular pre-informed timings. Dry waste should be left for collection by the informal sector (sold directly to waste-buyers or given free or otherwise waste-pickers, who will earn their livehihood by taking the waste they need from homes rather than from garbage on the streets. High-rises, private colonies, institutions should provide their own bigbins within their own areas, separately for dry and wet wastes. (Wikipedia.org.solid waste policy in India)

2.4 Treatment Technologies

The types of technologies that will be appropriate for municipalities will be specific to their waste generation to treat their municipal solid waste with the intention of reducing the amount of waste for disposal. There are technologies that are suitable for mixed waste stream (wet and dry waste), as well as for the treatment for source separated waste where recyclates (dry waste) are removed from the waste stream. Green waste (garden waste) can be treated by treatment technologies which include mechanical, biological and thermal processes.

2.4 1. Mechanical Biological Treatment

Mechanical Biological Treatment (MBT) refers to the treatment of waste using both mechanical and biological processes. The separation processes utilised in MRFs are preliminary treatment in MBT, where recyclates are separated from the waste stream through mechanical processes and organic waste are treated biologically through anaerobic digestion or composting (Smith et al., 2001). This reduces the organic fraction of waste (Marsh et al., 2007). Verantwortung, 2014 descibes mechanical treatment systems are used in various stages of waste treatment. They can be used for sorting and separation processes as part of material recycling facilities key function, shredding and screening as a pre-post treatment stage of biological and thermal treatment, or used in conjunction with biological or thermal treatment as part of mechanical biological treatment (MBT) and mechanical heat treatment (MHT) system from mixed waste streams.

2.4.1.1 Recycling and MRF

2.4.1.1.1 Recycling

Mixed recycling is input into the process in an untreated form. A series of processes can be undertaken to either remove waste which cannot be treated (oversized items and contamination) or to prepare waste so that it can be accepted by the mechanical technologies at the next stage of the MRF process. (Verantwortung, 2014)

Reducing and reusing are the most effective ways to avoid the generation of waste. Once the waste is generated and collected, the best alternative is recycling where the materials generally undergo chemical transformation. As much as 95% of a product’s environmental impact occurs before it is discarded or disposed (Friedrich and Trois, 2011), most of it during the manufacturing and extraction of virgin raw materials. Recycling is a complex waste management issue which is beyond the scope of this study; however, in terms of GHG emissions it presents definite advantages for municipalities in all countries. (Friedrich and Trois, 2011).

However, recycling involves a separated stream of waste, whether source separated or separated later on (after collection) (Annepu, 2012) The informal recycling sector, (waste pickers who reclaim recyclables in the waste management system) in developing countries plays a pivotal role in reducing GHGs, as shown by Chintan (2009) for India. In Delhi alone, about 962 x 10^3 tonnes of CO_2 were saved through informal sector recycling, which attained very high recovery rates (mixed paper, 95%, mixed plastics and metals, 70% and glass, 75%). These informal GHG savings compare favourably with other formal initiatives (CDM projects for waste to energy and composting) being more than three times greater (Chintan, 2009). In addition to GHG savings, the informal recycling sector provides an income for about 15 million waste pickers in 2007 alone and offered other advantages to the formal waste management system at local level (e.g., reduced volumes of waste, savings on the cost of collection, transport and disposal, and the extended life of a landfill) (Wilson et al., 2006; Medina, 2008). However, these marginalized groups are not supported by the authorities, lack access to finance (e.g., a carbon trading scheme) and are in conflict with formal reduction projects (access to recyclables is reduced in the case of WTE projects). South African legislation (Waste Bill, Act 59 of 2008) does not recognize the role of waste pickers in municipal waste management (Friedrich and Trois, 2013).

The recycling process is different from the production process of the substituted products, and comparable function needs to be defined to determine the amount of products that are being replaced. While the composition of waste-derived products and virgin-material-derived products may be different, the impacts of the disposal of these products of a comparable life cycles assessment. Part of the recycling process includes production processes with modified technologies and updated facilities. (Chen et al., 2011).

In the present recycling process, or the business-as-usual (BaU) process, waste plastics are shredded into pellets and granules. For the BaU technology, Polypropylene (PP) and Polythylene (PE) were recycled to produce plastic resin (50% PP and 50% PE), and the remainder was assumed to replace wooden products. (Asrupt et al., 2009).

Friedrich and Trois (2013) examined GHG emissions from different municipal waste management systems in developing and developed countries with a focus on the African continent and SA. Developing countries do not have an obligation to report on GHG and there is less data and information on waste management in general and in particular for the quantification of GHG. In the absence of such data, a variety of assumptions are made in calculating the waste generation rate for African countries (IPCC, 2006) which presently seem to be over-estimated. In investigating GHG emissions from individual processes there is agreement on the magnitude of the emissions expected from each process (generation of waste, collection and transport, disposal and recycling). Recycling brings about the highest savings of GHG, followed by composting and incineration with energy recovery. The disposal of waste in landfills has some of the highest GHG emissions. These emissions are of particular concern in developing countries due to the methane released by dumpsites and landfills.

Recovered plastic waste can be utilised for material recycling or energy utilization. Material recycling is recycling into new products, while energy utilization may include the use of the plastic waste as fuel in industrial processes or the production of solid fuel for energy production facilities such as power plants. Plastic recycling may follow one of two routes according to the products that are being produced and the materials that recycled plastic replaces. Recycling of plastic into new, high-quality plastic products requires that the recycled plastics cannot reach the quality required by high quality plastic products. Hence downcycling is encouraged and is usually Recycled plastics cannot reach the quality required by high quality plastic products, Hence downward recycling is promoted.used for products such as fences, garden furniture and pallets, that are often made of other materials (Astrup, Fruergaard and Christensen, 2009).

2.4.1.1.2 Materials Recovery Facilities (MRFs)

Materials Recovery Facilities form part of the waste treatment process by providing a method for the recovery of recyclables and separation of organic waste (Bovea and Powell, 2006). Mechanical treatment systems are utilised in various stages of waste treatment. They can be used for sorting and separation processes as part of materials recycling facilities (MRFs) key function, shredding and screening as a pre-or post treatment stage of biological and thermal treatment, or used in conjunction with biological or thermal treatment as part of mechanical biological treatment (MBT) and mechanical heat treatment (MHT) system for mixed waste stream. (Verantwortung, 2014)

The recovery or reclaiming of resources from waste can provide much needed income for the lower income strata. Local governments can invest in MRFs in which recyclates are removed from the waste stream. These include paper, fabric, metal and glass (Couth and Trois, 2010). The sales of recyclates are competitive among the low income strata. Transport costs to factories that use recyclates are exhorbitant therefore the cost of a kg of recyclates are minimal.

Resources or materials recovery is a policy that should be embraced in developing countries because it will contribute to the development of organized, systematic waste management, and result in a considerable reduction in the amount of waste that requires disposal. Diaz et al. (2007) note, that, it deals meaningful employment and improves social and environmental conditions. Resource recovery provides a source of income for a relatively large number of people in lower income strata. It can be implemented at two levels:

1) Manual recovery of the solid waste by individuals before collection, treatment or disposal; and
2) A combination of manual and mechanical processes carried out on a relatively large scale in accordance with a plan approved by the local government (MRF).

Recovery is well-defined as the process in which the refuse is collected without prior separation, and the desired materials are separated at a central facility. A typical MRF is illustrated in the Figure 2-3 below.

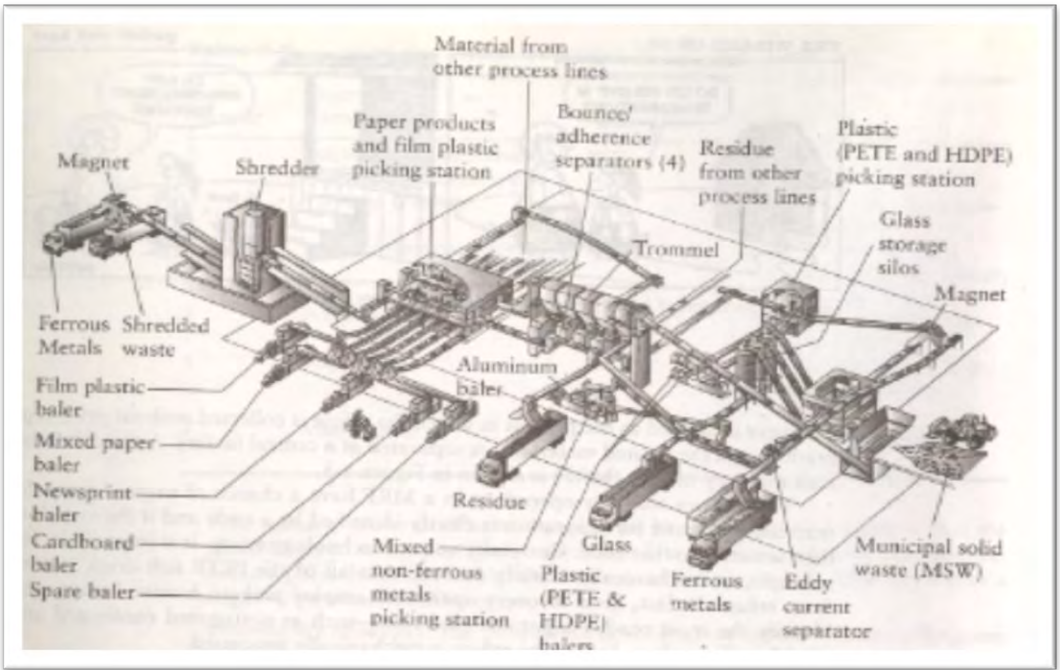

Figure 2- 3 Materials Recovery Facility Source: Integrated Solid Waste Management (Vesilind, Worrell and Reinhart, 2002)

At this stage of the process a MRF will have a partially sorted waste stream with a large proportion of non-recyclable materials removed. A number of techniques can be employed to separate specific materials at this stage with a varying degree of complexity dependent upon the target material. (Verantwortung, 2014) The various recovery operations in an MRF have a chance of succeeding if the material presented for separation is clearly identified by a code and if the switch is sensitive to that code. Currently, no such technology exists. For example, it is impossible to mechanically identify and separate all PET soft drink bottles from refuse. Most recovery operations employ pickers, human beings who identify the most readily separable materials such as corrugated cardboard and HDPE milk bottles before the waste is mechanically processed (Vesilind, Worrell and Reinhart, 2002). Verantwortung, 2014 described that homogenous material streams allowed that some mechanical sorting technologies will separate a product stream with a small of contamination. He further explained that this improves the quality of recyclate produced which ultimately lead to a higher market price for the materials segregated by a MRF.

Most refuse items are not made from a single material; in order to use mechanical separation, these items must be separated into discrete pieces consisting of a single material. A common “tin can” also contains metal in its body, zinc on the seam, a paper wrapper on the outside, and perhaps an aluminium top. Other common refuse items pose equal challenges to separation. One means of producing single-material pieces and thereby assisting in the separation process is to decrease the particle size of refuse by grinding the clean (single material) particles. This results in many clean (single-material) particles. The size-reduction step, although not strictly materials separation, is employed in some MRFs, especially where refuse-derived fuel is produced. Size reduction is followed by various other processes, such as classification (which separates light paper and plastics) and magnetic separation (for iron and steel) (Vesilind, Worrell and Reinhart, 2002). Verantwortung, 2014 elaborated that typically a MRF will separate steel through the use of overband magnets and aluminium using eddy currents (relying on applying an electrical charge to the material). These will usually be applied to the 3D stream although can be applied to multiple streams. Glass can be separated on account of its size (for example using a star screen, debris roll screen often with the assistance of a glass breaker which smashes the glass into manageable pieces. If the MRF accepts glass and paper combined, the quality of the paper may be compromised by glass shards and therefore have a reduced market. If the glass fraction is of high enough quality it can be sorted by colour using optical sorting equipment at dedicated facilities, although a more common use is as a secondary aggregate. Secondary aggregates are by-products of other industrial processes that have been used in construction. (https://www.nibusinessinfo.co.uk/content/using). It was further elaborated that paper can be separted at an early stage using star screen (or similar technologies) based on its two dimensional nature. The MRF will separate cardboard from the mixed paper stream, and if practicable will target newspaper or similar material value.

While it seems attractive, the recovery of materials is still a marginal option. The most problematic task faced by an engineer designing such facilities is the availability of firm markets for the recovered product (Vesilind, Worrell and Reinhart, 2002).

Studies show that recycling produces significant decreases GHG emissions by reducing the consumption of virgin materials and the energy required for production processes (WRAP, 2006).

2.5. Biological Technologies: Waste composting and Anaerobic Digestion

The biological technologies under review are Anaerobic Digestion (AD) and composting, while the thermochemical technologies are Pyrolysis, Conventional Gasification and Plasma Arc Gasification. Landfill Gas (LFG) to energy was investigated at Gorai Landfill Site in India and the Newcastle landfill as a case study.

Mechanical Biological Treatment (MBT) is a waste treatment process that includes mechanical waste screening and biological treatment that reduces the organic fraction of the waste (Marsh et al., 2007). The residue of by-products from the biological treatment can be pelletized into Refuse Derived Fuel (RDF) to improve the bulk density of the waste for easy and efficient loading into a combustion process to create energy (Marsh et al., 2007).

The separation processes in MRFs are used for preliminary treatment of MBT, where recyclates are separated from the waste stream through the mechanical processes and organic wastes are treated biologically through anaerobic digestion or composting (Smith et al., 2001).

2.5.1 Waste Composting

The United Nations Environment Program (UNEP) (2011) defines composting as the biological decomposition of biodegradable solid waste under primarily aerobic conditions to a state that is sufficiently stable for nuisance-free storage and handling and is satisfactorily matured for safe use in agriculture. As noted by the Cornell Waster Management Institute, composting can also be defined as human intervention in a natural process of decomposition. The biological decomposition accomplished by microbes during the process includes oxidation of the carbon present in the organic waste. Energy released during oxidation is the cause of a rise in temperature in windrows during composting. Due to this energy loss, aerobic composting falls below anaerobic composting on the hierarchy of waste management. Anaerobic composting recovers energy and compost and is discussed in detail (Annepu, 2012).

The total carbon content of MSW can be separated into two main categories - biogenic carbon and fossil carbon (Moller, 2007, cited in Couth and Trois, 2012). Biogenic carbon is mainly found in biodegradable fractions, such as organic kitchen waste, cardboard (bio-waste), and paper. Fossil carbon is non-degradable and is found in plastic and synthetic fabric. The anaerobic degradation of biogenic waste in landfills generates CH_4 which is an important GHG with global warming potential 21 times greater than CO_2. However, the volume of methane formed can be significantly reduced by the composting of MSW prior to disposal (Couth and Trois, 2012).

Originally, composting was categorized into aerobic vs anaerobic and many arguments were offered in favour of one or the other. However, over a period, the approach became the usual one, and anaerobic composting fell into disfavour (Diaz, Savage and Golueke, 1994). In SA biogas consumption is presently confined to wastewater treatment works, some rural applications and a solitary landfill site. Kolbe, Svidov and Oliver's study sought to optimize landfill design and operation to improve biogas generation and subsequent utilization, thereby converting this waste product into a resource. Biogas is taken to be any biologically generated gas with methane (CH4) and carbon dioxide (CO_2) as its main constituents, and comprises of gas, sludge gas, sewer gas and marsh gas. In a well operated landfill, the waste material is compacted and isolated at the end of each working day with a soil cover. This results in the formation of a large number of waste cells which is limited, both due to the effects of compaction and the barrier formed by the daily cover layer.

Composting has the advantage that 98% of the emissions can theoretically be evaded during the period that the waste is disposed of, whereas CDM landfill gas projects can only capture and combust around 50% of emissions from the landfill gas production curve for the registered CDM project period. Furthermore, Couth and Trois (2012) investigated bulk landfill gas production over a period of 40 years for the case study of MSW production of 230 kg/head/year at a 56% organic content for a population of 1 000 000. The study showed the quantity of the gas that can be virtually captured and combusted over 40 years, and that a composting project can theoretically avoid 98% of gas emissions over a period of 10 years. In figure 2-4 is indicative of the gas sim production of composted waste.

Consequently, whilst composting CDM projects indicate to the immediate avoidance of nearly all methane emissions, CDM income is reduced and delayed. This anomaly should be addressed by the UNFCCC, and if the Kyoto Protocol is changed, Carbon Emission Reductions (CER) should be paid for CH_4 emissions avoided by composting the waste (Couth and Trois, 2012).

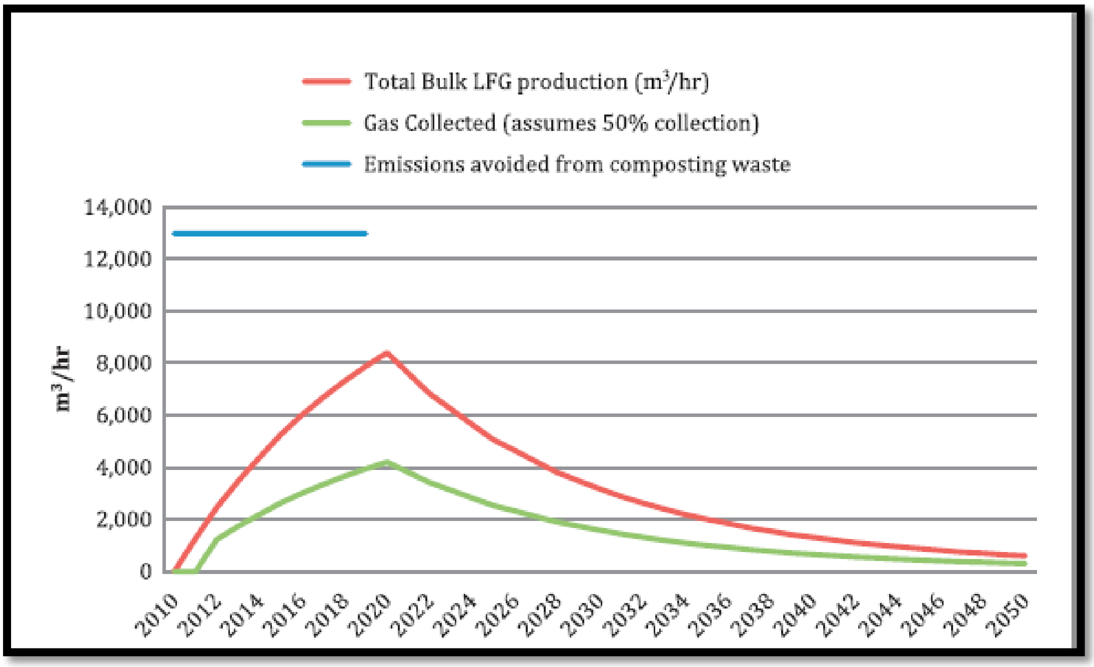

Figure 2- 4 GasSim Predictions of LFG (Source: Couth and Trois, 2012)

2.5.2 Anaerobic digestion

The zero waste model allows the majority of biogenic waste to be either anaerobically digested or composted. Anaerobic digestion (AD) refers to the degradation of biogenic waste substrates through the action of micro-organisms under anaerobic conditions (Tchobanoglous et al., 1993). According to Ostrem (2004), anaerobic digestion produces useful products in the form of digestate, which can be utilised as soil conditioner/fertilizer, and biogas, composed primarily of methane and carbon dioxide, which can be used for energy generation.

2.6 Anaerobic Digestion Technologies

The United States Environmental Protection Agency defines AD as a procedure where microorganisms break down organic materials, such as food scraps, manure and sewage sludge, in the absence of oxygen. In the context of SWM, AD (also called Anaerobic Composting or Bio-methanation) is a method to treat source-separated organic waste to recover energy in the form of biogas, and compost in the form of a liquid residual. Biogas consists of methane and CO_2 and can be used as fuel or, by using a generator, can be converted to electricity on site. The liquid slurry can be used as organic fertilizer. The ability to recover energy and compost from organic waste input AD above aerobic composting on the hierarchy of waste management.

This process occurs naturally on landfill sites when little or no oxygen is present as well as in various other environments such as wetlands (Ostem, 2004).

The AD process includes the following series of phases and biochemical reaction identified by Ostem (2004):

i) Hydrolysis: insoluble organic waste substrates (which include carbohydrates, protein and lipids) are broken down into soluble organics (respective monomers of simple sugars, amino acids and fatty acids) by hydrolytic bacteria.

ii) Acidogenesis: This phase includes the further breakdown of the soluble monomers formed during hydrolysis into simple organic compounds (volatile fatty acids, ketones and alcohols) through the action of acidogenics bacteria.

iii) Acetognesis: Acetogenic bacteria alter the resulting organic compounds from acidogenesis into organic acids (principally acetic acid), CO_2 and hydrogen (H_2).

iv) Methanogenesis: Products from acetogenesis are changed into methane (CH_4). Methanogenesis occurs primarily through the conversion of the acid formed during acetogenesis into methane (acetotrophic methanogenesis) or through the reduction of CO_2 by H_2 (hydrogenotrophic methanogenesis).

2.6.1 Products of Anaerobic Digestion

Biogas: in the context of this study, biogas refers to the gaseous product produced through AD of biogenic MSW. Biogas generally contains 55%-70% of methane, 30%-45% of CO_2 and trace gases (Monnet, 2003).

The average calorific value for biogas is approximately 23 $MJ/m^{3.}$ Biogas may be utilised to generate either electricity or heat, or a combination of the two termed co-generation or Combined Heat and Power (CHP). Biogas is generally scrubbed and the other gases present are removed to meet environmental standards and prevent the corrosion of metal components of equipment (Ostem, 2004).

2.6.2 Digestate

The digestate or sludge comprise of liquid and solid residue produced through the AD process and is essentially immature compost. Digestate involves dewatering and maturation before use. Screening and pasteurization processes may also be important to remove contaminants and ensure pathogen control for a higher quality compost or soil conditioner (RIS International, 2005; Coulon, 2010). The digestate produced can be used as a soil fertilizer or conditioner after dewatering and maturation. The utilisation of digestate fertilizer is beneficial to the agricultural sector and to the environment, reducing dependency on artificial chemical fertilizers. Digestate can also be utilised for landfill rehabilitation and landscaping (Ostem, 2004).

The benefits of AD are:

i. Reduced GHG/carbon emissions
ii. Renewable energy
iii. Satisfies environmental legislation
iv. A flexible technology that is easily included with other zero waste strategies
v. Income generation from compost, electricity and certified emission reductions

2.7 Aerobic Composting

Aerobic composting of mixed waste results in a compost contaminated by organic and inorganic materials, mainly heavy metals.

Composting is a controlled method for the decomposition of biodegradable matter under measured conditions. It is an aerobic process that allows for the creation of thermophilic bacteria from the release of biologically produced heat. If temperatures continue to rise to between 60^0C and 70^0C, pathogenic micro-organisms are destroyed and the final product material can be considered safe for land use (Couth and Trois, 2012).

Compost from efficiently sorted organic waste can be used as a fertilizer, replacing the use of mineral fertilizers; this reduces nitrate leaching. However, composting of garden refuse from MSW in South Africa has yielded poor quality compost due to feedstock contamination from plastic bags and other portions of the waste stream (Couth and Trois, 2010). In addition, as a result of the aerobic nature of the composting process, it produces less GHG emissions than landfilling (Friedrich and Trois, 2011).

Composting of organic waste is attained using in-vessel composters (IVCs) and windrows. In developing countries, these technologies are used to control moisture content, temperature and oxygen (Couth and Trois, 2012). Composting occurs in two stages, fermentation or active composting and maturation. In the fermentation stage waste is first added to the windrow, where aerobic decomposition occurs, which is the consumption of oxygen by microorganisms.

The temperature of the compost pile rises to between 40^0C and 60^0C. As the decomposition rate slows, the maturation phase begins. This is indicated by a reduction in the temperature. Once the compost pile reaches the temperature of the surrounding air, the maturation is complete (Couth and Trois, 2012). The carbon to nitrogen ratio is particularly important as these are the two most important elements in the composting process. Carbon is the main provider of energy, while nitrogen creates protein for microbial population growth.

Dome Aeration Technology (DAT) is basically a modification of the windrow composting method which does not require periodic turning. A system of thermally driven advection produced by temperature gradients between the windrow and the external environment provides a forced aeration mechanism (Griffith and Trois, 2006). DAT composting is best for the treatment of biogenic wastes due to its lower energy requirements and high efficiency, and therefore lower operating costs (Trois and Simelane, 2010).

Couth and Trois (2012) described DAT as a low cost and low energy solution to composting. A steel mesh structure is utilised to create large air spaces in the windrow known as domes and channels. These provide oxygen and temperature control through encouraging air flow through the windrow. Domes are placed vertically in the centre of the piles, while the channels extend from the exterior towards the interior, without reaching the centre. This technology is also known as passively aerated windrows as no turning is necessary. The hot gases developed during the composting are free to escape through the centrally located some chimney (Couth and Trois, 2012). Figure 2-5 shows a sample schematic of the DAT composting, with the domes and channels.

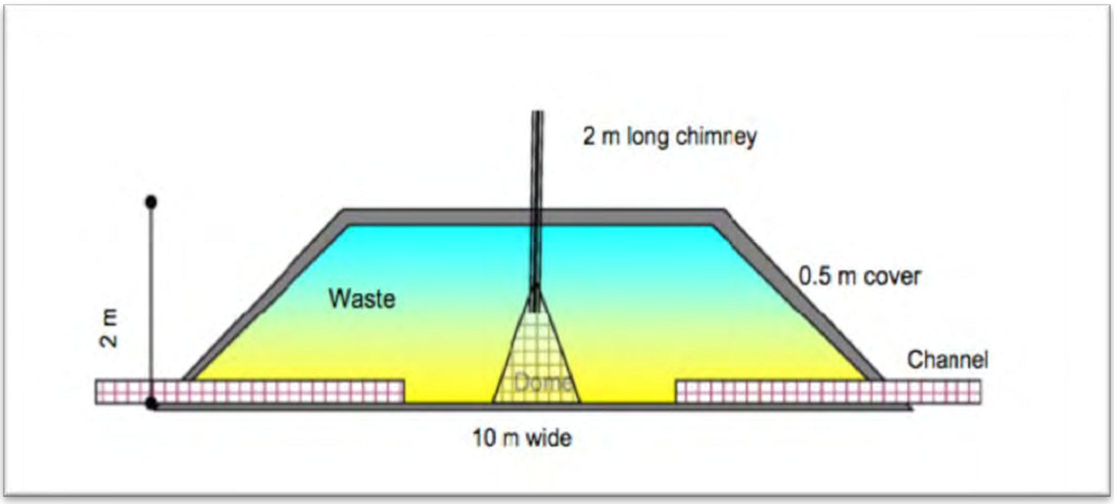

Figure 2- 5 Schematic of DAT composting (Source: Couth and Trois, 2012)

2.7.1 In-vessel composting

Enclosed reactor composting systems make provision for the decomposition of biogenic wastes within a reactor. These reactors are designed to enable a high degree of process control to optimize the composting process. Temperature, moisture content, pH and aeration parameters can be scrutinized and adjusted to optimum levels. A typical reactor system consists of a rotating drum (usually 3 meters in diameter), air blower (aeration mechanism) and an air filtration (odour control) unit (van Harren, 2009). The rotating action allow for efficient mixing, ensuring even distribution of micro-organisms, heat and moisture.

The size reduction increases reaction rates, due to the greater surface area of individual substrates. Reducing the waste particle size make provision for micro-organisms to digest a greater amount of material, increases population growth rates and produces more heat, all of which improve the overall efficiency of the aerobic composting process. A particle size of 25-75mm is considered optimal (Tchobanoglous et al., 1993). Mixing or turning of the waste material is also essential for even and uniform distribution of microorganisms, moisture and nutrients (Tchobanoglous et al., 1993). Compost can be used in a wide array of applications, the most common being as a soil conditioner, landfill cover material and fertilizer for agricultural landscaping and horticultural purposes. Another major benefit to the environment is the reduction in the use of chemical fertilizers, and reduced soil erosion. The quality of the compost made is measured by its level of essential plant nutrients such as nitrogen and potassium and depends greatly on process control. Screening of the matured compost is also required to remove contaminants such as plastic and metal. Although it is easier to implement and requires less capital investment depending on the system type adopted, it is ultimately influenced by the quantity of the waste to be composted. Technologies such as forced aeration and in-vessel systems are less likely to be implemented if sufficient input wastes are not available. Due to higher capital investment they are more technologically advanced; and require electricity and frequent monitoring and maintenance (Trois and Jagath, 2011).

2.8 Thermochemical technologies

Mass burn incineration is a form of thermal treatment where waste is combusted in incineration, producing incinerator ash, flue gases (CO_2 and water vapour), particulates and heat (Smith et al., 2001).

2.8.1 Incineration

Incineration decreases the volume of waste, and with an efficient processing method, residual organic matter is reduced completely into an inert ash, which can be safely disposed of on landfill sites without the formation of leachates (Smith et al., 2001). Refuse Derived Fuel (RDF) refers to MSW that has undergone mechanical pre-treatment to remove non-combustible materials such as metals and glass prior the separation and sorting processes of MRFs (Smith et al., 2001). The waste to be combusted is then compressed into bricks or pellets, combusted in on-site facilities and sold (Trois and Jagath, 2011). The thermal technology of incineration is not investigated. In the EU, the number of incineration plants is growing with approximately 453 plants across Europe (Saner et al., 2011). This is as a result of EU directives and policies that are shifting the focus of MSWM practices from landfilling towards waste prevention and materials and energy recovery (Saner et al., 2011). However incineration is detrimental to the environment as it releases toxins into the air as well as creating harmful ash. This put an end to natural resources and contributes to climate change (Caruso et al., 2006). Incineration is defined in modern waste management as the burning of waste without recovering materials (Wagner, 2007). The disposal of incineration residues without the formation of leachates is an ideal case that I have not heard of in reality. Later in the paragraph, you contradict this statement. In addition, there is ongoing full-scale trials to recover materials from both bottom (Morf et al., 2013) and filter ash (Fellner et al.,2015)

Incineration of waste discharges dioxins and furans into the atmosphere. These chemicals are hazardous to human health and are known as Persistent Organic Pollutants (POP). According to Chamane (2008), POP can result in diseases including tuberculosis, asthma and cancer. Incineration releases dust and waste particulates into the air. The waste is not treated or removed from the environment. In addition, reducing the waste to ash does not promote recycling, reuse and reduction, because an incinerator requires large amounts of waste to operate. Hence the energy contained in recyclables is wasted (Chamane, 2008). The disadvantage of incineration involves its high capital cost, and the fact that not all waste can be incinerated, like construction and demolition waste.

The emission of pollutants from incineration is an important drawback that has resulted in the closure of many incineration facilities throughout SA due to concerns over pollutants and air quality (DEAT, 2007). While incineration technology has become more advanced and involves many pollution control measures, it remains a “highly contentious waste management option” (Smith et al., 2001).

2.8.2 Pyrolysis and Gasification

Pyrolysis and gasification are advanced thermal options that may result in reduced emissions of pollutants. Pyrolysis produces products in liquid, solid and gaseous form. The liquid, referred to as bio-oil, it is volatile and can be utilised as a fuel, while the solid fraction is a carbon product called char (Cheung et al., 2011). The gas produced is known as syngas. The syngas is cleaned, i.e., particulates are removed, and the cleaned syngas is used to generate electricity.

The heating of feedstock is the main process of the pyrolysis system. This is a mainly endothermic reaction that includes cracking the matter (Cheung et al., 2010). There are three possible reactors for pyrolysis, a rotating kiln reactor, heated tube reactor and surface contact reactor. The surface contact reactor can accommodate small particles sizes (DEFRA, 2007). It operates at high temperatures and the small particles are rapidly heated to maximise the process of pyrolysis (DEFRA, 2007).

The cleaning of the syngas includes the removal of unwanted impurities from the thermo chemically-produced gas. These include ammonia, hydrocarbons, nitrogen-containing gases, alkali metals and other particulates (Cheng & Young, 2010).

For electricity generation, the syngas can be burned in a boiler to power a steam turbine or can be used directly in a gas engine (DEFRA, 2007). It is suggested that the pyrolysis plant be located in close proximity to an existing power plant, allowing the syngas to be transferred to it and thereby maximising energy efficiency.

Gasification is the heating of organic matter in the presence of limited oxygen temperatures above 650^{0}C (DEFRA, 2007). A controlled amount of oxygen is allowed to enter the gasification reactor, enabling the organic matter to react (Young, 2010). Conventional Gasification is almost identical to this system, differing only in the treatment of feedstock other than waste. Gasification is a sequence of complex reactions. The first is combustion of the feedstock to produce gases, char and heat. The heat is then used to dry organic matter and to kick-start the endothermic reactions to produce syngas (Kishore, 2009). In Figure 2.6 is an advanced thermal treatment plant.

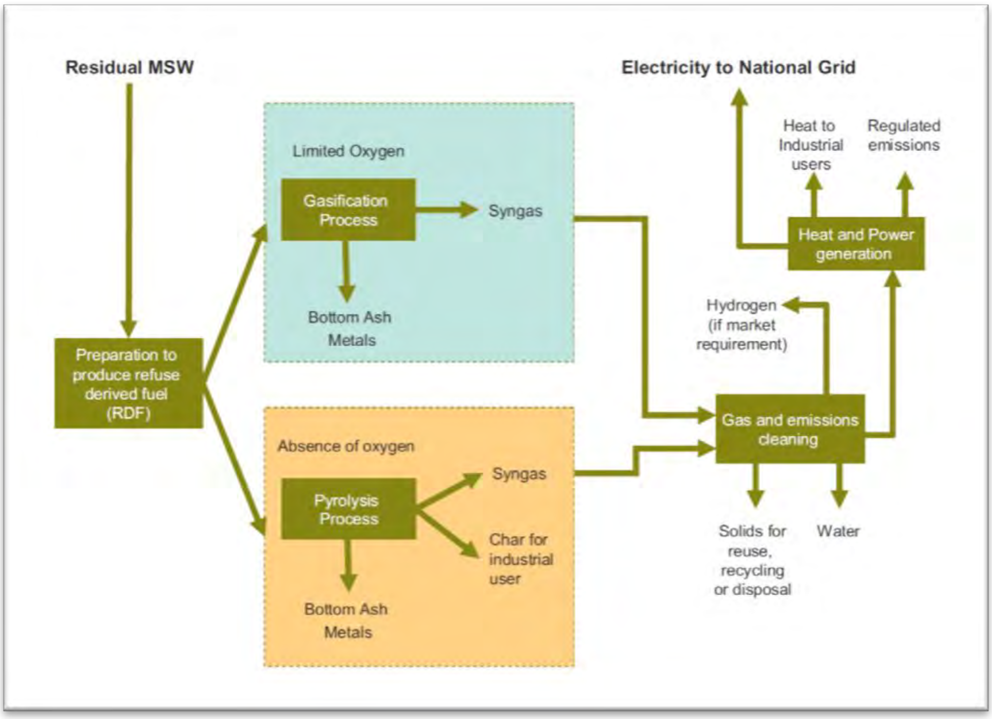

Figure 2- 6 Advanced Thermal Treatment Plant (Source: DEFRA, 2007)

2.8.3 Plasma Arc Gasification

This is an emerging technology that utilises thermal decomposition of organic waste for energy/resource recovery. The system uses a Plasma Reactor that houses one or more Plasma Arc Torches which, by applying high voltage between two electrodes, generate a high voltage discharge and consequently an extremely high temperature environment (between 5 000^0C and 14 000^0C. This hot plasma zone dissociates the molecules in any organic material into individual elemental atoms while the inorganic materials are simultaneously melted into molten lava (urbanindia.nic.in).

The waste material is directly loaded into a vacuum in a holding tank, pre-heated and fitted to a furnace where the volatile matter is gasified and fed directly into the plasma arc generator. It is pre-heated electrically and then passed through the plasma arc, dissociating it into elemental stages. The gas output after scrubbing comprises mainly of CO and $H_{2.}$ The liquefied product is mainly methanol (urbanindia.nic.in).

It is claimed that this whole process safely treats any type of hazardous or non-hazardous material. It has the advantage that NOx (oxides of Nitrogen) and SOx (oxides of Sulphur) gas emissions do not occur in normal operations due to the lack of oxygen in the system (urbanindia.nic.in).

2.9 The Hierarchy of Sustainable Solid Waste management activities

The Hierarchy of Sustainable Waste Management developed by the Earth Engineering Centre at Columbia University is usually used as a reference for sustainable solid waste management and disposal. The hierarchy of waste management recognises that reducing the use of materials and reusing them is the most environmentally friendly method. Source reduction begins with reducing the amount of waste generated and reusing materials to prevent them from entering the waste stream. The waste is generated until the end of “reuse” phase. Once the waste is generated, it needs to be collected. Material recovery from waste in the form of recycling and composting is recognized as the most effective way of handling waste (Annepu, 2012). Both practice and research have acknowledged that the waste hierarchy need not necessarily be streamlined if a life cycle assessment has proven that doing so makes sense from an environmental perspective.

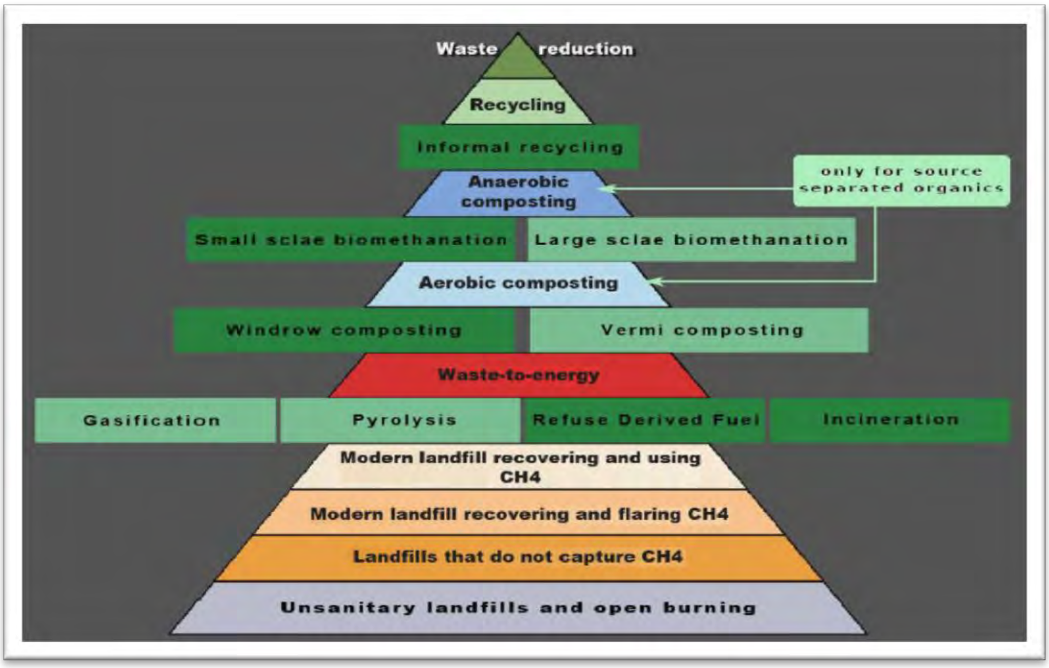

Figure 2- 7 Sustainable SWM Hierachy (Source: WTERT (Waste-to-Energy Research and Technology Council) Annepu RK 2012)

Global climate change and its impact on human society has become a reality that is receiving attention and action from the global and local community. Previously, scientists have endeavoured to draw politicians' attention to the catastrophic impact of global climate change, caused by excessive human-induced GHG emissions. However, it was not until the late 1990s that the global community took these warnings seriously. This led to landmark international mitigation agreements such as the United Nations Framework Convention on Climate Change (UNFCCC) in 1992 followed by the Kyoto Protocol under the Convention in 1997 (Friendenthal, Kristiansen and Malmdorf, 2004).

In South Africa, the National Waste Management strategy outlines the hierarchy of waste management. It details the order of priority of waste management. Every effort should be made to avoid the creation of waste at the first stage. If this cannot be avoided, appropriate fractions must be recycled or reused. This is the primary focus of this study. The third step is the treatment of waste which leads to alternative technologies; the fourth stage is the disposal of waste which is often landfilled and the final stage is the remediation of waste.

Figure 2- 8 Waste Hierarchy (Source: DEA, 2010)

The Kyoto Protocol's Clean Development Mechanism (CDM) program entails capturing and destroying methane and obtaining Certified Emission Reduction certificates (CERs) which are tradable commodities throughout the world and are purchased by companies which have their own carbon sequestration requirements (CSR). The initiative is designed to inspire developed nations to help developing nations establish sustainable and environmentally beneficial technologies. This includes working closely with the UNFCCC (UNFCCC, 2012).

According to the Kyoto Protocol (Dec 1997), there are six GHGs: carbon dioxide, methane, nitrous oxide, hydroflorocarbon, perflourocarbons and sulphur hexaflouride. Landfill gas typically contains 60% CH4 and 40% CO^2 as the generated CH4 has at least 21 times more effect in reducing CO^2 emissions, albeit that there are considerably more CO^2 emissions from industry and transport than CH4 emissions. The Kyoto Protocol established the rationale and target objectives for a global emission reduction strategy. In assessing a potential LFG management project, it is crucial that one is aware of current and pending energy sector and environmental regulations that could affect the viability of the project. Prominent issues in the development of a solid waste policy include:

- Reduction of waste
- Maximization of waste reuse and recycling
- Promotion of healthy environmental waste deposition and treatment; and
- Extension of waste services.

2.10 Conditions for a sustainable energy system

A sustainable energy system can be defined as one that provides for present energy needs without compromising the ability of future generations to fulfil their energy requirements (Goldemberg and Johannson 1995). At the same time, the system has to be affordable to users and contribute to socio-economic development. If SA is to take the path of sustainable energy, it is important to establish the real cost of such energy (including environmental costs) and to integrate the energy system with national development goals.

South Africa is making progress in ensuring that its economic development is sustainable and that particular attention is paid to the way in which economic, social and environmental assets are used. Several environmental problems have been identified and several government departments have developed policy measures to address these concerns, particularly in the areas of climate change, air quality, waste management and surface and groundwater pollution. It is known that good quality growth is essential to ensure that the country's development is sustainable and that its environmental resources remain intact to meet the consumption needs of both present and future generations. These priorities are reflected in the national Framework for Sustainable Development in SA (DEA, 2008) as well as the National Strategy for Sustainable Development and Action Plan (DEA, 2011).

Setting a fixed target or emissions cap relative to a specific base year for SA would require rapid reductions in GHG emissions over a relatively short timeframe. In order to be effective, it involves a sufficient number of entities to participate, as well as adequate trading volumes to generate an appropriate carbon price. As change is unlikely to happen in the South African energy system due to the presence of an oligopoly, one should focus on municipal solid waste management to reduce GHG emissions.

The MSWM system in both India and SA is discussed in depth in subsequent chapters. The zero waste model developed by Jagath and Trois (2011) simulated various scenarios that divert these 'valuable' waste fractions from landfill disposal on the basis of a dry-wet waste diversion model. The model estimated the GHG impacts, and landfill space savings which comprise different combinations of zero waste strategies. From the preliminary research conducted, the following strategies were selected as the basis of the model's scenarios which were evaluated as alternatives to the status quo of waste management in Indian and South African municipalities:

i. Mechanical pre-treatment, separating of recyclables and recycling;

ii. Biological treatment: composting or anaerobic digestion of the wet biogenic fractions, and

iii. Landfilling all waste or residual waste, with landfill gas recovery.

2.11 Greenhouse Gas Emissions Reduction

The consequences of a country's failure to implement mitigation strategies could be dire. It is estimated that the cost of inaction is five times higher than mitigating GHG emissions. It is therefore very important that the South African government adopt policies and procedures to mitigate the environmental and social problems resulting from existing solid waste management practices and implement a system that reduces the potential for future problems. In Figure 2-9 illustrates that technology support policies to reduce cost for long-term decarbonisation. It also demonstrates that the carbon price mediates action economy-wide and that policy to unlock cost effective energy efficiency potential.

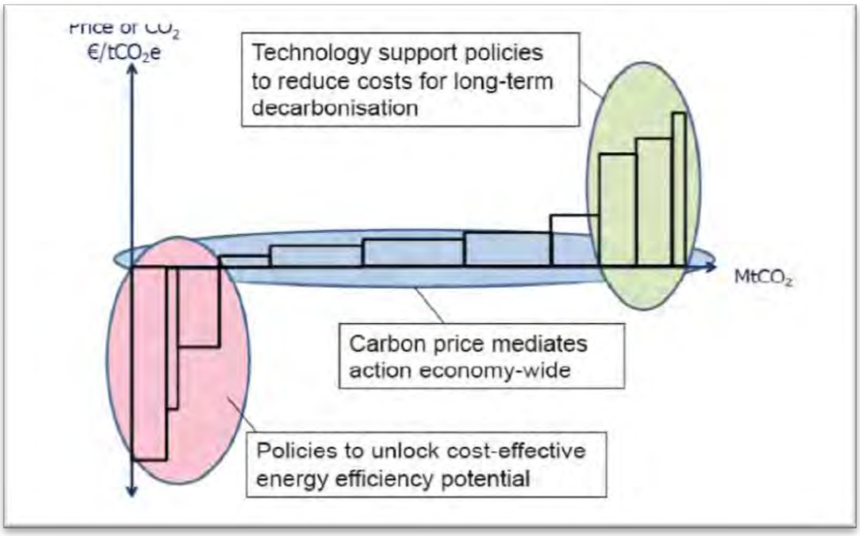

Figure 2- 9 Waste Technology and Policy in South Africa (Source: National Treasury, 2013)

It is critical that legislators understand that legislation that explicitly targets air emissions from the waste management sector, rather than national air emissions for all industrial/commercial sectors may negate the potential value of CER. Specific legislation would in fact be counterproductive to the goal of encouraging LFG management projects in SA and elsewhere in both developed and developing countries. The waste management sector should accept and comply with the standards set by all the air emission regulations that are applicable to the industry and government in the applicable jurisdiction. (National Treasury, 2013)

The Kyoto Protocol requests the adoption of GHG reduction credits only in instances where the act is voluntary. Therefore, in considering a potential LFG management project, it is crucial that one is aware of all current and upcoming environmental regulations that could affect the viability of the project as a voluntary act. In Figure 2-10 is an illustration of South African national laws applicable to a CDM LFG project for prior approval for generation plants for self-use, but no licensing requirement. This has since change following the new Waste Act which requires a licensing activity permit.

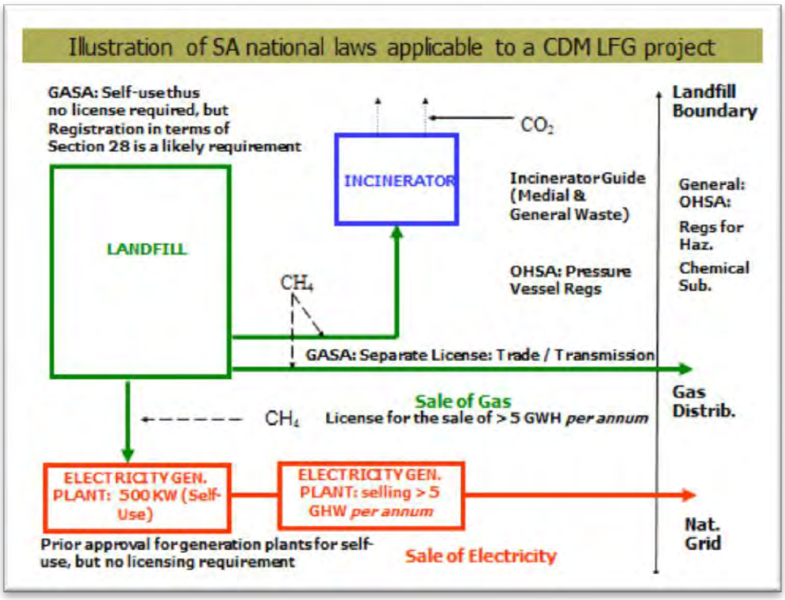

Figure 2- 10 National CDM Regulations Source: Courtesy of DEAT 2008

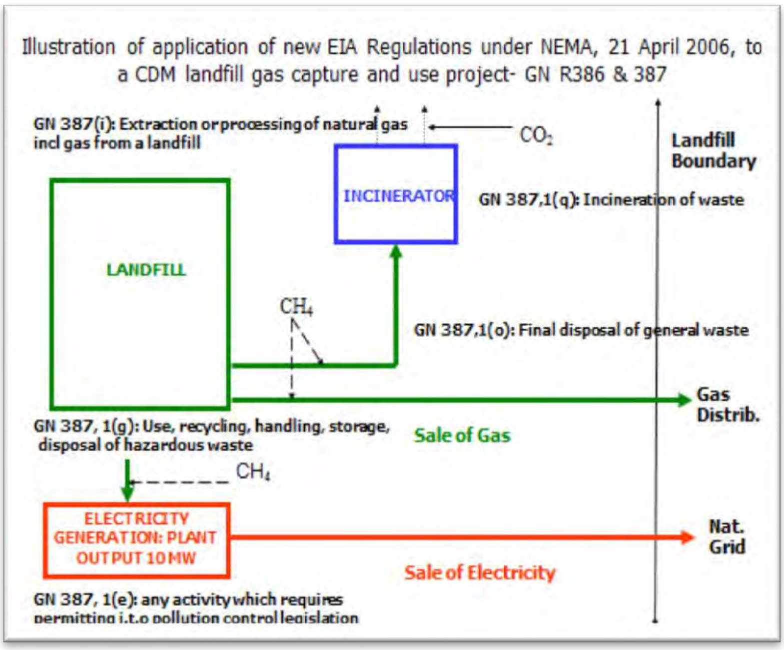

Figure 2- 11 National EIA Regulations Source: Courtesy of DEAT 2008

In Figure 2-11 is an illustration of EIA regulations under NEMA in 2006 to a CDM landfill gas capture and use project. According to EIA regulation 386 and 387 details the extraction or processing of natural gas which is inclusive of gas from landfill. The regulation made provision for incineration of waste, final disposal of general waste and use, recycling, handling, storage, disposal of hazardous waste. The regulation further considered any activity which required permitting in terms of pollution control legislation. Energy policies and associated legislation determine the ability to market the products of LFG management, such as emission reductions or energy. Current energy markets are in the process of developing policies on emission reductions that are directly applicable to Landfill Gas to Energy (LFGTE) projects, and estimating the cost of producing various energy products and introducing them to the market. The Departments of Energy and Environmental Affairs are the primary government entities responsible for creating an enabling environment for WTE in SA. In addition to the policy context, both departments are developing and implementing initiatives to promote and facilitate WTE (SANEDI, 2013).

2.12 Basic Techniques of Energy Recovery

Annepu (2012) notes that energy can be recovered from the organic fraction of waste (biodegradable as well as non-biodegradable) using the following methods:

- Thermo-chemical conversion: This involves thermal decomposition of organic matter to produce either heat, energy, fuel oil or gas; and
- Bio-chemical conversion: This involves thermal decomposition of organic matter by microbial action to produce methane gas or alcohol.

Thermo-chemical conversion processes are useful for wastes containing a high percentage of organic non-biodegradable matter and low moisture content.

The gaseous products released from a landfill (methane and CO_2) are the result of microbial decomposition. During the early life of the landfill, the predominant gas is CO_2. As the landfill matures, the gas is composed almost equally of CO_2 and methane (Annepu, 2012).

Because methane is volatile, its movement must be controlled. The heat content of this landfill gas mixture (16000-20000kJ/m^3), although not as substantial as methane alone (37000 kJ/m^3), has adequate economic value that many landfills have been tapped with wells to collect it. Because of their toxicity, trace gas emissions from landfills are of concern. More than 150 compounds have been measured at various landfills (Annepu, 2012).

Energy is a critical consideration of sustainable development. Successful sustainable development necessitates clean, renewable energy resources that are affordable, have minimal impact on society and are environmentally compatible (Kothari et al., 2010).

International carbon markets are still developing and evolving. The future value of emission reductions generated by LFG management is a matter for speculation. However the UNFCCC's (2012) development of the Clean Development Mechanism (CDM) project cycle may offer ways to acquire value from LFG management projects as an incentive to improve landfill design and operation. Developing this market could also supplement LFGTE projects to make them more financially viable.

Barton et al.'s (2008) study illustrates GHG emissions in developing countries for a few general scenarios. The results concluded that: sanitary landfills with no LFG capture resulted in 1.2 tonnes of CO_2 equivalents per tonne of waste, sanitary landfills with gas collection and flaring released 0.19 tonnes of CO_2 equivalents per tonne of waste and sanitary landfills with LFG capture and electricity generation produced 0.09 tonnes of CO_2 equivalents per tonne of waste (Barton et al., 2008).

2.13 Landfill gas to Electricity: Case studies in South Africa

According to Jewaskiwitz, Mills and Barath (2011) Landfill Gas to Electricity CDM projects have been known to take years to develop, from conceptualization through to final design and implementation. No matter how beneficial these projects appear at the outset, the requirements of the CDM process cannot be taken lightly. In an effort to speed up the process and start generating valuable emission reductions, proper cognisance must be taken of the engineering factors required to produce a successful project over the longer term. The engineering aspect, including landfill design and the on-going operation of the landfill, poses the greatest number of variables, directly impacting the potential of the project in terms of gas volumes and gas quality, the two main factors that determine the financial success of the project. Coupled to this is the effective operation of the gas extraction system following installation, in order to achieve the project's objectives and ensure project sustainability. Figure 2.12 is illiustrates a schematic layout design of LFGTE project.

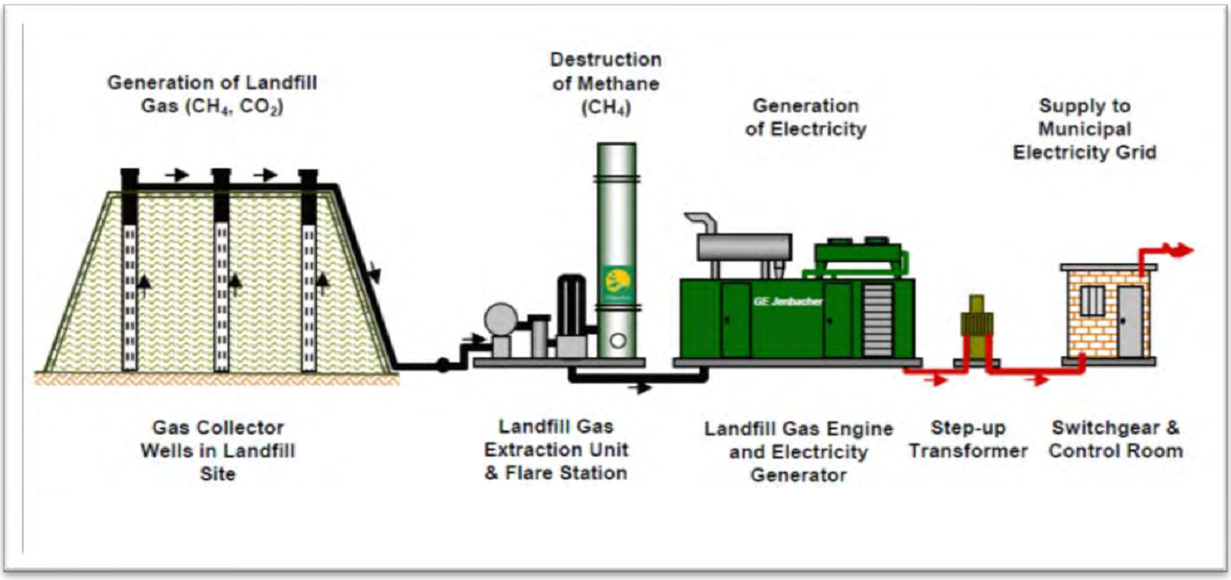

Figure 2- 12 Schematic layout of LFGTE Source: Jewaskiewitz, Mills & Barratt, (2011)

2.13.1 Inception of the eThekweni landfill gas to energy project

The project was financially supported by the World Bank's Prototype Carbon Fund (PCF). The PCF is one of many carbon financing mechanisms operated by the World Bank. It was established in July 1999 (early in the evolution of the international carbon market) with the intent of promoting market initiation by encouraging investment in CDM and Joint Implementation (JI) projects that could be registered under the Kyoto Protocol (www.carbonfinance.org).

The PCF is a public-private partnership consisting of six governments (Canada, Finland, Norway, Sweden, The Netherlands, and Japan) and 17 private sector companies, with a total budget of US$180 million. The World Bank was mandated to identify suitable projects for investment, and to secure CERs, which are then distributed to participants in the PCF according to the percentage of their investment in the Fund. As an initial carbon financing mechanism, the PCF's portfolio has been closed for some time, while the World Bank has continued as a player in the international carbon market, including through the development of a series of other carbon investment funds. However, the 2002 discussions between the World Bank and eThekweni Municipality, under the auspices of the PCF, were novel in the context of international carbon finance. Following the formulation of a landfill gas CDM project in 2002, a financial model to assess the viability of the project was prepared in 2003. This included a four-year pay-back period (Strachan et al., 2006).

2.13.2 CDM Project Assessment

A CER evaluation report was prepared in May 2003 with the aim of predicting the CERs in tonnes of CO_2 equivalent (tCO2e) for 21 years. CERs measure the carbon credits associated with CDM projects, with each CER representing 1 tCO2e mitigated. Gas calculations were prepared using a first order decay model prepared by Oxford University and subsequently compared with the first version of the Gas Sim model. This was preferred to other models, as it yields 4% lower values than LandGEM and meets the requirement that a conservative approach is adopted in the technical assumptions underpinning CDM projects. (Strachan et al, 2006).

Negotiations were held with the World Bank and a Memorandum of Understanding was agreed in February 2003. Subsequently, a prolonged EIA process, the contracts for the landfill gas extraction and electricity generating systems were finally awarded in January 2006. The commissioning of the landfill gas extraction systems was completed in November 2006 and the reciprocating gas engines and electricity generation systems were installed and commissioned in December 2006. The successful implementation of these electricity generation schemes has provided eThekweni Municipality with a total generation capacity of 1, 5 MW (Strachan et al, 2006).

Strachan emphasised that technical and construction related problems, most of which were unique to each site, were encountered, particularly during the gas extraction contract. The technical differences between the two sites, only 40km apart, were vast. The influence of property engineered lining systems, waste compaction, waste composition, rainfall and the capping system all played a major role during construction, and even now, during the operation of the plants.

2.13.3 Experience gained from the implementation of the CDM project

A detailed site investigation and pumping trial to prove the sustainable gas well extraction rate from any particular landfill is serious. Such an investigation would typically cost a few hundred thousand rand and should be seen as an investment rather than a cost. This would enable the project developer to accurately determine the number and spacing of gas wells required and would ultimately assist in determining the financial feasibility of the project. A desk study and a detailed gas generation assessment model are important, but this needs to be verified in practice, especially since assumptions often have to be made during the modelling process where accurate waste and site data does not exist. At the La Mercy landfill, it would appear that the volume of leachate in the site and the quantity and type of soil cover material used during landfilling has had significant influence on the drainage properties of the waste body, resulting in the low extraction rates thus far. This was not envisaged prior to construction (Strachan, 2006).

The spacing and layout of gas wells should be carefully considered, based on site-specific knowledge and pumping trial results. Designing a gas well layout with nominal spacing of 50m centres, based on the industry rule of thumb, is simply not good enough when one considers the cost of gas well installation (to the order of R100 000 per gas well). Site-specific conditions dictate the extraction sphere of influence of each particular gas well, and this directly determines the extraction efficiency of the overall system as compared to the expected gas generation rates predicted through the initial modelling process. Determining factors include the type of lining system (if any), allowances for leachate drainage, the type and quantity of daily cover material used during landfilling, the degree of waste compaction attained and the nature of the surface or cover of the landfill, including surface drainage design. Gas wells should also preferably not be positioned near the edges of a landfill. (Strachan et al, 2006).

Wellhead seals need to be properly designed and constructed, in order to prevent the ingress of air during extraction conditions. The most likely point of ingress will be at the physical wellhead/seal interface, where a leak will either be propagated by the gas under residual positive pressure, or by exceeding a certain negative pressure during extraction. At Mariannhill, a simple 500mm deep hydrated bentonite seal proved effective, whereas at La Mercy, difficulties have been experienced with an improved seal incorporating a cement stabilised bentonite seal and a 5m wide plastic skirt, tightly taped to the wellhead body. Seals will become compromised at the point where residual pressure within the well cannot dissipate within the waste body of the landfill, or the waste body simply cannot produce a reasonable flow of gas under extraction conditions. In this case the higher the suction pressure, the greater the likelihood of a leak, either through the seal or through the surrounding surface of the landfill capping material. In addition, during periods of down-time, gas wells should be vented at the wellheads to avoid compromising the gas well seals as a result of the build-up of residual gas pressure within the wells (Jewaskiewitz, Mills and Barratt, 2002).

The design of the gas collection pipework layout must be carefully considered. International experience has shown that no more than three or four gas wells should be connected to any particular branch line, as more than this, results in inefficient extraction rates. This was illustrated by the gas quality and pressure readings taken on the nine gas riser lines at Mariannhill. In addition, each branch off the main collector line should be equipped with an isolation valve and monitoring point to enable the collective sampling of gas extracted from all the gas wells located upstream of that point (Jewaskiewitz, Mills and Barratt, 2002).

The design, construction and operation of a landfill must take cognisance of typical gas extraction requirements when an LFG extraction project is envisaged. This includes the physical sizing of landfill cells to provide a sufficiently large area for an effective sphere of influence of the envisaged gas well, the ability to provide a sufficiently large area for an effective sphere of influence of the envisaged gas well, the installation of a lining system incorporating a leachate drainage system (where leachate production is expected), and the proper selection and minimal application of daily cover material. In addition, the landfill capping design needs to be carefully considered, allowing for a surface of relatively low permeability which facilitates the drainage of excess surface water (Jewaskiewitz, Mills and Barratt, 2002).

The location of the extraction and generation compound must be carefully considered so as to avoid the possibility of LFG migration from the site becoming a problem. The area should preferably be located on high ground which also assists in draining condensate away from the gas inlet to the GDU (Jewaskiewitz, Mills and Barratt, 2002).

If a gas extraction system is planned for a site, the design, construction and operation of the landfill itself must also take cognisance of typical gas extraction requirements. This includes the size and three-dimensional shape of landfill cells to provide a sufficiently large area and volume for an effective sphere of influence of the gas wells, the use of a proper lining system incorporating a leachate drainage system (especially where leachate generation is expected) and the proper selection and minimal application of daily cover material. In addition, the landfill capping design needs to be carefully considered, allowing for a surface of relatively low permeability which facilitates the drainage of excess surface water. It was confirmed at the Mariannhill and Ekurhuleni sites, that due to high levels of air ingress, uncapped areas of a landfill tend to have an extremely limiting effect on the extent of negative extraction pressures exerted on the gas wells in these areas (Jewaskiewitz, Mills and Barratt, 2002).

Once the design and planning phase of the gas extraction system has been completed and the project owner has a fair indication of the expected gas quality and extraction rates, it may decide to put the gas to productive use immediately following the construction of the extraction system. Although this would mean that income generation through the sale of electricity and secondary emissions reductions would potentially be realize sooner, this is a risky step at such an early stage. Only after the gas extraction system has been in operation for some months, and the well field has been properly balanced, will a project owner have the hard facts and figures upon which to base such a decision, considering the cost of a power generation system compared to a relatively simple and cost effective flaring unit. In addition, this period would also allow for sampling and detailed analysis of the gas. Landfill gas is known to contain many contaminants, including sulphur compounds, halides, water vapour, silicon crystals and siloxanes, which can cause a wide range of engine maintenance problems. Testing and analysis would provide information for the planning and design of gas treatment systems, if necessary, and budgeting for additional preventative maintenance (Jewaskiewitz, Mills and Barratt, 2002).

According to Jewaskiewitz, Mills and Barratt (2002), project development involves the construction, commissioning and operation of the gas extraction and utilization system. It is important for the project team, including the project owner, consultants and contractors, to work towards the common goal of producing as much good quality gas as possible, and the design and budget should be sufficiently flexible to implement the necessary measures to achieve this objective. For example, when adverse conditions such as drilling refusals are encountered, the budget and design should allow for re-drilling at alternative locations.

2.14 Case Study of Ekhurleni Municipality

According to Jewaskiewitz (2002), CDM will not transform a poor landfill operation into a good one, and the mere fact that a landfill exists and the relevant extraction and generation technologies are available, are not ingredients for instant success. The engineering aspect, covering landfill design and the ongoing operation of the landfill, poses the greatest number of variables, directly impacting on the potential of the project in terms of gas volumes and gas quality, the two main factors determining the financial success of the project. Coupled with this is the effective operation of the gas extraction system following installation, in order to achieve the project objectives and ensure project sustainability. During project development, the requirements for project verification must also be borne in mind and attended to, especially within the design, construction and operational phases, so as to ensure a maximum CER claim.

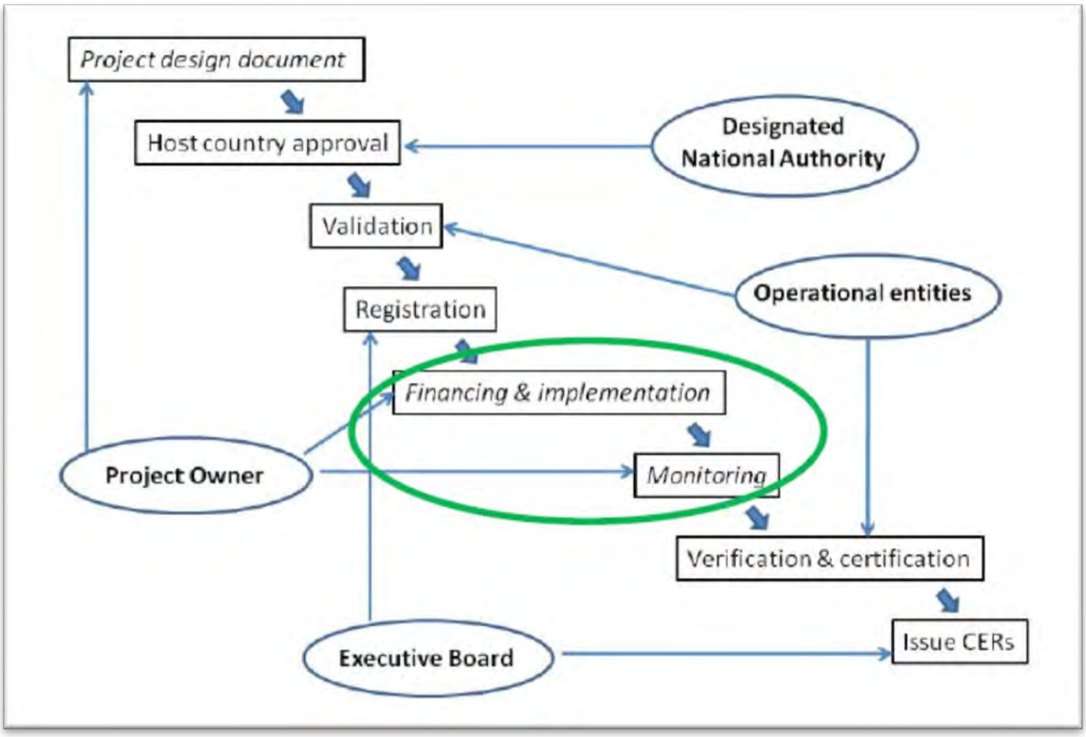

Figure 2- 13 Current CDM process in SA (Source: Jewaskiewitz, Mills & Barratt, 2002)

The Ekurhuleni Metropolitan landfill gas extraction and flaring project is a CDM project, pending registration with the Executive Board of the UNFCCC. The diagram above illustrates the CDM process.

In terms of the CDM process, the project owner is technically responsible for, and has the most control over three phases: the Project Design Document (PDD), Financing, and Implementation and Monitoring (the O&M Phase). Significant long-term expenditure is required in order to arrive at the third phase, and it is normally at this point that the project owner is reluctant to maintain high levels of expenditure, especially as income from the sale of CERs has not yet been derived, and will only begin to be realized after a year or two of operation. This is unfortunate, as O&M is a critical link in the project chain that ties the physical construction of the system to the verification and certification of emissions reduction claims by the project owner.

CDM management goes hand-in-hand with effective O&M. O&M activities provide for the proper working of the gas extraction and flaring system and reduced down-time, as well as the accumulation of all the data required for the calculation of CERs. The quality and integrity of the data acquired through the operation of the system is directly influenced by the level and quality of the O&M service.

The overarching objective of effective O&M is the maximization of landfill gas recovery in terms of volume and optimum quality (45% to 50% methane), from an existing installation. For this to be achieved, a sustainable extraction rate must be established, resulting in a balance between extraction effort and the continuous generation of landfill gas within the landfill, noting that extraction is also known to stimulate gas generation. Effective O&M will also result in the minimization of unscheduled down-time of the LFG extraction and flaring system through effective plant management. Such effort also provides continuous data and information that can be used for forward planning and budgeting for maintenance.

It is also essential that the project owner or developer understands that a landfill is effectively a “”living organism” that is non-homogeneous and ever changing, that physical movement and different settlement across the landfill is continuous, and that appropriate budgeting for future repairs to the gas collection network should be considered.

In addition to day-to-day O&M, accurate monitoring and record keeping is integral to the success of a CDM project. Setting up the monitoring system is fairly straightforward, but the plant operator needs to regularly check that the instrumentation and automated data logging system is functioning properly. Of critical importance is the efficient filtering and processing of the raw data, including the elimination of nonsensical data, the timeous identification of faulty instrumentation, and the presentation of the processed data in a format appropriate for project verification. The transparency of data processing and a conservative approach assists in ensuring a smooth verification process. (Jewaskiewitz, Mills and Barratt, 2002).

Of critical importance is the understanding that the CDM aspect of the project only really starts with the effective commissioning and operation of the gas extraction system, and that revenues are directly related to the quality of the information recorded on a continuous basis. Meeting all the requirements of the PDD and CDM Management Manual for the project, including all environmental ROD and legal requirements, as well the implementation of a fully functional QA/QC system is crucial. The verification process is stringent and unforgiving, and the project team needs to be well prepared. The focus of project verification is not only data collection, CDM calculations and figures, but the overall quality of the entire project, from design through to implementation, operations and monitoring. (Jewaskiewitz, Mills and Barratt, 2002).

2.15 Sustainable development and Waste to Energy

Kothari et al. (2010) report that the paths to sustainable development and WTE are the continuation of current energy use tools with modifications, the global adoption of alternative energy technologies for electricity generation and transportation, supplementing current energy resources with alternative renewable energy sources such as biomass and WTE technologies and the development of clean energy sources for distribution systems and production routes (Kothari et al., 2010). Energy is a critical consideration in sustainable development. Successful sustainable development requires clean, renewable energy resources that are affordable, have a minimal impact on society and are environmentally compatible.

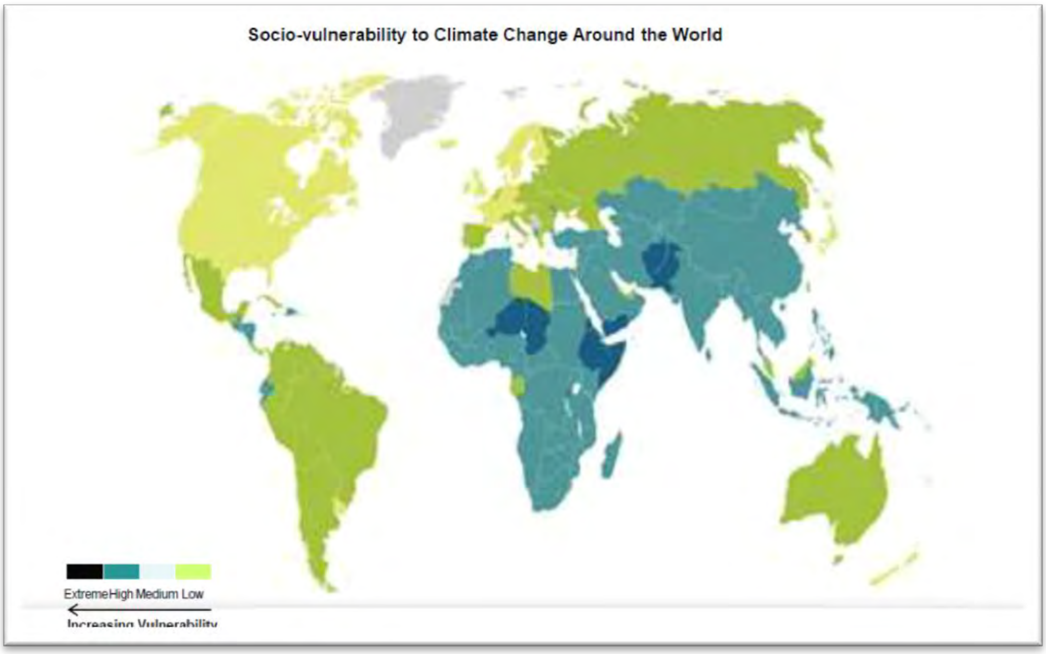

Figure 2- 14 Social Vulnerability to Climate Change (Source: National Treasury, Maple Croft, 2012)

Sustainable development is a concept that states, that one should be able to meet the needs of the current citizens of the world, without inhibiting future generations from meeting their needs. One could say that the natural resources on earth are shared not only with the people on earth today but with future citizens. In this vein, while people may use the resources available, they should never deplete a natural resource (SAEP, 2003).

The Kyoto Protocol's CDM program involves capturing and destroying methane and obtaining CERs that are tradable commodities throughout the world and are purchased by companies which have their own CSR. The initiative is designed to motivate developed nations to help developing nations establish sustainable and environmentally beneficial technologies. This involves working closely with the UNFCCC (2012).

According to the Kyoto Protocol (December 1997) six gases are GHG: carbon dioxide, methane, nitrous oxide, hydroflorocarbon, perflourocarbons and sulphur hexaflouride. Landfill gas typically contains 60% CH4 and 40% CO^2 as it generates CH4 at least 21 times more effective in reducing CO^2 emissions, albeit that there are considerably more CO^2 emissions from industry and transport than CH4 emissions.

2.16 Technical aspects of the potential of an Energy Source

Although several negative issues can arise from the presence of LFG, a number of benefits are associated with the proper management of LFG, and its potential for use as an energy source. LFG management projects that collect and flare LFG have the potential to generate revenue through the sale and transfer of the emission reduction credit, which is an incentive and means to improve the design and operation of the landfill and to develop a better overall waste management system. Emission reductions represent global and national objectives to improve air quality. Emission credits and Green Power energy premiums are two key mechanisms to achieve the goal of "Emission Reduction". Different terminology is used to refer to emission reductions such as ERs, CERs and GHG credits. These terms essentially refer to the same thing, which is best defined as the quantity of emission reductions converted and presented in the common unit of equivalent tonnes of CO^2 emissions reductions. The CER designation will always be equivalent tonnes of CO^2. It assumes that the emission reductions have been certified to meet a specific set of standards and requirements (World Bank Report, 2004).

2.16.1 Landfill Design and Operating Standards and Requirements

It is critical to have a clear understanding of current and future design and operating standards for the landfill because these could have negative effects on a potential LFG management project in many ways.

According to a World Bank Report (2004), legislation dictating the daily operations of the landfill has the capacity to effect the generation of LFG if there are requirements for the construction or operations of the landfill. For example, there could be a requirement to use a low permeable daily cover, which would impede the ability to collect LFG. There may also be impediments to the use of techniques, such as moisture addition to the waste, as is used in bioreactor landfills to increase the initial rate of LFG generation.

In addition the World Bank Report addressed legislation affecting the type of waste permitted in a landfill can have negative effects on an LFG management project if there is an emphasis on removing organic material from the waste stream. This is because LFG is generated by the organic fraction of the decomposition waste.

Future projections of waste filling are a significant component of LFG generation projections and are therefore directly tied to the value of the resource and the economic justification necessary to support a project. It is important to not only have a good understanding of the current regulations and policies governing the design and operations of the landfill, but also be aware of any upcoming legislation that could affect the viability of an LFG management project. The general life of these projects (10 to 20+ years), especially LFGTE projects, makes them vulnerable to the introduction of future legislation, especially with respect to establishing voluntary GHG emissions reductions.

2.17 Chapter Summary

This chapter enabled an understanding of waste management practices and principles with an emphasis on the most viable waste management technologies that would be appropriate for different size municipalities. It highlighted the legislation and policies in SA, with the national strategies emphasizing recycling and reuse of materials which is high on the waste hierarchy. It is more environmentally and economically effective to avoid the creation of waste than to introduce these unwanted products into the waste management system.

Sustainable development in SA was contextualized within its use of technologies to reduce GHG emissions. The process involved in mechanical sorting of recyclables at a material recovery facility was investigated, as well as biological treatments of organic waste and the principles of anaerobic digestion. Composting options were also considered and various technologies and outcomes of aerobic treatment were assessed.

This systematic literature review provided an understanding of waste management, available treatment technologies and challenges noted in case studies of WTE options in SA.

3. METHODOLOGY

3.1 Introduction

This chapter details the methodology adopted for this study.

The primary objective of this research study was to develop an institutional framework that will quantify the environmental impacts of the zero waste strategies that target specific fractions of the MSW stream of the landfill site in Mumbai, specifically the Deonar Landfill Site and Newcastle Municipality landfill site in SA.

- To conduct a comprehensive waste stream analysis for Deonar Landfill site; Mumbai-India and Newcastle landfill site in Kwazulu Natal-South Africa.

- To determine the sources, characteristics and quantities of municipal solid waste generated and to calculate the GHG savings that could be achieved in municipalities' waste management strategy (reducing the quantity of waste generated, reusing the materials, recycling and recovering materials, combusting for energy recovery and landfilling, if economically viable).

- To develop an institutional framework for municipalities that deals with the strategic process in waste management.

The results of the statistical analysis are critically reviewed and an institutional framework is developed that could assist municipalities in developing countries like SA and India to determine the best management strategy to maximise the reduction of GHG emissions from waste. Best waste management practices as a mitigating tool are compared with current/alternative methods.

3.2 Structure of the study's Methodological approach

In this chapter, the study's investigation process of is discussed in detail. The rationale for the study and the selection of the case study are highlighted. The systematic literature review clinically reviewed technologies that led to the scenario analysis. Finally, the institutional framework which details a matrix that demonstrates the level of priority in the spheres of government was developed. In Figure 3.1 is a schematic diagram of the development of the rationale for the study. The selection of the case studies which are in developing countries being that of India and South Africa. A system literature review followed by the case studies of India: Mumbai and South Africa: Newcastle. A socio-economic study which was administered in selected random areas in India: Mumbai and detailed their waste generated at household in those areas. It also depicts a detailed waste stream assessment (WSA) of both Deonar Landfill site in Mumbai, India and Newcastle Landfill site in Kwazulu Natal, South Africa. Finally, the institutional framework which details a matrix that demonstrates the level of priority in the spheres of government was developed

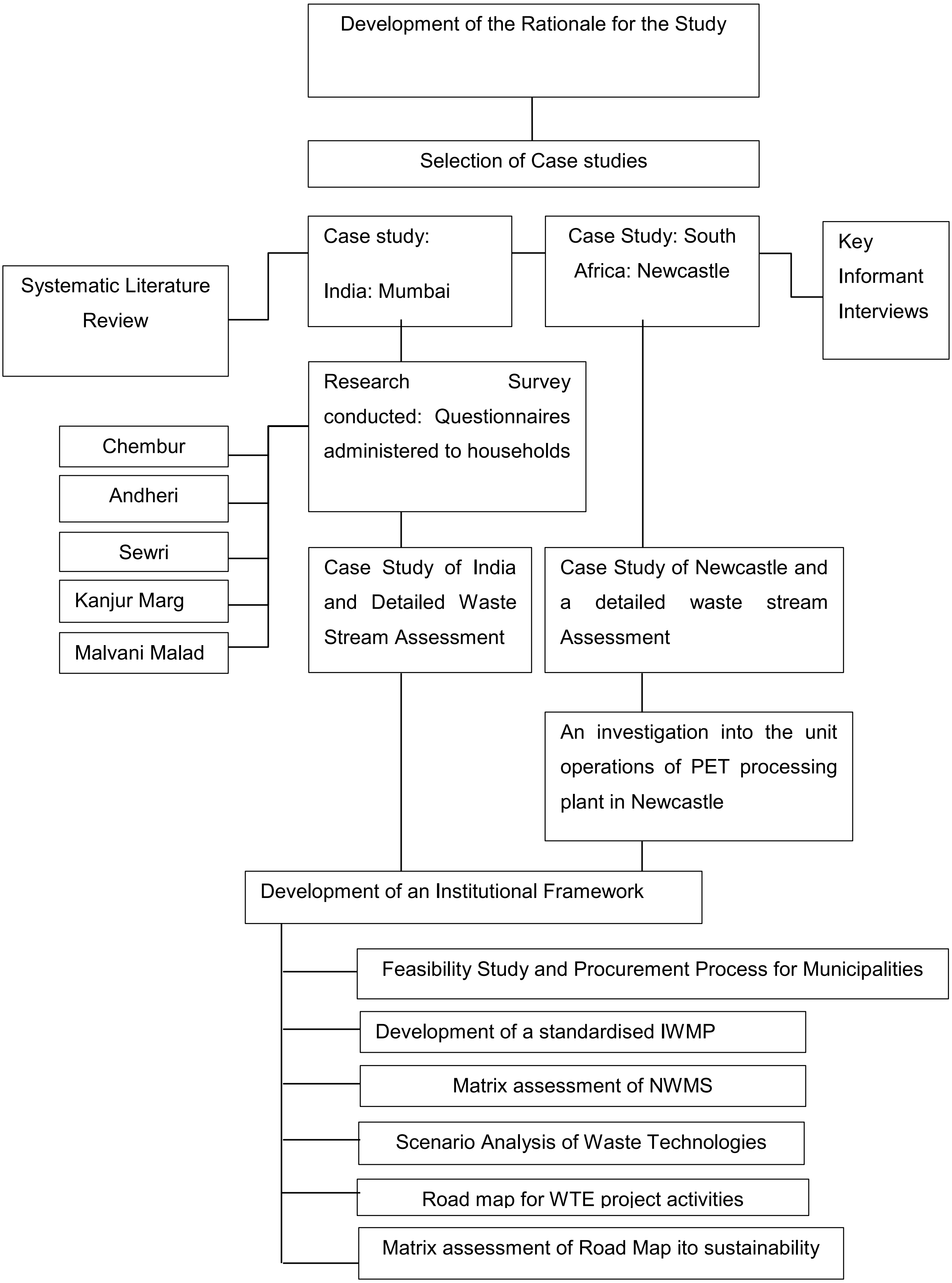

Figure 3- 1 Structure of the Methodology

A systematic literature review differs from a standard literature review in that the former aims to find all the data on a specific subject regardless of the author's bias (Nightingale, 2009).

3.3 Investigative Approaches

3.3.1 Quantitative research

Sukamolson (2005) and Sibanda (2009) described quantitative research as gathering of numerical data where mathematical models are used to interpret numerical data to explain specific phenomena. When a researcher employs a quantitative research method, it is very important to use the correct research design and data collection instruments (Sukamolson, 2005).

3.3.2 Qualitative research

According to Sekaran and Bougie, 2009 states that the qualitative data gathered needs to be analyzed. The three steps in this process being data reduction, data display and drawing the conclusion. Data reduction refers to the process of coding and categorizing similar themes together.

Data display quotations in a matrix or graph form to identify patterns. Conclusions can be drawn from the analysis of the qualitative data (Sekaran and Bougie, 2009).

3.3.3 Mixed methods

This approach involves a combination of qualitative and quantitative data. There are merits in combining these approaches. A quantitative study method can be contextualized with the use of qualitative responses from respondents in a survey. In contrast, a qualitative study can be enhanced by the inclusion of relevant quantitative information. The credibility of statements can be strengthened through the combined use of these approaches (Chan, 2001).

3.4 Selection of Case Study

According to Benbasat et al. (1987, p370) case studies are valuable when:

- It is necessary to study the phenomenon in its natural setting;
- The researcher wishes to ask "how" and "why" questions, so as to understand the nature and complexity of the processes taking place;
- Research is conducted in an area where few, if any, previous studies have been undertaken.

A case study is reflective of a phenomenon in its natural setting, employing multiple methods of data collection to gather information from more than one person.

For the purpose of this study, the case study was conducted in Newcastle, South Africa and the Municipal Corporation of Greater Mumbai (MCGM). It focused on the generation, collection, transportation and disposal of MSW by incorporating it into an integrated waste management plan that will be used to develop an institutional framework.

The methodology involved a mixed methods approach drawing on qualitative and quantitative data. The case study was selected based on the knowledge gained from the research questionnaire for a survey conducted in India, key informant interviews and a systematic literature review. A series of semi-structured interviews were conducted with individuals who held senior positions at the MCGM in India and this dissertation was completed in my capacity as a waste practitioner at Newcastle Municipality, who has an intimate knowledge of this research area.

The selection of the case study was informed by the key informant interviews which provided knowledge on the technological assessment and selection specific to an area, waste stream and context. It was interesting to note that solutions from one municipality cannot be utilized in another municipality. The dynamics of each municipality are based on a number of factors.

The literature review presented the status quo of waste in SA and India. Waste management technologies and systems were examined in order to understand the technologies implemented in the case studies. An institutional framework is also developed around understanding policies in the implementation of these waste management technologies.

3.5 Reasons for the selected landfill sites

MCGM and Newcastle Local Municipality (NLM) were selected due to their representation of other developing countries' municipalities in terms of their socio-economic parameters, and MSW management systems. The Deonar landfill site was selected from two landfill sites due to the potential of projects that can be implemented on site. As a medium-sized municipality, NLM was selected to benchmark waste management practices across municipalities of different sizes in the country and to identify an appropriate scenario for each municipality. The waste stream analysis can therefore be considered representative of the NLM waste stream as a whole and of an integrated waste management approach; the analysis assesses the current environmental benefits of MRF operations and recycling recovery rates.

Table 3 - 1 Selected Landfill sites and waste tonnes/ annum

Landfill selected and classification	**Waste streams tonnes/ annum**
Newcastle Landfill	46 621
Deonar Landfill	2 330 233

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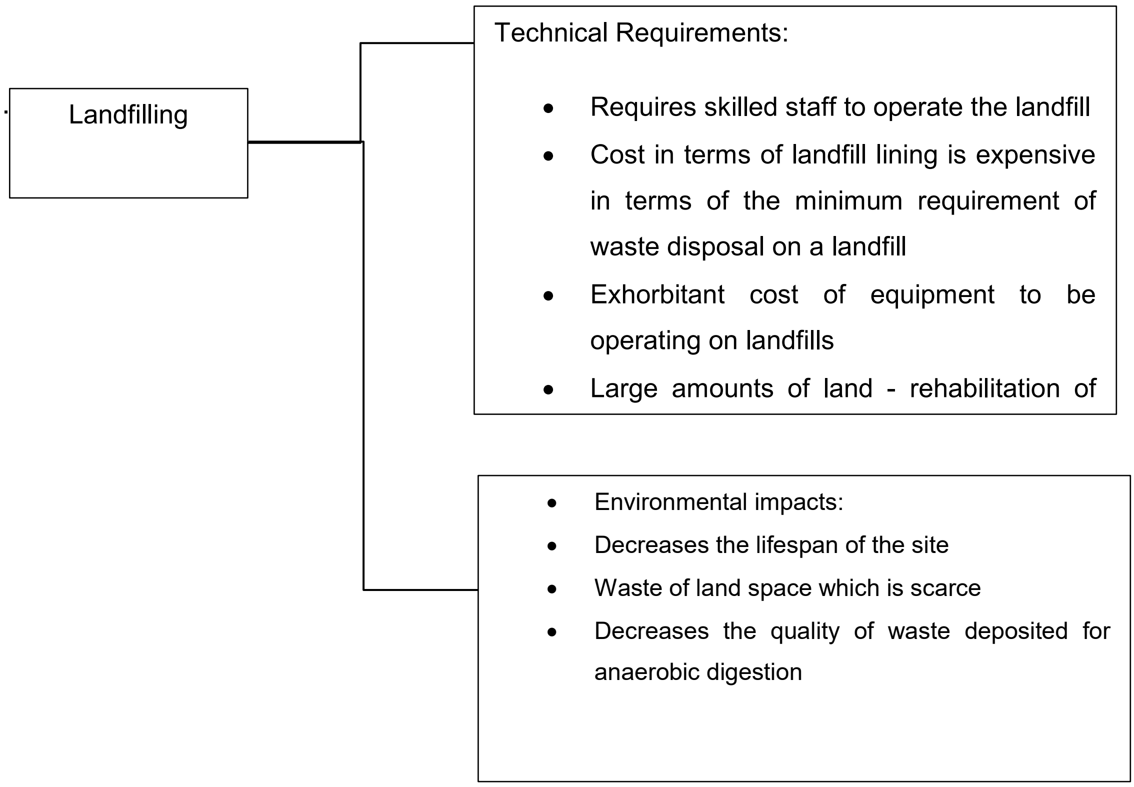
3.5.1 Selection of the MSW strategies

A desktop study of waste management methods and technologies was undertaken to identify potential zero waste strategies to be evaluated in various waste management strategies. The selection criteria for this initial assessment of strategies were the implementation requirements, technical feasibility, and impacts on the environment and waste management systems.

Scenario 1:



Scenario 2:

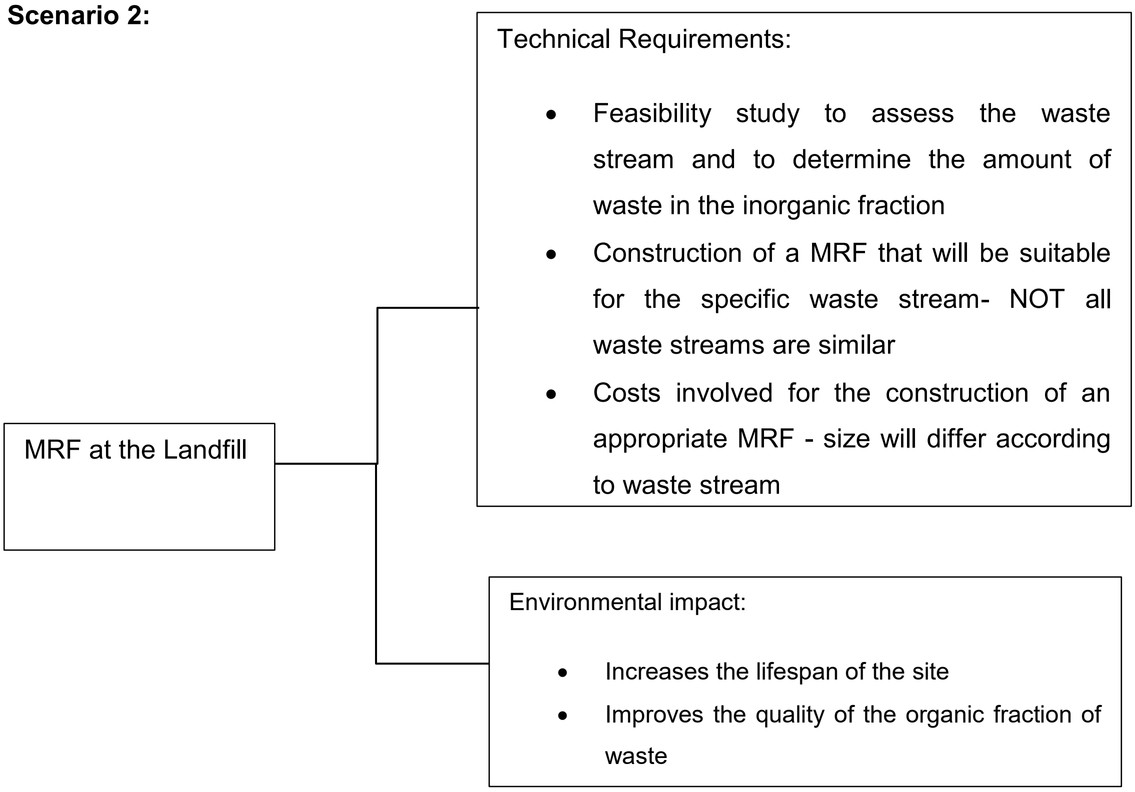
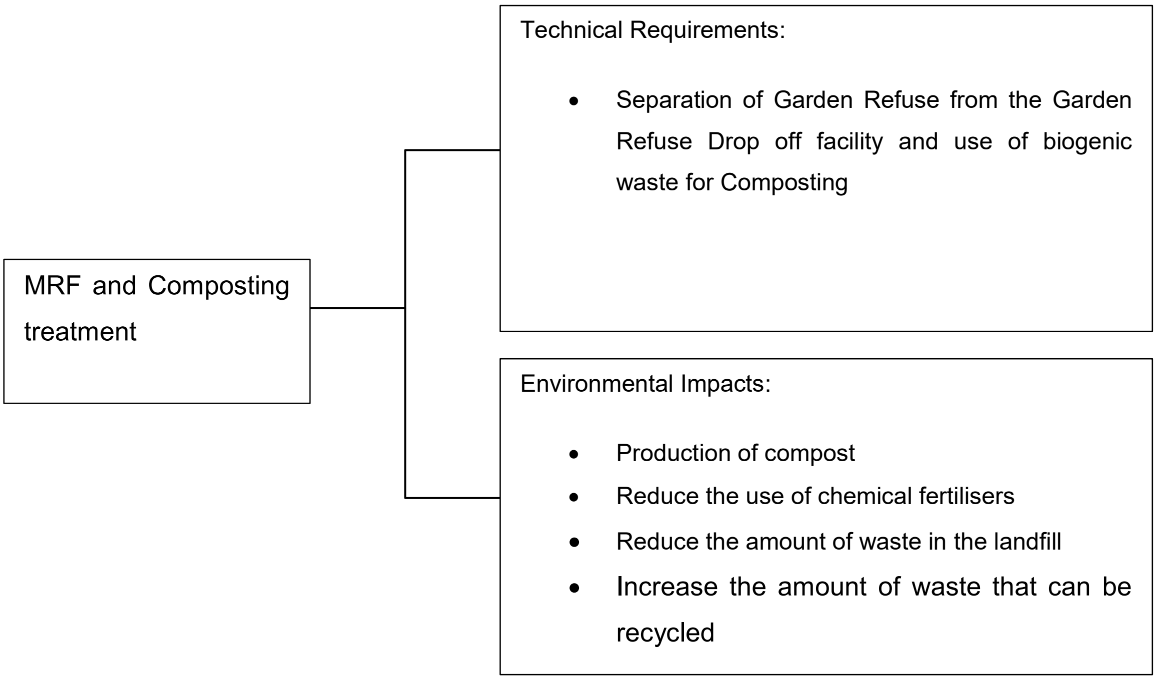


Figure 3- 2 Schematic lay-out of waste management scenarios in municipalities

Scenario 3



Scenario 4

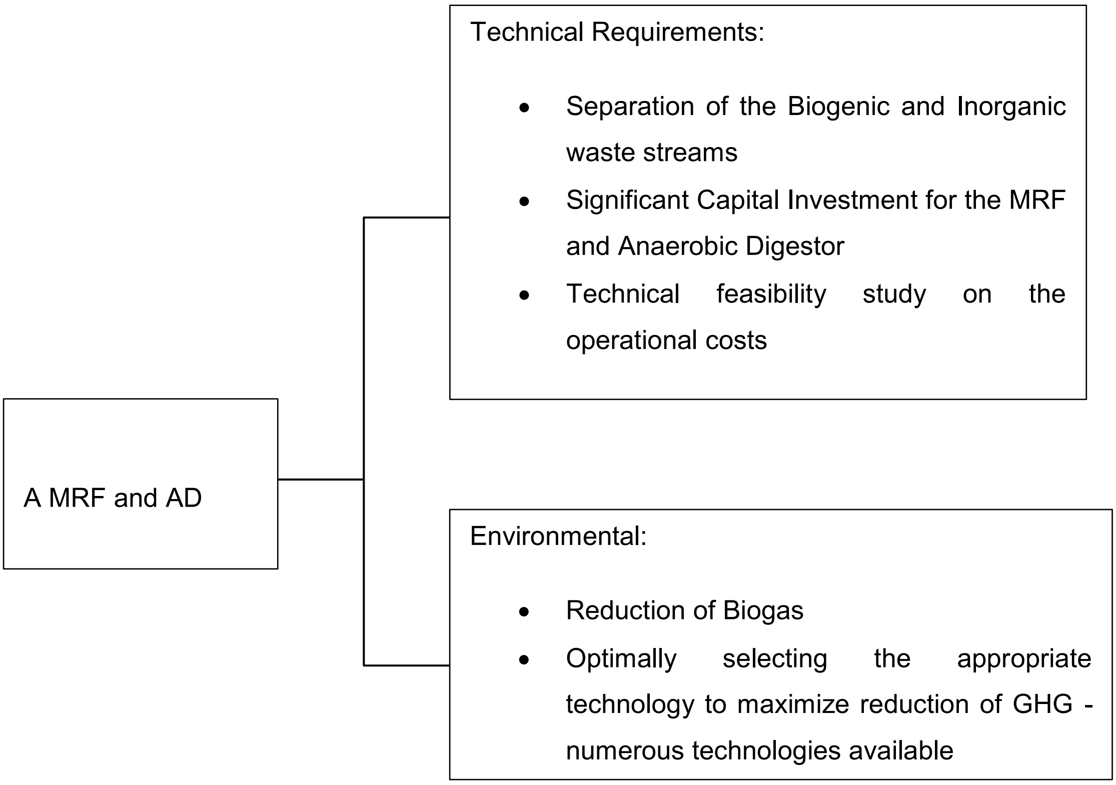
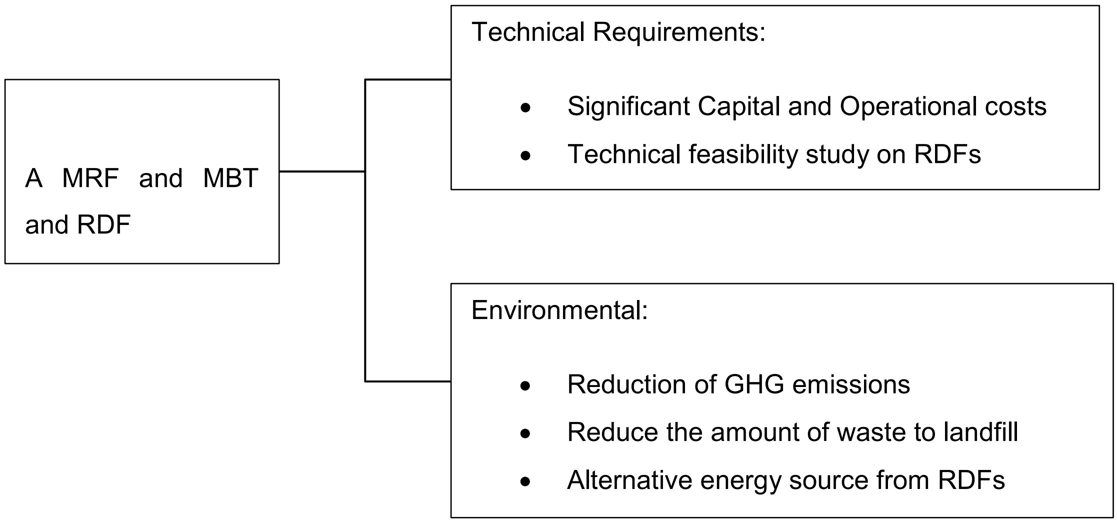


Figure 3- 3 Schematic lay-out of waste management scenarios in municipalities

Scenario 5



Scenario 6

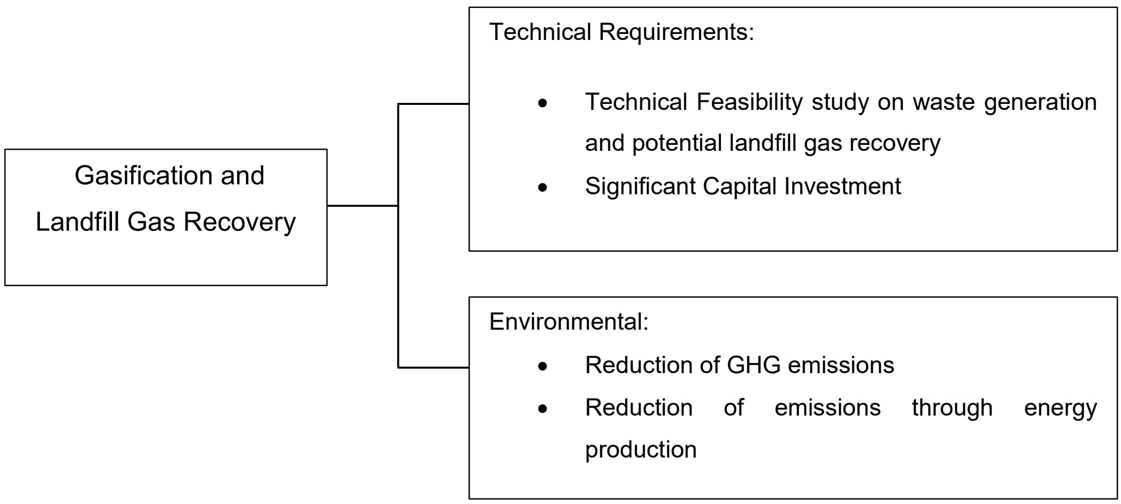


Figure 3- 4 Schematic lay-out of waste management scenarios in municipalities

According to Douglas (2007), source separation in South African municipalities is not financially feasible. Source separation impacts operational costs if there is a separate system for the collection of the dry waste. South African municipalities face challenges in meeting the needs of un-serviced areas. Thermal treatment of MSW was not selected due to uncertainties regarding new technologies and the pollutants produced through the treatment of MSW (Smith et al., 2001).

3.6 Simulated waste management scenarios

The waste diversion strategies and treatment methods include current waste disposal in South African municipalities (landfilling and landfill gas recovery) as well as the potential waste management strategies previously outlined (recycling, anaerobic and aerobic composting) (Jagath and Trois, 2010). Although, as noted, Douglas (2007) is of the opinion that source separation is not feasible, it is a scenario for a waste diversion strategy.

Surveys enable a researcher to obtain information about practices, a situational analysis or views at one point in time through questionnaires and interviews. A questionnaire guideline can be drawn up to focus and steer the interview process (Jagath and Trois, 2010). A questionnaire was designed to understand the MCGM's waste management system. A random sample was drawn from different areas in Mumbai. A total of 825 questionnaires were completed by households in Mumbai. Interviews with households in Mumbai were conducted in person with an interpreter to assist in elaborating on the questions and to simplify when required.

Table 3 - 2 Households interviewed in the City of Mumbai on Waste Generation

Area surveyed	No. of Households interviewed
Chembur	141
Andheri	200
Kanjur Marg	153
Sewri	128
Malad	203
	825

Key informant interviews are qualitative research that is conducted with an expert to gain insight into a specific field. The objective is to gain knowledge from people's first-hand experience (UCLA, 2004).

Table 3 - 3 Key informant interviews

Key Informant	Position
1	Chief Engineer who was the high level decision maker in Municipal Solid Waste
2	Executive Engineer of the Deonar Landfill site involved in the planning and design of the site
3	Executive Engineer of the Gorai Landfill site involved in the closure and rehabilitation of the site
4.	Manager of Landfill operation at Deonar site

Key informant interviews were critical in understanding the topic and in guiding the selection of the relevant case study. Deonar landfill was the preferred site for further investigations in the MCGM.

An assessment of the incoming waste streams at Deonar and Newcastle landfills. Both sites are operated as trench method landfilling.

3.7 Development of an Institutional Framework for Municipalities

In terms of the National Waste Management Strategy (1998) the primary objective of introducing an integrated waste management plan is to integrate and optimize waste management procedures in order to achieve maximum efficiency and minimize costs.

The primary objective of the post-apartheid government's waste management policy is to move from a fragmented to an integrated approach to waste management. A key component of this policy is the adoption of a hierarchical and internationally accepted approach to waste management. i.e., waste prevention, waste minimization, collection, transportation, recycling, treatment and final disposal.

3.8 Waste Stream Analysis Methodology

3.8.1 Planning and design of Waste Stream Analysis

The methodological approach to the WSA of the Newcastle landfill site and the Deonar landfill site were researched extensively after which a "site-specific" approach was selected. This approach entailed physical sampling, sorting and characterization of waste streams from the selected focus areas. The focus was "recyclables" and "biogenic" waste as these fractions have the greatest potential for recovery, re-use and WTE strategies. The WSA was planned and designed with the assistance of landfill and waste managers at the two sites. A schedule of the number and type of loads and their respective collection areas for each sampling of loads was conducted by a team of "waste recovery pickers". A two-week study was conducted at both at the Deonar and Newcastle landfill sites. All pickers were briefed during the assessment, and were trained to recognize, classify and separate recyclables and other waste fractions.

3.8.2 Waste classification categories

The waste classification system used to sort and separate the samples was based on guidelines drawn up by the City of Cape Town's Integrated Waste Management Plan (IWMP). The main waste categories were Paper and Cardboard, Plastic, Glass and Biogenic waste. These waste groups were considered the most common waste received due to their potential for recycling, AD and aerobic composting.

Table 3- 1 Newcastle and Deonar landfill sites waste categories for sample analysis (Source: adapted from the City of Cape Town's Integrated Waste Management Plan 2002)

Paper and Cardboard	
Newspaper	Heavy letter
Common Mixed Waste	Scrap Boxes and Cardboard
CMW: General mixed paper	Tetra pak (Juice and Milk cartons)
Plastic	
Low density polyethylene	Packaging films, shrink wrap
High density polyethylene	Juice bottles, vest shopping bags
Polyethylene-terephthalate	Clear soda and drink bottles
Polypropylene	Yogurt, margarine, ice-cream containers
Polyvinyl chloride	Sewage pipes, cable insulation
Polystyrene	Packaging, take away cutlery and crockery
Glass	Metals
Green glass bottles and containers	Cans (steel/tins)
Brown glass bottles and containers	Beverage cans
Clear glass bottles and containers	Other metals
Biogenic wastes	
Organic food wastes (Putrescibles)	
Garden refuse: green waste	
Other waste	
Wood waste	Electronic waste
Tyres	Batteries
Textiles, cloth	

3.8.3 Equipment and materials

The following equipment and tools were used to separate the waste to enable it to be weighed:

- Protective gloves for sorting
- Plastic bags for sorted waste
- Digital scale for weighing
- Personal Protective Equipment for staff assisting with the separation of waste

Figure 3- 5 Tools required for waste separation at Newcastle Landfill site (Source: photo Kelly T, 2012)

3.8.4 Sampling Methodology

Trucks were weighed on the weighbridge and they offloaded in a demarcated area. Loads were sampled using the “quarters” approach (Tchobanoglous et al., 1993). Each load to be sampled was quartered until a sample of which the sample were separated according to the waste classification category and weighed. This is regarded as a random method of sampling (Tchonobanglous et al., 1993).

Designated waste truck loads were assigned to the research team and were diverted to a demarcated area on site. The trucks emptied their loads and once samples were acquired recyclables, biogenic waste and other waste fractions were separated**.**

Figure 3- 6 Gathering of samples for analysis from Compactor Trucks at the Newcastle Landfill site (Source: photo Kelly T, 2012)

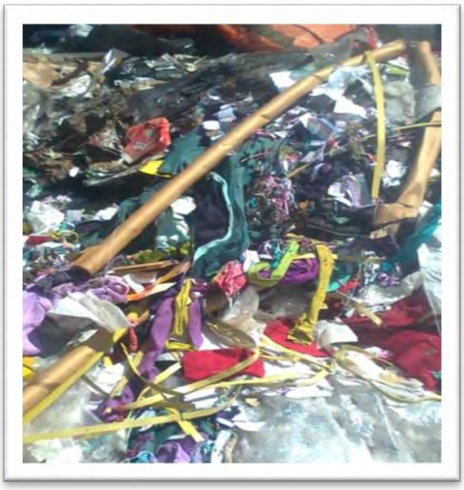


Figure 3- 7 A typical waste sample load from the compactor trucks at Newcastle Landfill site (Source: photo Kelly T, 2012)

The figures below describe the waste fractions identified by sampling the MSW stream. The fractions were then weighed on the scale and recorded.

Figure 3- 8 Biogenic food waste which comprises of garden waste and food waste (Source: Photo by Kelly T, 2012)

Figure 3- 9 Inorganic-plastic which comprises of PET, HDPE, Polypropylene and Residual Plastic(Source: Photo by Kelly T, 2012)

Figure 3- 10 Inorganic waste comprising of metal can, clear and brown glass (Source: Photo by Kelly T, 2012)

Figure 3- 11 Inorganic waste comprising of cardboard boxes, white paper (Source: Photo by Kelly T, 2012)

Residual waste (unknown waste after recyclables and other large items were removed) that could not be separated consisted of contaminated paper, mixed plastics, fine organics, soil and other inert materials. This was subjected to residual waste analysis. This approach was time consuming as it took a long time to sort this waste. The residual waste analysis was considered the most accurate approach in the characterization of this residual waste and therefore the entire sample as a whole. All the data was recorded and electronically transferred.

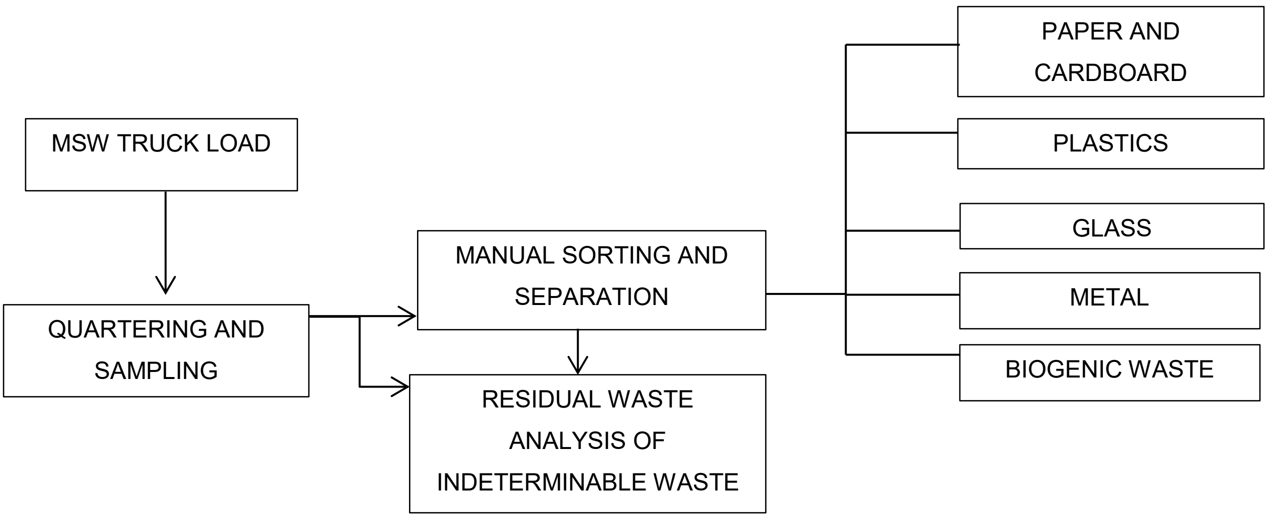


Figure 3- 12 Schematic diagram of sample procedures in Mumbai and Newcastle

Once all the designated loads were sampled, all equipment was cleaned and stored for the next day of sampling. The waste sampled was then cleared and removed as per arrangement with the landfill manager.

3.8.5 Approach to data analysis

The studies reviewed were conducted on a much larger scale (nation-wide); therefore more than one waste facility/landfill site was selected for sampling.

3.9 Chapter Summary

This chapter discussed the methodology employed to conduct this study. A mixed methods approach using qualitative and quantitative data was adopted to undertake a case study of the MCGM and NLM. The case study was selected based on the knowledge gained from the questionnaires administered to households, the interviews with key informants and a systematic literature review.

The literature review identified viable waste technologies for the treatment of MSW in Newcastle, SA and the MCGM in India. The key informant interviews, and interviews with households provided insight into the status quo of municipal solid waste management which was essential in the development of the rationale for the case study.

Finally, the integrated waste management systems were examined to develop a sustainable institutional framework that encompasses municipalities' integrated waste management plans.

4. THE STATUS QUO OF MUNICIPAL SOLID WASTE MANAGEMENT IN DEVELOPING COUNTRIES

Case Study: MCGM

4.1 Introduction

The case study within the MCGM focused on MSW services, waste management systems and infrastructure, with an emphasis on the Deonar landfill site. The municipality was selected to draw a comparison of socio-economic factors in developing countries. Table 4.1 details the waste generation per capita/day by various countries globally. India generates .46kg/capita/day.

Table 4- 1 Waste Generation by Country (Source: Waste generation per capita per day, Shukla, 2008)

Country	Rate (kg/capita/day)
United States	2.08
Australia	1.89
Denmark	1.81
Canada	1.75
Netherlands	1.67
United Kingdom	1.53
Germany	1.48
Italy	1.37
China	1.08
Turkey	0.97
Brazil	0.89
Indonesia	0.70
India	0.46

4.2 Geographical location of the MCGM/Mumbai

Mumbai has a coastal section of 603 sq. km. The city of Mumbai can be divided into three sections, namely, the island (or main city), the western suburbs and the eastern suburb. Mumbai, the financial and commercial capital of India, is spread over an area of approximately 437.71 km^2 and has a population of more than 12 million. Mumbai generates approximately 6 500 tonnes of MSW per day. The MCGM is responsible for providing solid waste management services to the city of Mumbai. Municipal Solid Waste is a heterogeneous kinds of solid wastes that are not transported with water as sewage, and may include biodegradable (putrescible) food waste called garbage, and non-putrescible solid waste like paper, glass, cloth materials, metal items, etc., called rubbish. The quantity of MSW produced by a society depends on its residents' living standards.

Table 4- 2 Absolute amounts of waste generation (Source: Courtesy of the MCGM, 2012)

Description of waste	Absolute amounts Tonnes/Day
Total MSW generation	6500
Total Construction and Demolition generated	2500
Biomedical waste generated	25

4.3 Waste Generation

Classification of waste is imperative when conducting a waste stream analyses to allow for comparison with data from national and international studies (Olver et al., 2009). Compatibility of waste data with the waste classification used in GHG modelling software is also important. For example, data records may list all plastic materials as 'plastic' whereas GHG models provide detailed classifications such as 'High Density Polyethylene' (HDPE). Although representative assumptions can be made in the modelling process, it is preferable to have a compatible and consistent waste classification system. Municipal Solid Waste can be classified into two basic fractions (Trois and Simelane, 2010). The wet fraction comprises biogenic waste such as food and garden waste. The dry fraction comprises materials such as recyclables (primary paper, glass, plastic and metals) and other inert dry materials. Davis and Cornwall describe solid waste as a generic term to describe the things we throw away. It includes items that we commonly describe as garbage, refuse and trash. Solid waste is primarily a problem in highly populated areas.

The per capita waste generation rate in India increased from 0.44kg/day in 2001 to 0.5kg/day in 2011, fuelled by changing lifestyles and the increased purchasing power of urban Indians. Urban population growth and the increase in per capita waste generation have resulted in a 50% increase in waste generation by Indian cities within a decade.

According to Davis (2013) Mumbai generates waste to the tune of approximately 7 025 tonnes per day. This consists of 5 025 tonnes of mixed waste (bio-degradable and recyclable) and 2 000 tonnes of debris and silt.

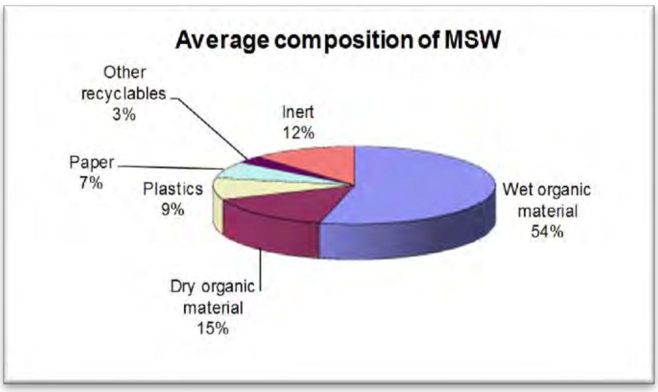


Figure 4- 1 Average composition of MSW (Source: Courtesy of MCGM, 2012)

An individual’s generation of waste depends on their socio-economic conditions. For example, an affluent family will generate on average about four to five kg of mixed waste per day; a middle class family will generate between one and three kg of mixed waste per day and a lower income family living in a slum will generate close to 500 grams per day. According to the Evolve Road Map of India (2010) Mumbai generates about 6 500 tonnes of waste every day, including waste from households, markets, hotels and restaurants and commercial establishments. Fifty per cent of this waste is biodegradable (mainly kitchen and market waste or ‘wet waste’), 20% is ‘dry’ recyclable waste such as metal, glass, rubber, cloth and plastics, and the rest is construction and other waste. On average, a person generates about half a kilogram of waste a day, with the middle and the upper classes producing much more waste per person than the poor.

Figure 4- 2 Waste Compactors and Roll on/off Trucks collecting waste (Source: Photos: Kelly T, 2012)

Biodegradable (wet) waste is made up of vegetable and fruit remainders, leaves, spoiled food, egg shells and different types of material cloth. Recyclable (dry) waste consists of newspaper, plastic, battery cells, wiring, iron sheets, glass, etc. Debris includes demolition waste, construction waste, renovation waste, etc.. Figures 4-2 and 4-3 illustrate the waste transportation methods in the City of Mumbai by means of Compactor size trucks, Roll on trucks and Dumper trucks.

Figure 4- 3 Collection of Garden Refuse and Biodegradable Waste (Source: Photos: Kelly T, 2012)

Table 4- 3 Waste services provision by type of household (Source: Courtesy of MCGM, 2011)

Description of Collection	**%**
Door to Door Collection	12
Slums	30
Street Sweeping	15
Community Bins	30
Markets and Hotels	12
Beaches	1

4.4 Waste Collection

In various housing societies there are garbage collectors employed that collect waste generated from each household and dump it in the garbage bin situated at specific street corners.There are around 5 800 community bins in the city. In the case of South Mumbai, trucks collect garbage bins and transport them to a transfer station located in Mahalakshmi. Separate transport is arranged for transferring the garbage from Mahalakshmi to the northern part of Mumbai where the dumping grounds are situated. From all other parts of the city, garbage is sent directly to the dumping grounds. Nearly 95% of the waste generated in the city is disposed of in this manner. This largely manual operation involves 35 000 personnel employed by the MCGM and a fleet of 800 vehicles, including vehicles hired from private contractors, that work in shifts each day. The MCGM spends about Rs15-20 lakh per day collecting and transporting garbage and debris with municipal and private vehicles undertaking about 2 000 trips every day. (Statistics are courtesy of MCGM, 2011)

With the fast growth of the population and the city, waste management is becoming increasingly intractable, from waste collection to disposal. Initially, the municipality collected garbage from community bins placed at various roadside locations where people would dump their waste. However, these open bins were soon overflowing, and garbage was thrown around the bins and in the neighbourhood, causing a stench and problems of public sanitation and health, besides being eyesores. To avoid these problems and to ensure that garbage was not dumped on roads, under the new municipal management by-laws of 2006, the MCGM introduced a system of point-to-point collection of waste, where housing societies and commercial establishments would collect their waste and hand it over directly to MCGM vehicles every day at various pre-designated points. However, the new system did not make much of a difference, as it could not cover all parts of the city, particularly slum areas, and housing societies were often unable to collect all the waste before the vehicles arrived.

Figure 4- 4 Open dumps around Sewri in Mumbai (Source: Photos: Kelly T, 2012)

Figure 4- 5 Waste collection from HDPE bins (Source: Courtesy of MCGM, 2011)

Figure 4- 6 Waste receptacle containers/ Bulk containers 1.75m^3 and 8m^3 (Source: Courtesy of MCGM, 2011)

In Mumbai, refuse is generally collected in individual houses in small containers, and then picked up by sweepers with small hand driven lorries/carts and dumped into the bulk containers. The refuse is finally carted away by the municipal trucks, for further disposal during the day. These methods are unsatisfactory as there is continuous overflowing of these bulk containers. The tip off area is always filled with rubbish.

The wheeled container bins are popular in high density areas such as apartment complexes and flat clusters and other commercial properties due to the reduced space required.

Figure 4- 7 Waste receptacles/ Bulk containrs in and around Mumbai (Source: Photos: Kelly T, 2012)

According to Davis (2013), low-serviced areas, including the slum colonies are not seen as the rightful recipients of the formal system of solid waste management (SWM). The local government extends its services only to regularized slums which are declared official or recognized under the census of slums. This step-motherly treatment is, in effect, caused the city to deteriorate, since slums form 60% of Mumbai. Moreover, these official boundaries cannot prevent the spread of dirt and disease. A study conducted by Youth for Unity and Voluntary Action (YUVA) in 1998, covering 100 communities in the slum pocket of Jogeshwari (East), found that while residents were aware of the problems related to inadequate household disposal of waste and systems of collection and transportation of garbage in the community, there was very little community involvement in solving the problem.

Figure 4- 8 Use of YUVA in slum areas (Source: Photo courtesy of MCGM, 2011)

4.5 Transportation

The Mumbai Corporation has a fleet of 337 municipal and 913 private vehicles. On average there are 1 872 trips per day to Deonar, Mulund and the new Kanjur Marg landfill sites. Approximately 5 000 municipal staff are employed for collection. The four transfer stations have a combined capacity of 1 900 tonnes per day. The corporation has 21 garages for its Transport Division. The older dumping grounds were on the outskirts of the city when they started but today, because of the rapid expansion of the city and population pressure, they are surrounded by residential areas. The Deonar dump is about 47 metres high and is overflowing, creating health and environmental problems for residents as well as the MCGM. Moreover, there are about 182 illegal open waste dumps in the city. It is predicted that the waste generated in the city will grow by around 50% to 9 000 tonnes a day in the next four decades, forcing the MCGM to identify new dumping grounds which it is finding difficult to do.

The Mumbai Corporation has improved transportation through augmenting the capacity of existing stations and constructing new refuse transfer stations. The corporation also hires new standardized closed vehicles and involves the private sector. According to Davis (2013), some truckers earn a livelihood by collecting waste and transporting it for disposal. However, proper disposal remains a concern, as there is very little space in Mumbai. It has to be carted over long distances; this increases transportation costs so significantly as to make the entire "business" unprofitable. In some cases, it has been dumped clandestinely in creeks, destroying valuable mangroves. As Mumbai has a coastal stretch of 603 km^2, it has numerous creeks that occupy marshy land during high tide.

Table 4- 4 Municipal vehicle fleet and private vehicles (Source: Courtesy of MCGM, 2011)

No.	**Types of Vehicles**	**Municipal Owned Vehicles**	**Private Owned Vehicles**	**TOTAL**
1	Compactors Double axle	117	386	503
2	Compactors Single axle0		315	315
3	Skip Vehicles (Dumper Placers)	96		96
4	Small Tipper		138	138
5	Tipper (8 ton)	98		98
6	Stationary Compactors	26		
7	JCBs	19		19
8	Bulldozers	20		20
9	Poclain	5		5
10	Crawler Dozer		2	2

Figure 4- 9 Waste Collection vehicles (Source: Photo: Kelly T, 2012)

Figure 4- 10 Waste collection vehicles- one tonne offloading into Compactor Truck (Source: Photo: Courtesy of MCGM, 2011)

4.6 Transfer Stations

Transfer stations are at strategic points where waste is sorted for the purpose of recycling and only residue waste is transported to the landfill site. The aim is to reduce the operational costs of transporting waste.

The Mahaluxmi Transfer Station receives an average 900 tonnes of waste per day. Around 720 tonnes of compacted waste is transported daily to the disposal sites in bulk carriers, saving around 60 trips in a day. There are plans to establish transfer stations at Versova, Kurla and Gorai. Presently, Versova receives 3 15 tonnes per day (TPD), Gorai 4 10 TPD and Kurla 550 TPD. Transfer stations operate with the help of excavators/loaders for loading and bulk carriers for transporting waste.

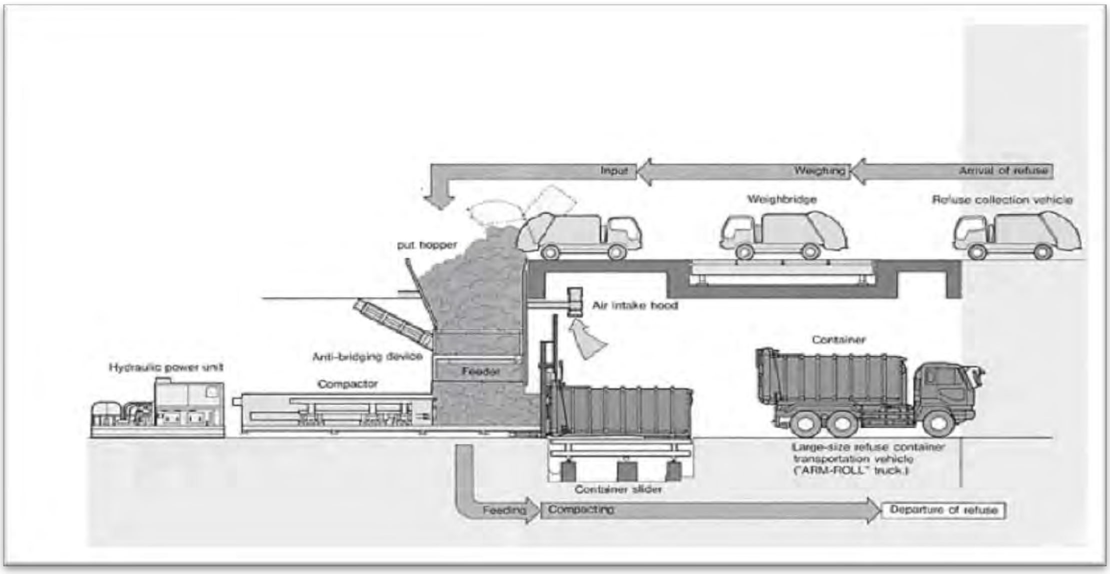


Figure 4- 11 Schematic layout of a Transfer Station at Mahaluxmi (Source: Photo courtesy of MCGM, 2011)

Figure 4- 12 Transfer station at Mahaluxmi (Source: Photo courtesy of MCGM, 2011)

4.7 Landfill Sites

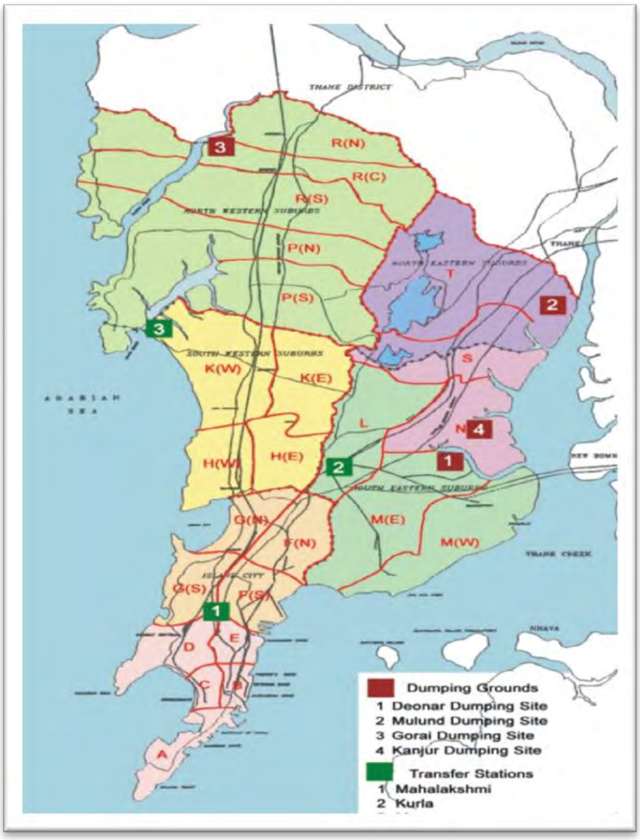


Figure 4- 13 Map of MCGM indicating landfill sites and transfer stations (Source: Courtesy of MCGM, 2011)

Four landfill sites are currently operated by the MCGM. The Deonar Landfill site, the Gorai dumpiste, Kanjur Marg landfill site and Mulund landfill site.

4.7.1 Scientific Landfill Closure and Methane Capture Project, Gorai

According to officials at MCGM, the Gorai dumpsite is located in the Western suburbs of Mumbai and its spatial area of 19.6 hectares has been operational since 1972. The site is adjacent to Gorai Creek and is closed to habitation. The daily receipt of MSW was approximately 2 200 TPD from Western Suburbs of Mumbai until 31 December 2007 after which the MCGM stopped dumping fresh waste at Gorai. The project included scientific closure and converting about 19.6ha of land into green landscaped space. There are residential areas in close proximity to the Gorai site. The practice of open dumping followed since 1972 caused significant environmental damage to the neighbourhood. Approximately, about 3.24 million tonnes of waste up to an average height of 26 meters was lying at the site. The closure design is inclusive of gas collection, a venting system, leachate collection and surface water drain. (MCGM Report, 2009).

Waste composition is an important consideration in evaluating an LFG recovery project. Landfills that have a high percentage of the organic content will produce landfill site sooner and over a short length of time. Moisture content and “degradability” are also other determinables. Data on the composition of the waste disposed of at the Deonar landfill was not available. Waste composition data was available from the Gorai landfill.

Table 4- 5 Components of waste and fractions from the waste stream received in Gorai (Source: Courtesy of the Mumbai Corporation, 2011)

Component	**Fraction of Waste stream (%)**
Food waste	35.7
Garden waste	6.3
Wood waste	0
Paper and cardboard	11.8
Plastics	5.0
Rubber, leather	2.5
Textiles	7.5
Other organics	0
Metals	0.8
Glass and ceramics	0.4
Construction and demolition waste (including sand and earth fill)	30.0
TOTAL	100

The MSW accumulated on the site had almost reached its highest capacity.

The site currently comprises an approximately 120 ha area used for waste disposal, with depths ranging from about three by 22 meters. The MCGM planned to close approximately 69ha which was part of the disposal area. The site was situated in the Eastern suburb of the city, adjacent to Thane Creek, on an area of about 132 ha of land was rehabilitated.

Figure 4- 14 Closure and Rehabilitation of Gorai Landfill Site in Mumbai (Source: Photo courtesy of MCGM, 2011)

The Scientific Closure Plan for Gorai Dumping Ground included the relocation and reformation of existing waste which also included a layer of a liner system. There was a landfill gas collection and flaring system and leachate collection system. The construction of a compound wall on the landward side and sheet piling on the creek ward Construction of a compound wall on the landward side and sheet piling on the creek ward side to prevent leachate from entering the creek. (MCGM Report, 2009).

The Gorai scientific closure project envisages a landfill gas recovery system at the site in order to reduce methane (CH4) emissions in the future. The capture and combustion of methane results in a substantial reduction of GHG emissions and thus has the potential to earn carbon credits in the form of CERs under the CDM. The project has received Host Country Approval from the National CDM Authority, Ministry of Environment and Forests, Government of India. It was in the advanced stages of being registered with the UNFCCC (MCGM Report, 2009).

The MCGM has signed an Emission Reduction Purchase Agreement (ERPA) with the Asian Development Bank (ADB), in terms of which part of the CERs generated at Gorai Dumping Ground were sold to ADB for which the MCGM would receive an advance of approximately Rs. 26 crores. It was expected that the MCGM would receive total revenue of Rs. 72.9 crores from the sale of CERs (MCGM Report, 2009).

Overall project implementation benefits

The project aimed to eliminate methane and replace it with fossil fuel electricity generation to prevent GHG emissions. It resulted in significant environmental and public health and hygiene improvements, the elimination of foul odours, fire and vermin, improvement in the quality of creek water, rejuvenation of mangroves, and an increase in the avian fauna population.

4.7.2 Mulund landfill site

This site is located in the Eastern suburbs of the City in an area of about 25 ha along the Thane Creek and has been operating since 1968. Presently, the site receives around 600 tonnes a day of MSW from the city and the Eastern suburbs of Mumbai. (MCGM Report, 2009).

4.7.3 Kanjur landfill site

A new site was proposed at Kanjur Village to accommodate the increasing waste generated by Greater Mumbai with a design capacity to handle 4 000 tonnes of waste per day. Provision is made for incineration and autoclaving of biomedical waste. The corporation now plans the “partial closure” of the Deonar and Mulund dumping grounds and the development of “sanitary landfills” (sanitary dump sites) and waste processing plants at the sites. A sanitary landfill and waste processing plant will also propose to be built at Kanjur Marg. At these sanitary landfills, wastes will be compacted and covered with different layers of linings - construction debris, high-density polythene, etc. - to prevent water from seeping into the dump. Deep foundation walls will be built to prevent water from the dumps contaminating ground water and water leaching out will be treated and released into the drainage systems and the nearby creeks. (MCGM Report, 2009).

4.7.4 Deonar Landfill Site

The Deonar landfill has been operating since 1927 currently receives about 10 million tonnes of waste in place and was projected to stop receiving organic waste and be partially closed in 2010 after receiving approximately 12.7 million tonnes of MSW. The site is currently about 120 hectares, with depths ranging from about 3 to 22 meters. MCGM plans to close approximately 69 hectares of the existing disposal area in the future. The waste from these areas will be excavated and transferred to the remainder of the 51 hectares. (MCGM Report, 2009).

The Deonar landfill is an unlined dumping ground that has been operational since 1927. The site is expected to remain operational for anouther 30 years, however in terms of Indian law and according to Davis (2010) it will be required to receive only inert waste after organic waste processing and a composting facility is established. It will be a controlled open dump owned and operated by the MCGM. It accepts domestic and commercial waste. In 2008, the site accepted approximately 1 326 000 tonnes of waste. Preliminary biogas modelling estimated that 2 200m3/hr of biogas at 40% methane with 60% collection efficiency could be recovered for capture and use in 2012. Biogas recovery will rise to peak of approximately 3,800m3/hr shortly after the closure. (MCGM Report, 2009).

4.7.4.1 Landfill Physical Characteristics

The total coverage of the exsiting landfill propert is 131 hectares, of which 120 hectares have been utilized for waste disposal. Of the total landfill about 69 hectares of easte have been removed from the southern and eastern portion of the site and depositing 51 hectare area in the northwest portion of the site. (MCGM Report, 2009).

The intention aimed at creating space within the site boundary for developing composting areas, leachate treatment areas, and future waste disposal areas. The 69 hectare area to be excavated contains waste deposits approximately 20 to 80 years old. The 51 hectare disposal area, which contains waste disposed over the past 20 years, was due to be partially closed by 2010. (MCGM Report, 2009).

4.7.4.2 Waste Disposal Rates

Historical records of waste disposal rates are not available for the Deonar landfill. There is a weighbridge at the entrance which actively records incoming trucks' capacity. The site averages around 6 000 metric tonnes of waste in a day.

4.8 RESULTS AND ANALYSIS

Waste Stream Analysis: MCGM- Deonar Landfill site WSA

4.8.1 Introduction

A waste profile of general fractions of the waste streams (recyclable, biogenic and other waste) is presented to differentiate between the proportions of dry, wet and residual waste fractions.

A pie-chart of general waste fractions is then presented to establish the contribution of the individual recyclable waste material groups - Paper and Cardboard; Glass; Metals and Plastics.

Finally, the specific fractions of each waste material group defined in the waste classification system are illustrated.

The interpretation of the results of the waste stream analysis notes any inconsistencies and correlation with expected results. The waste streams are compared on the basis of the originating source/activity of the waste generated, and the type of area. It was difficult to identify income groups as the areas in Mumbai are vast and amongst high income groups, there are low income and middle income groups. Income groups are mixed in every area.

A survey of 825 households was conducted to establish the amount of waste generated, how much of this waste is diverted to the landfill from the household and how much of that waste is landfilled.

The composition of the waste streams is then applied to average weighbridge data for the Deonar landfill site to obtain annual quantities of each waste fraction, used as input data for both the GHG modelling and cost and income analysis.

4.8.2 Chembur

4.8.2.1 Socio-economic analysis and waste generation in households in Chembur

Eighty four percent of the 141 household heads are male and 16% are female. Seven percent of the respondents stated that their highest standard of education was primary education, 30% secondary education and 63% tertiary education. Fifteen percent of the respondents had been living in the area for 21-30 years, 22% between 0-10 years, 54% between 11 and 20 years and 9% for more than 30 years. Thirty five percent of the respondents lived in households with between five and seven members, 51% between two and four members, and 14% between eight and 10 members. Fourteen percent of the respondents reported an income of Rs 5000 – Rs 10 000, 21% earned between Rs10 000 and Rs 20 000 and 58% received a total income of more than Rs20 000. Thirty five percent of the respondents indicated that they pay Rs 200-Rs500 and 6% paid Rs500- Rs1000 for waste services per month and 59% were uncertain how much they paid. Eighty one percent of the respondents indicated that their household generated 5-10kg of waste per week, 13% generated 11-15 kg, and 6% 16-30 kg of household waste per a week. Thirty two percent used a plastic bag from retailers in a bin, 50% used a bucket, 14% used a plastic bag and 4% used other methods. Ninety four percent of the respondents stated that the frequency of the waste removal by the municipality was once in two weeks and 6% said that they received a twice weekly service. Twenty three percent rated the service excellent, 60% indicated that it was good and 17% indicated that they received a poor service. Fifty five percent of these respondents have waste pickers sorting the waste from the household that can be recycled or reused and 45% said that there were no waste pickers on waste collection days. Furthermore, 55% indicated that they were not aware of any recycling programme in the area and 45% were aware of such a programme. Twenty two percent of the respondents did nothing about their waste, 13% made compost within their household and 35% were reusing and 30% recycling waste. In Chembur, 58% of the respondents stated that the area was characterised by illegal waste disposal and 42% said there was no illegal waste disposal. The figure below details waste generation at households in Chembur.

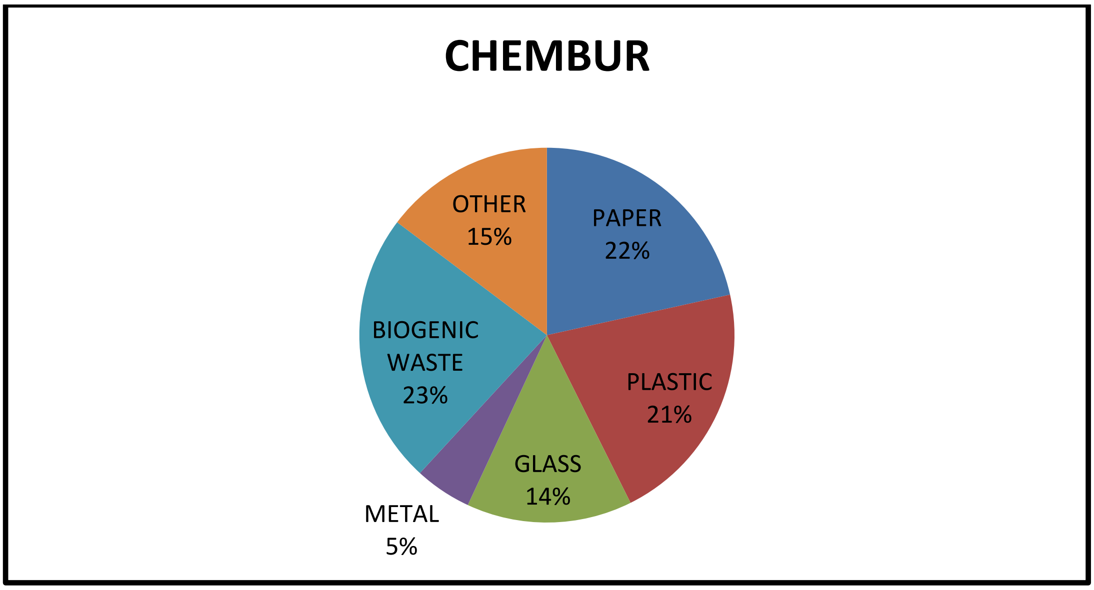


Figure 4- 15 Waste Generation at households in Chembur

Figure 4-15 highlights that 23% of the waste generated households is biogenic waste, 22% paper, 21% plastic, 14% glass and 15% other waste.

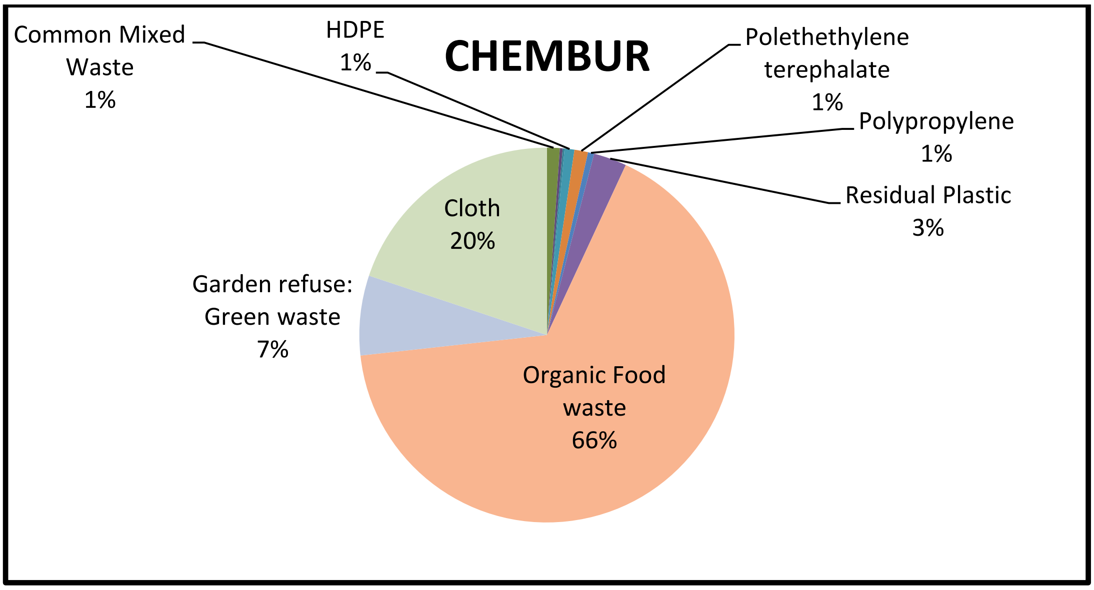


Figure 4- 16 Specific Waste Fractions in Chembur

Figure 4-16 contains a detailed waste stream analysis, highlighting that 66% of the waste stream is organic food waste, 20% cloth, 7% garden green waste, and 1% HDPE, Polypropylene, Polythethylene terephalate, Residual Plastic and Common Mixed Waste, respectively, received at the Deonar Landfill site from the Chembur area.

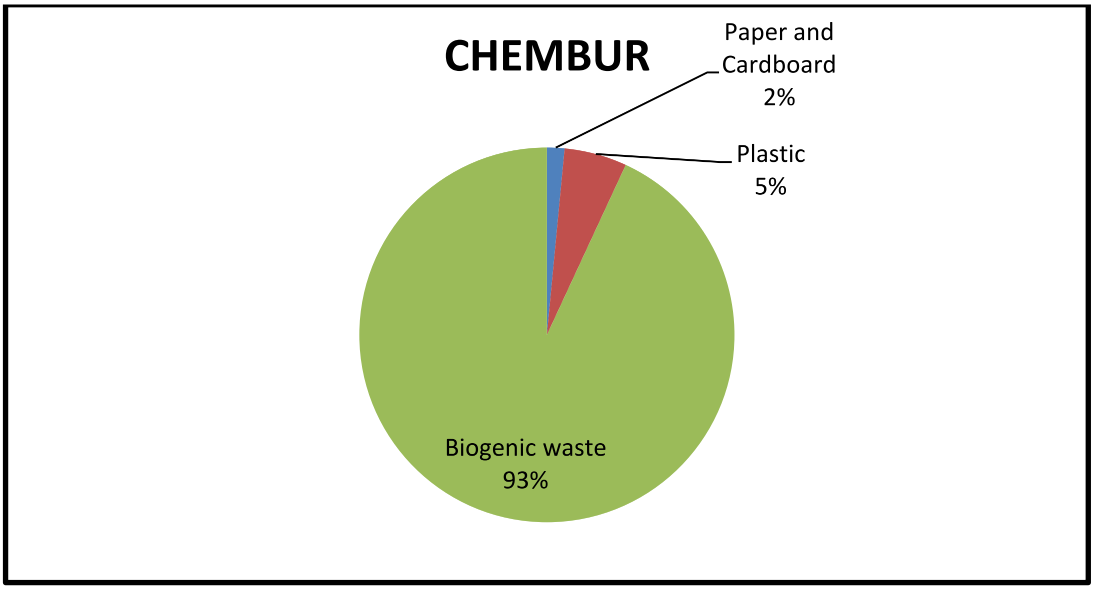


Figure 4- 17 General Waste Fractions

The general waste profiles for Chembur are presented in Fig 4-17. Recyclables are only 7% of the total waste stream comprise of 5% plastic and 2% paper and cardboard. In Chembur, a large percentage of the waste stream is removed by waste pickers for the purposes of recycling. Biogenic waste is a significant fraction of the total waste stream at 93%. Garden refuse comprises mostly palm leaves and flower waste.

4.8.3 Andheri

4.8.3.1 Socio-economic analysis and waste generation in households in Andheri

Of the 200 respondents, 95% of household heads are male and 5% are female. Sixty three percent of the respondents stated that their highest standard of education was primary education, 33% secondary education and 4% tertiary education. Fifty percent of the respondents had been living in the area for 21-30 years, 4% between 0 and 7 years, 44% between 11 and 20 years and 2% for more than 30 years. The majority (66%) of the respondents had between five and seven people living in their household, 26% two to four household members, 6% 8-10 members and 2% more than 10. Fifty eight percent of the respondents reported a total income of between Rs 5000 and Rs 10 000. Eighty six percent stated that they pay Rs 200-Rs500 and 14% paid Rs500-Rs1000 for waste services per month. Seventy four percent of the respondents indicated that their household generated between five and 10kg of waste per week, while 25% generated 11-15 kg and 1% between 16-30 kg of household waste in a week. Eighty three percent of the respondents used a plastic bag from retailers in a bin, 10% used a bucket and 7% used a plastic bag. Eighty five percent stated that the municipality removed waste once in two weeks, while 6% had a weekly service and 9% a twice weekly service. Sixty four percent of the respondents rated the service excellent, 33% indicated that it was good and only 2% indicated that they received poor service. Households that reported excellent and good service receive a daily waste pick up from each household, mainly in flats. Eighty seven percent of the respondents have waste pickers sorting the waste from the household that can be recycled or reused. Ninety seven percent indicated that they were not aware of any recycling programme in the area and 3% indicated that they were aware of such a programme. Ninety four percent did not use their waste for anything, but 5% made compost within their household and 1% was recycling. Forty percent of the Andheri respondents stated that their area was characterized by illegal waste disposal and 24% said there was no illegal waste disposal, with 36% not responding to this question. Ninety four percent stated that illegal waste disposal led to bad odours. Figure 4-18 also highlights that 34% of the waste generated was biogenic waste, 32% paper, 30% plastic and 4% glass.

Waste generation at households in Andheri.

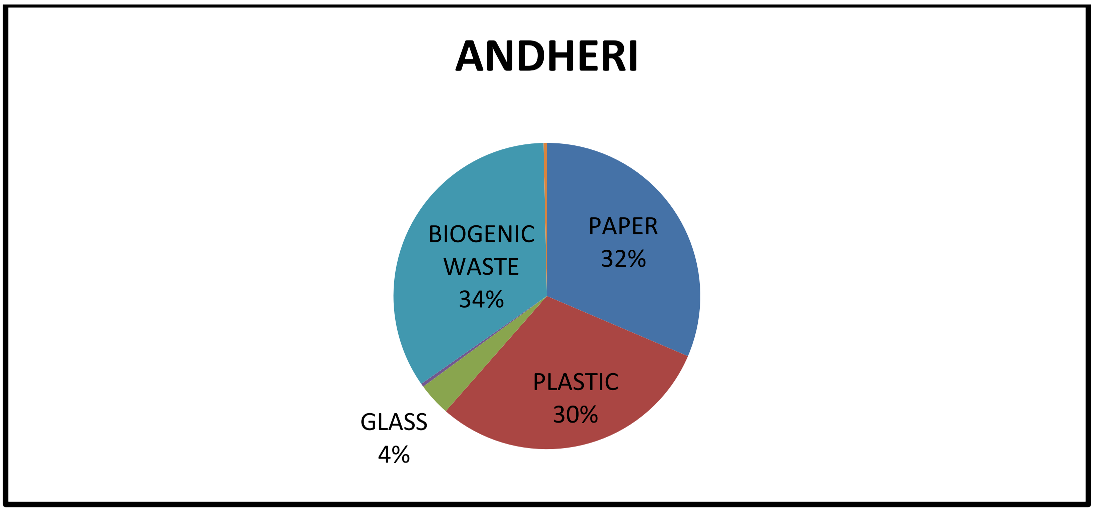


Figure 4- 18 Waste generation at households in Andheri

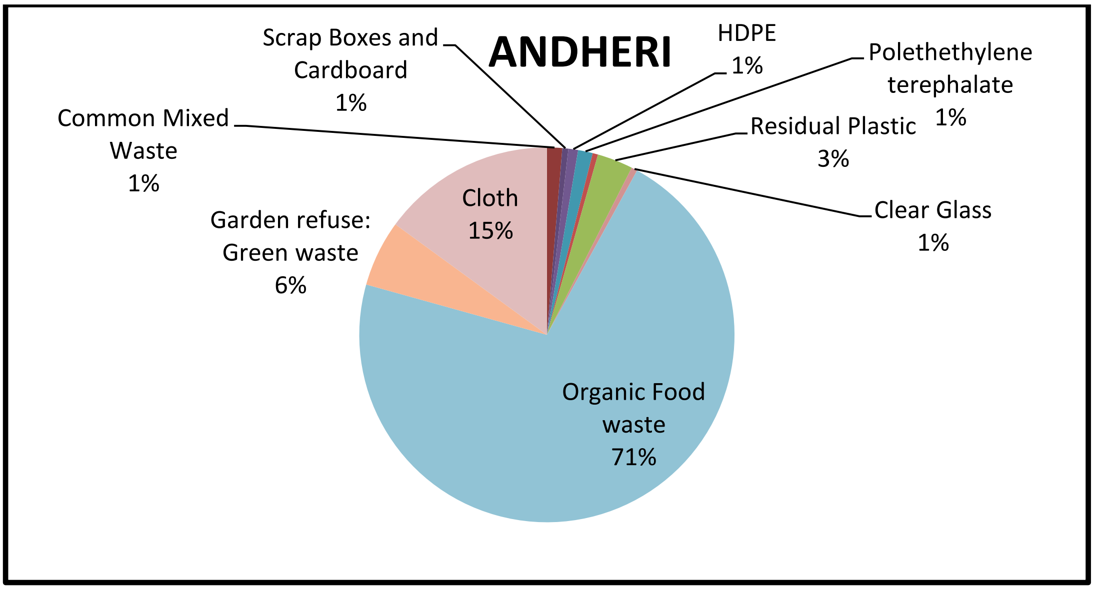


Figure 4- 19 Specific Waste Fractions in Andheri

Figure 4-19 contains a detailed waste stream analysis, highlighting that 71% of the waste stream is organic food waste, 15% cloth, 6% garden green waste, 3% residual plastic, and 1% common mixed waste, HDPE, Polythethylene terephalate and clear glass, respectively received at the Deonar Landfill site from the Andheri area.

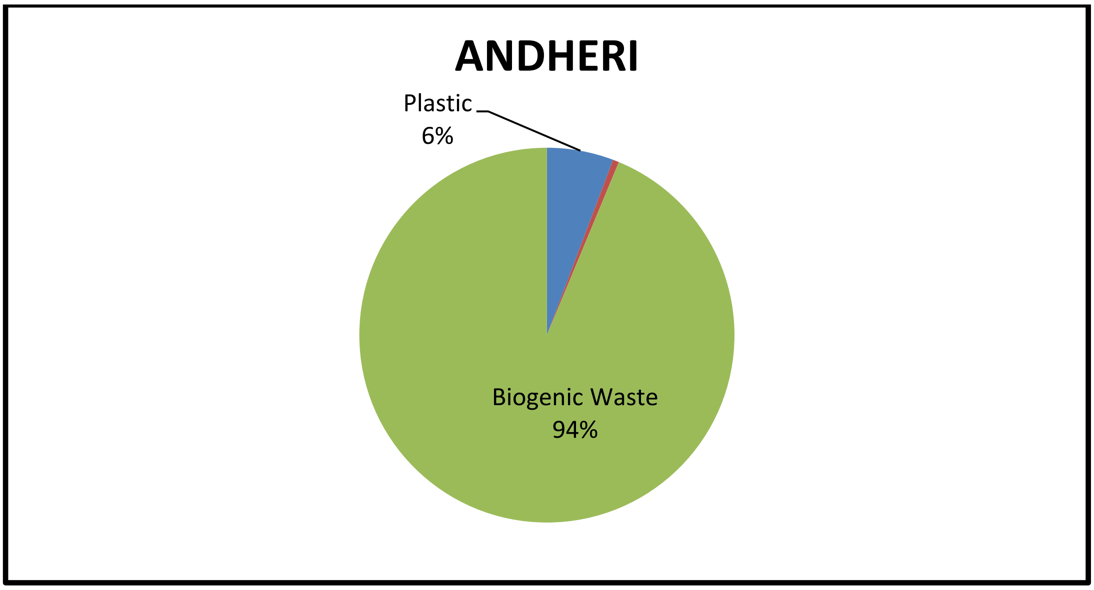


Figure 4- 20 General Waste Fractions in Andheri

The general and specific waste profiles for Andheri are presented in Figures 4-19 and 4-20. Recyclables which are only 6% of the total waste stream comprise of 5% plastic and 0.1% glass. In Andheri, a large percentage of the waste stream is removed by waste pickers for the purpose of recycling. Biogenic waste forms a significant fraction of the total waste stream at 94%. Garden refuse which comprises of mostly palm leaves and flower waste, makes up 6%. Due to the many clothing factories in this area, 15% is cloth waste.

4.8.4 Kanjur Marg

4.8.4.1 Socio-economic analysis and waste generation in households in Kanjur Marg

Of the 153 respondents, 95% household heads are male and 5% are female. Nine percent of the respondents' highest standard of education was primary education, 29% secondary education and 62% tertiary education. Twelve percent of the respondents had been living in the area for 21-30 years, 18% between 0 and 10 years, 12%11-20 years and 58% for more than 30 years. Twenty percent lived in households with five to seven members, 72% between two and four members, and 8% between eight and 10 members. Eight percent reported total income Rs 5 000 –Rs 10 000, 22% earned between Rs10 000 and Rs 20 000 and 69% earned above Rs 20 000. Forty four percent of the respondents indicated that they pay Rs 200-Rs500 and 15% paid Rs500- Rs1000 for waste services per month, while 41% were uncertain how much they paid. Eleven percent of the respondents indicated that their household generated 5-10kg of waste per week, 65% generated between 11 and 15 kg, and 24% were responsible for 16 to 30 kg of household waste per week. Forty one percent of the respondents used a plastic bag and 59% used a bucket. Ninety percent stated that waste was removed by the municipality once every two weeks, while 10% had weekly service. Thirty three percent of the respondents rated the service excellent, 58% indicated that it was good and 9% indicated that they received poor service. Sixty seven percent have waste pickers sorting household waste that can be recycled or reused, while 33% indicated they did not have waste pickers in the area. Ninety four percent of the respondents were not aware of any recycling programme in their area, with only 6% aware of such programmes. All the respondents (100%) did nothing in terms of compost made or recycling or reuse. In Kanjur Marg, all the respondents said that the area was not characterized by illegal waste disposal. In Figure 4-21 presents household waste in Kanjur Marg. Forty percent of the waste generated was biogenic waste, 4% paper, 25% plastic, 1% glass and 30% other waste.

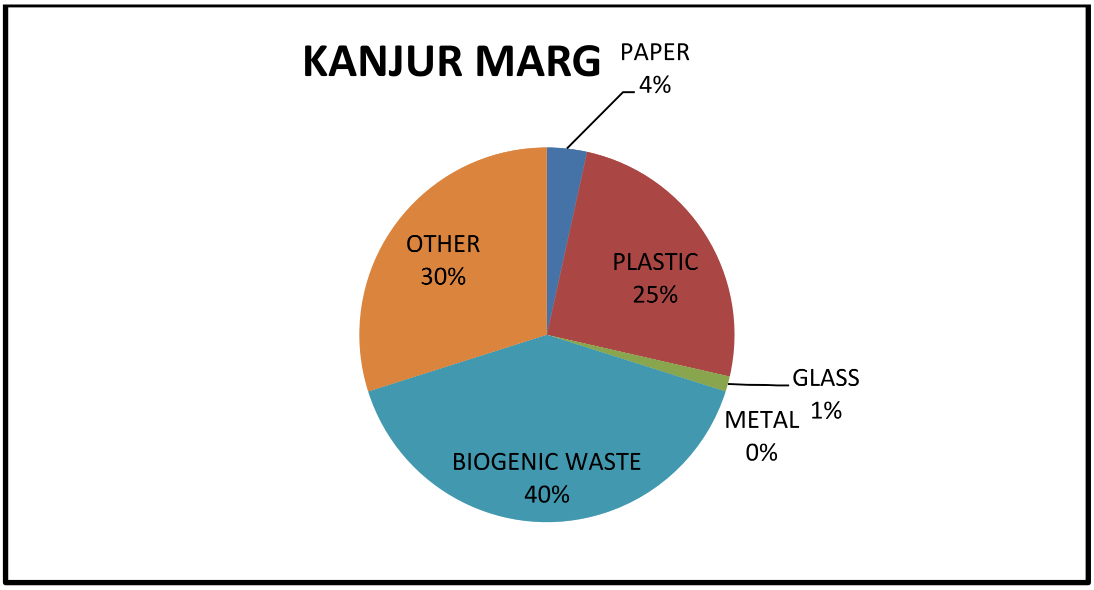


Figure 4- 21 Waste generation at households in Kanjur Marg

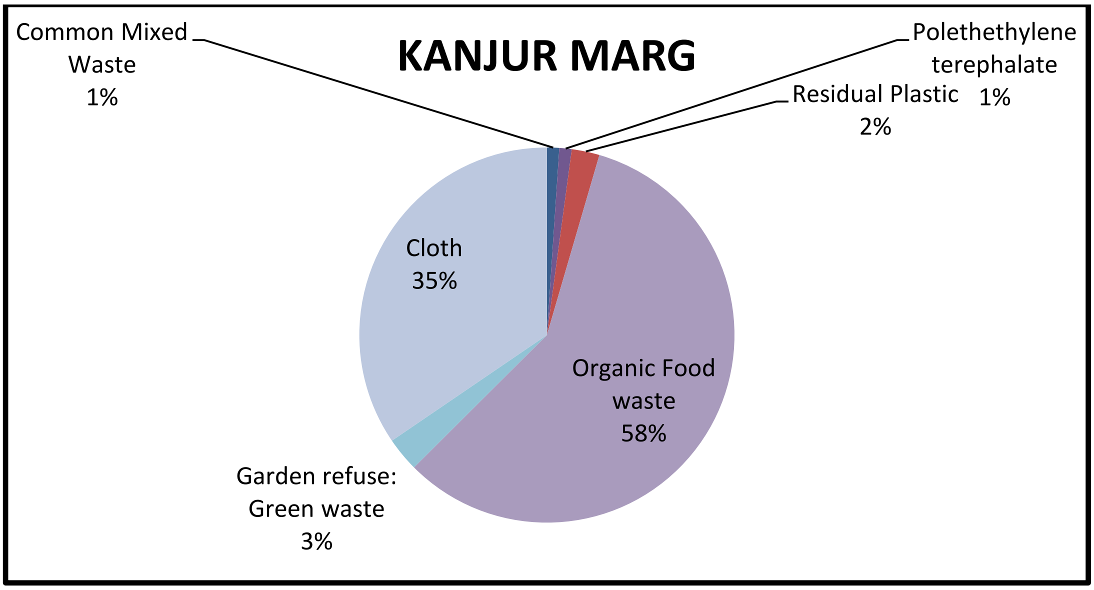


Figure 4- 22 Specific waste fractions in Kanjur-Marg

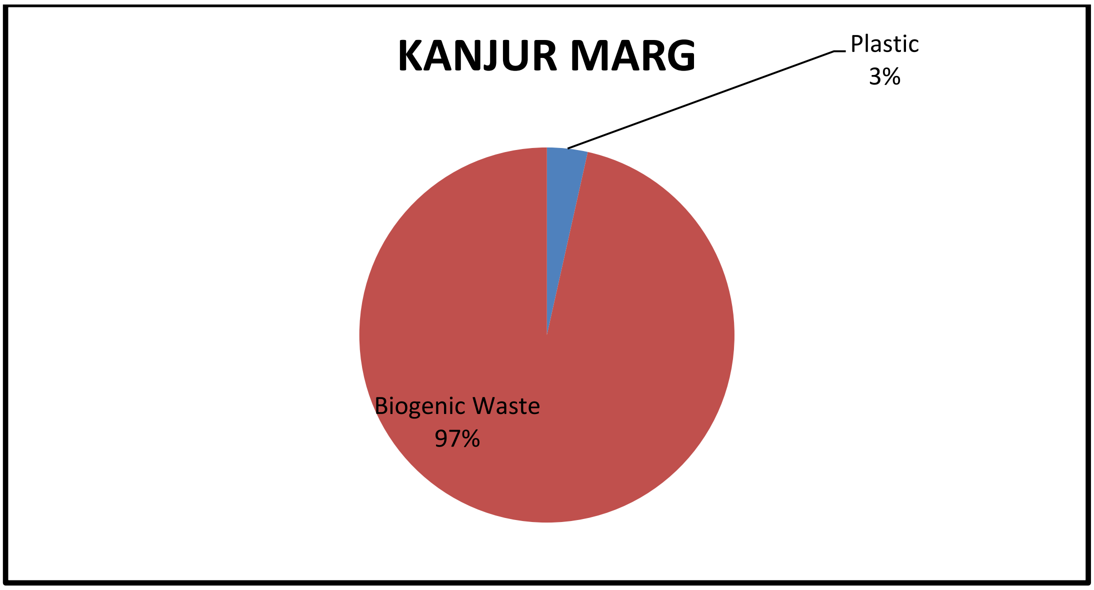


Figure 4- 23 General waste fractions in Kanjur Marg

The general and specific waste profiles for Kanjur Marg are presented in Figures 4-22 and 4-23. Recyclables which are only 3% of the total waste stream comprise of 3% plastic. In Kanjur Marg, a large percentage of the waste stream is removed by waste pickers for the purposes of recycling. Biogenic waste forms a significant fraction of the total waste stream at 97%. Garden refuse, which comprises mostly palm leaves and flower waste is at 3%. Due to the many clothing factories in this area, 35% is cloth waste.

4.8.5 Sewri

4.8.5.1 Socio-economic analysis and waste generation in households in Sewri

Of the 128 respondents, 84% household heads are male and 16% are female. Ten percent of the respondents stated that their highest standard of education was primary education, 42% secondary education and 48% tertiary education. Forty five percent of the respondents had been living in the area for 21-30 years, 6% between 0 and 10 years, 36% from 11-20 years and 13% for more than 30 years. Forty four percent of the respondents lived in households with between five and seven members, while 50% had between two and four members, 5% from 8-10 members and 1% more than 10 members living in their households. Thirty percent of the respondents reported a total income of Rs 5 000 – Rs 10 000. 86% of the respondents indicated that they pay Rs 200-Rs500 and 30% paid Rs500 - Rs1000 for the waste service per month; however, 59% of the respondents were not sure of the question and 9% paid between Rs500- Rs1000. Eighty three percent of the respondents indicated that their household generated 5-10kg of waste per week, while14% generated between 11 and 15 kg, and 3% between 16-30 kg of household waste a week. Seventy percent stated that waste was removed by the municipality once every two weeks and 30% reported a twice a week service. Four percent of the respondents rated the service excellent, 48% indicated that it was good and 48% stated that it was poor. Seventy percent of the respondents have waste pickers sorting the waste from their household that can be recycled or reused and 30% said that there were no waste pickers on waste removal day. Ninety eight percent were not aware of any recycling programme in the area and 2% were aware of such a programme. Seventy four percent of the respondents did nothing about their waste, 8% made compost within their household, 5% reused their waste and 12% were recycling. In Sewri, 62% of the respondents indicated that the area was characterized by illegal waste disposal and 38% said there was no illegal waste disposal. Fifty seven percent indicated that the illegal waste disposal caused bad odours and attracted rodents and insects as well as being unsightly. Figure 4-24 shows that 25% of the waste generated was biogenic waste, 27% paper, 25% plastic, 10% metal and 11% glass.

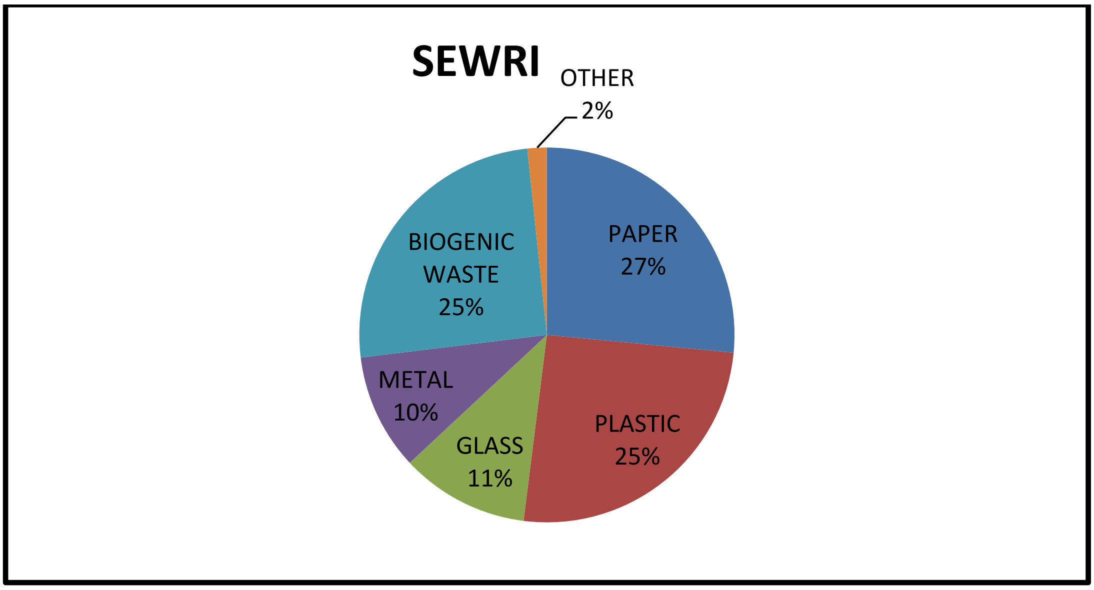


Figure 4- 24 Waste generation at households in Sewri

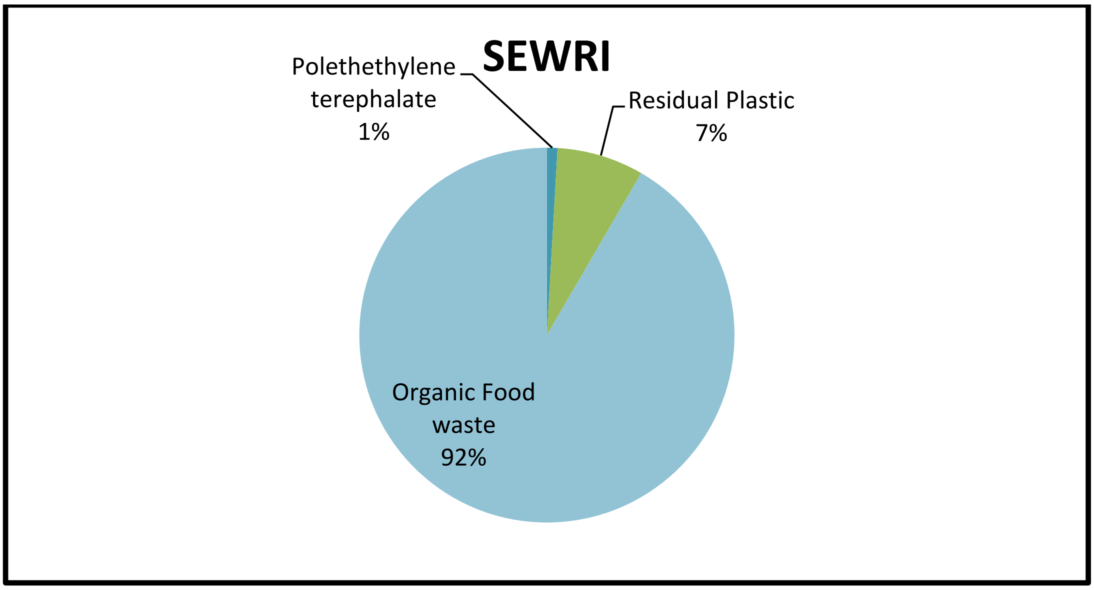


Figure 4- 25 Specific waste fractions in Sewri

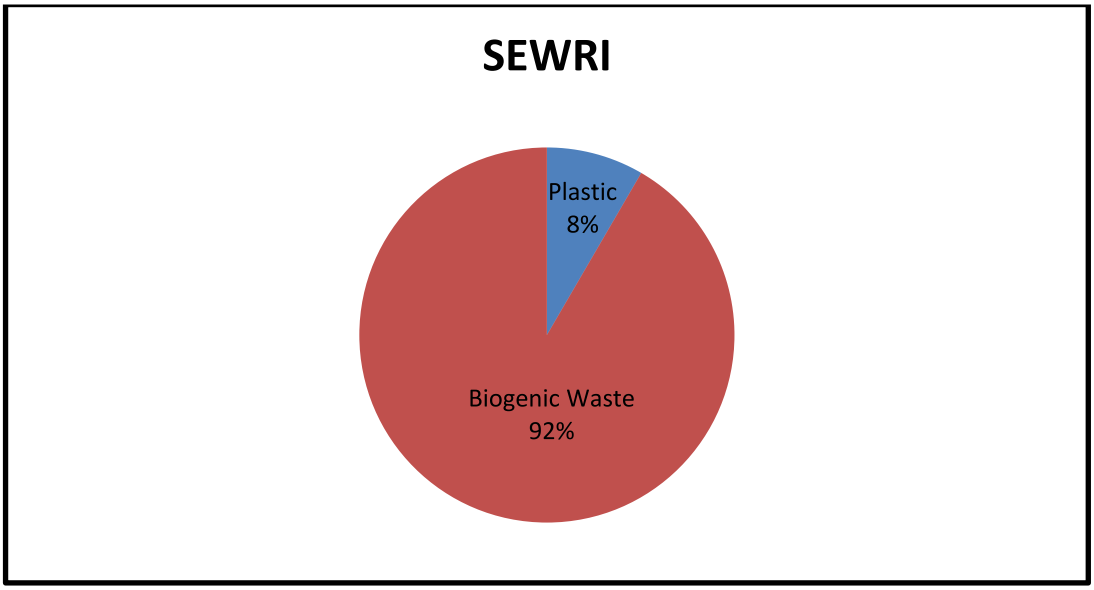


Figure 4- 26 General waste fractions in Sewri

The general and specific waste profiles for Sewri entering the Deonar landfill site are presented in Figures 4-25 and 4-26. Recyclables which are only 8% of the total waste stream comprise of 8% plastic. In Sewri, a large percentage of the waste stream is removed by waste pickers for the purposes of recycling. Biogenic waste forms a significant fraction of the total waste stream at 92%. Garden refuse, which comprises mostly palm leaves and flower waste is at 3%.

4.8.6 Malad

4.8.6.1 Socio-economic analysis and waste generation at households in Malvani, Malad

Of the 203 respondents, 49% household heads are male and 51% are female. Seventeen percent of the respondents stated that their highest standard of education was primary education, 57 % secondary education and 26% tertiary education. Sixteen percent had been living in the area for 21-30 years, 56% between 0 and10years, 36% 11-20 years and 2% for more than 30 years. Thirty nine percent of the respondents lived in households with five to seven members, 60% had two to four household members, and 1% between eight and 10 members. Twenty one percent of the respondents stated that their total income was Rs 5000–Rs 10 000, while 55% earned between Rs10 000 and Rs 20 000. Forty percent of the respondents indicated that they pay Rs 200-Rs 500 for waste services per month, while 4% paid Rs500- Rs1000 and 56% were uncertain how much they paid for waste services. Nine percent indicated that their household generated 5-10kg of waste per week, 73% generated between 11 and 15 kg, and 18% 16-30 kg of household waste a week. Twelve percent of the respondents used a plastic bag from retailers in a bin, 76% used a bucket and 8% used a plastic bag. Eighty two percent stated that the municipality removed waste once every two weeks, 12% had a weekly service and 6% reported that their waste was removed twice a week. Sixteen percent of the respondents rated the service excellent, 56% indicated that it was good and 28% indicated that they received poor service. Sixty six percent have waste pickers sorting their household waste that can be recycled or reused. Ninety six percent of the respondents were not aware of any recycling programme in the area, with only 4% aware of such a programme. Furthermore, 96% did nothing about their waste, 2% made compost within their household and 1% were reusing and recycling. In Malvani, Malad, 94% of the respondents stated that the area was characterized by illegal waste disposal and 6% said there was no illegal waste disposal. Figure 4-27 presents household waste generation; 27% of the waste generated was biogenic waste, 25% paper, 15% plastic, 9% glass and 23 other waste.

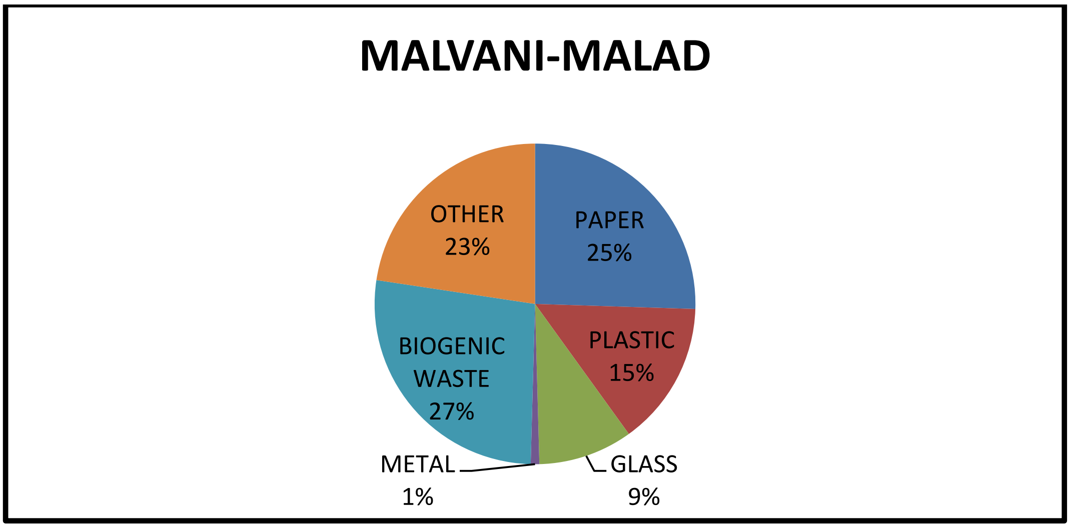


Figure 4- 27 Waste generation at households in Malad

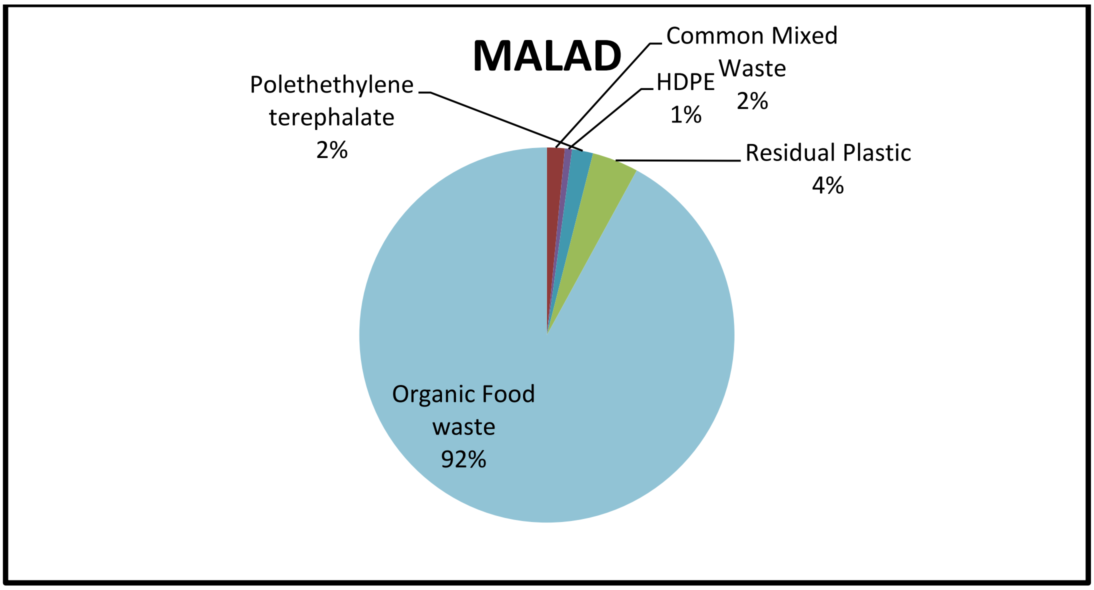


Figure 4- 28 Specific waste fractions in Malad

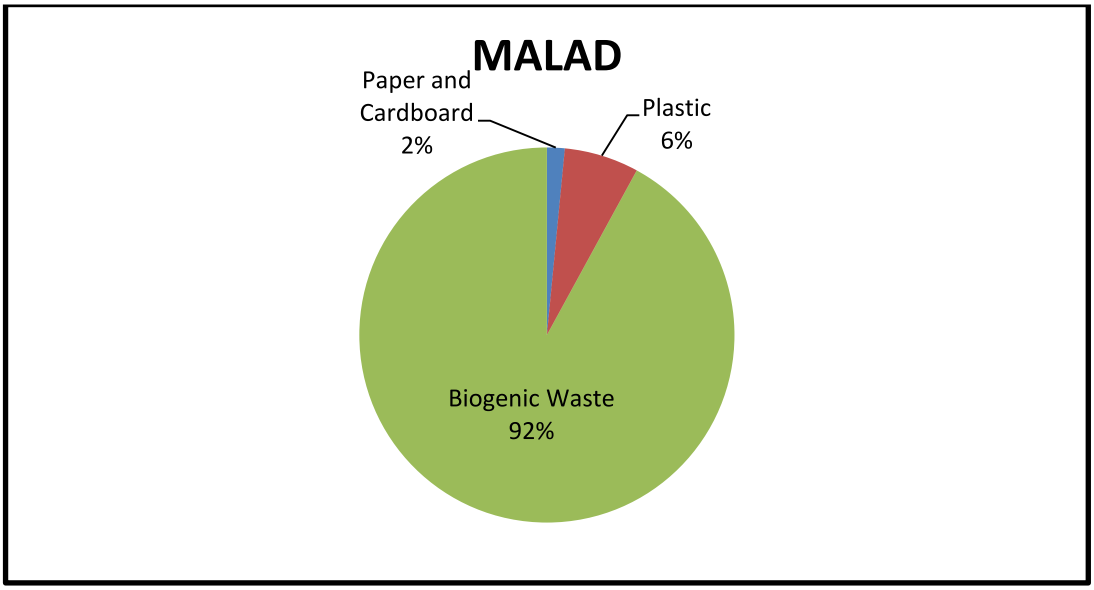


Figure 4- 29 General waste fractions in Malad

The general and specific waste profiles for Malad are presented in Figures 4-28 and 4-29. Recyclables which are only 8% of the total waste stream comprise of 6% plastic and 2% paper and cardboard. In Malad, a large percentage of the waste stream is removed by waste pickers for the purposes of recycling. Biogenic waste forms a significant fraction of the total waste stream at 92%.

4.8.7 Ghatkopar

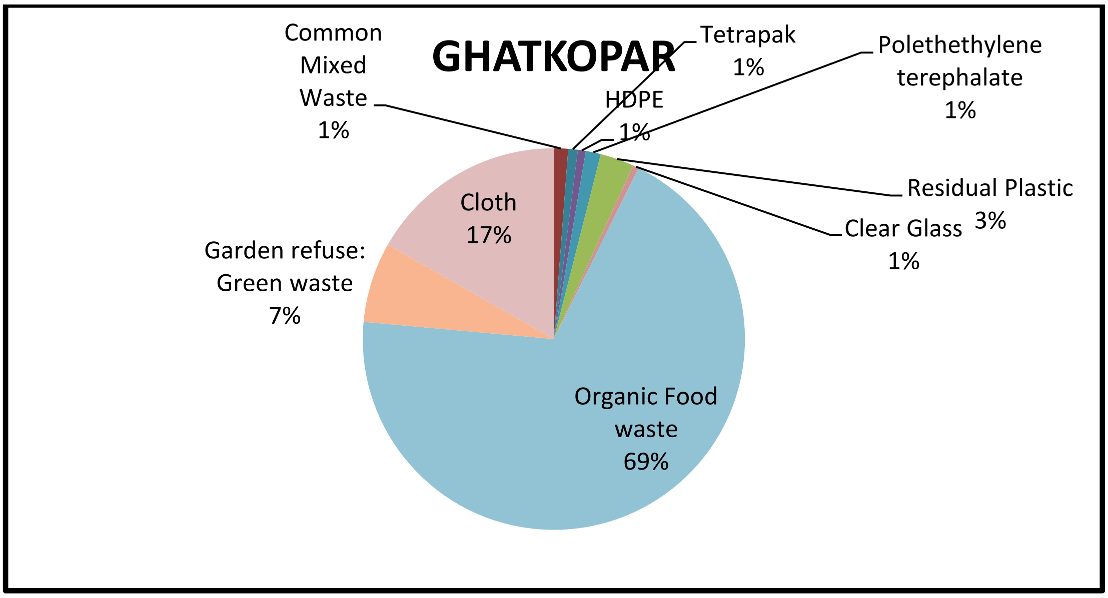


Figure 4- 30 Specific waste fractions in Ghatkopar

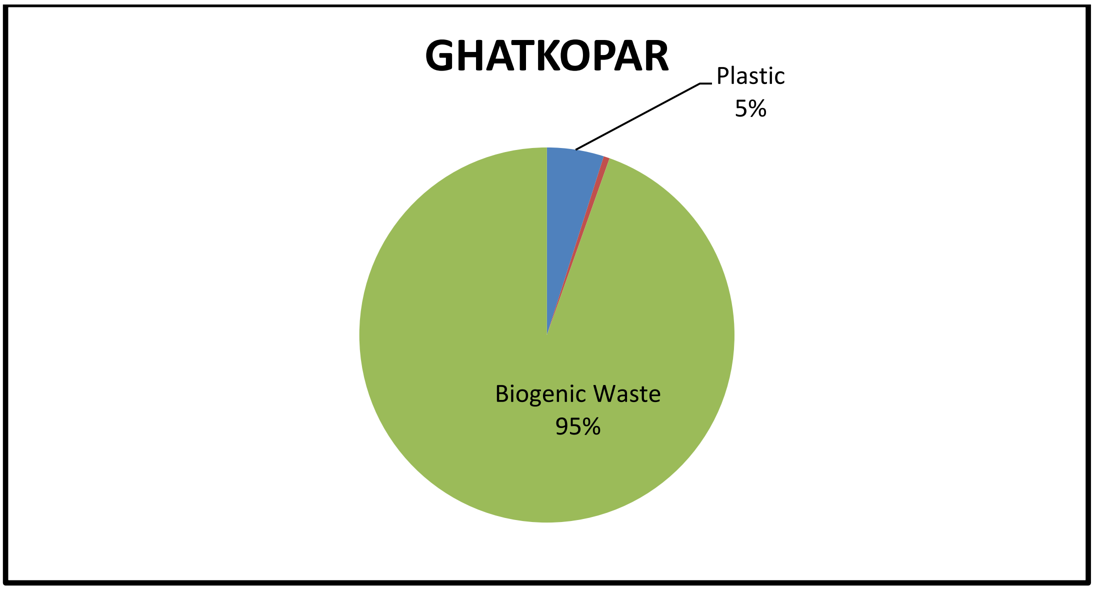


Figure 4- 31 General waste fractions in Ghatkopar

From Ghatkopar on, there is no socio-economic analysis that was conducted. The general and specific waste profiles for Ghatkopar are presented in Figures 4-30 and 4-31. Recyclables which are only 5% of the total waste stream comprise of 5% plastic. In Ghatkopar, a large percentage of the waste stream is removed by waste pickers for the purposes of recycling. Biogenic waste forms a significant fraction of the total waste stream at 95%. Garden refuse, comprised mostly of palm leaves and flower waste makes up 7%. Due to the large number of clothing factories in Ghatkopar, 17% is cloth waste.

4.8.8 Shivaji Nagar

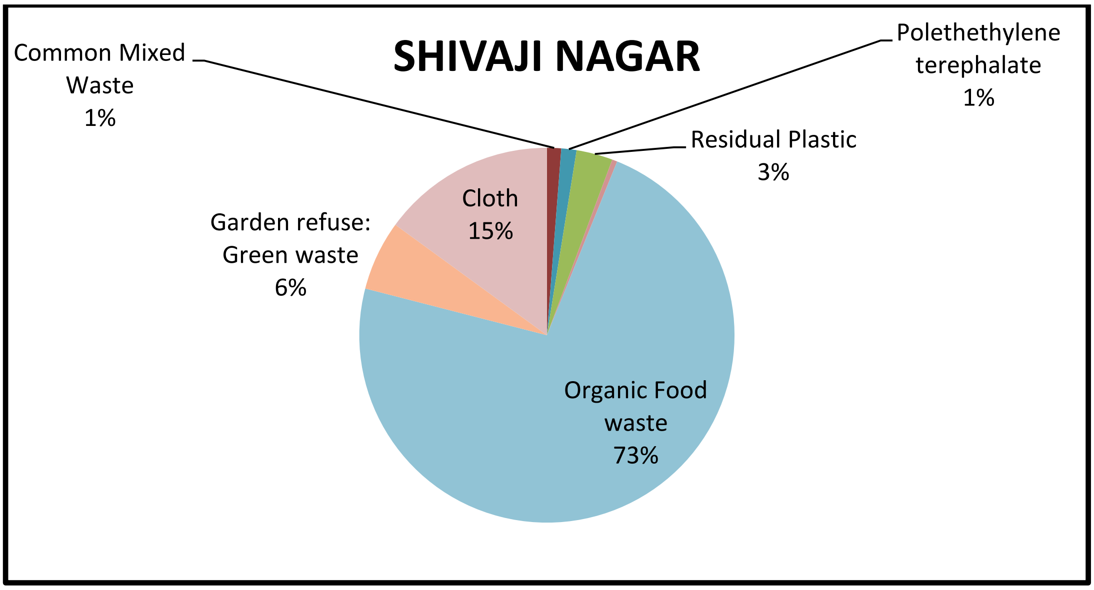


Figure 4- 32 Specific waste fractions in Shivaji Nagar

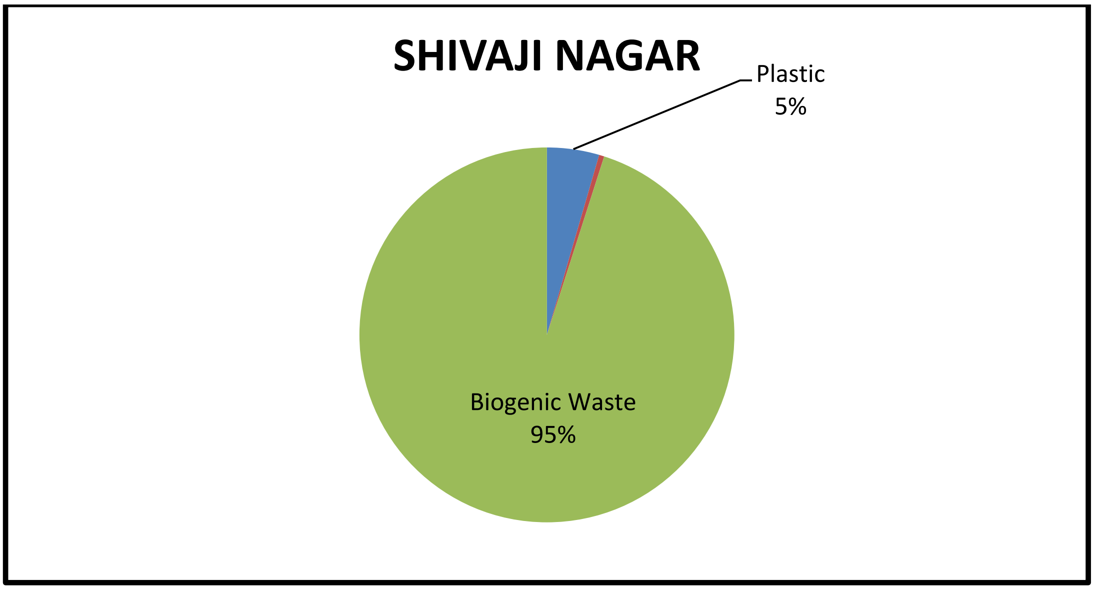


Figure 4- 33 General Waste fractions in Shivaji Nagar

The general and specific waste profiles for Shivaji Nagar are presented in Figures 4-32 and 4-33. Recyclables which are only 5% of the total waste stream comprise of 5% plastic. In Shivaji Nagar, a large percentage of the waste stream is removed by waste pickers for the purposes of recycling. Biogenic waste forms a significant fraction of the total waste stream at 95%. Garden refuse, which comprises mostly palm leaves and flower waste is at 6%. Due to the many clothing factories in Shivaji Nagar, 15% is cloth waste.

4.8.9 Byculla

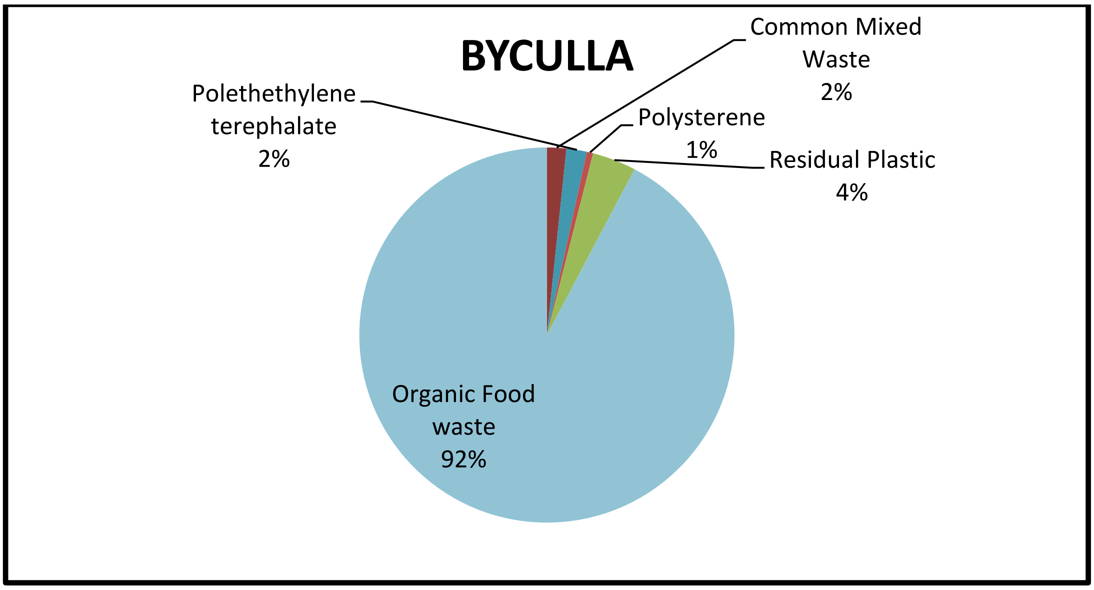


Figure 4- 34 Specific waste fractions in Byculla

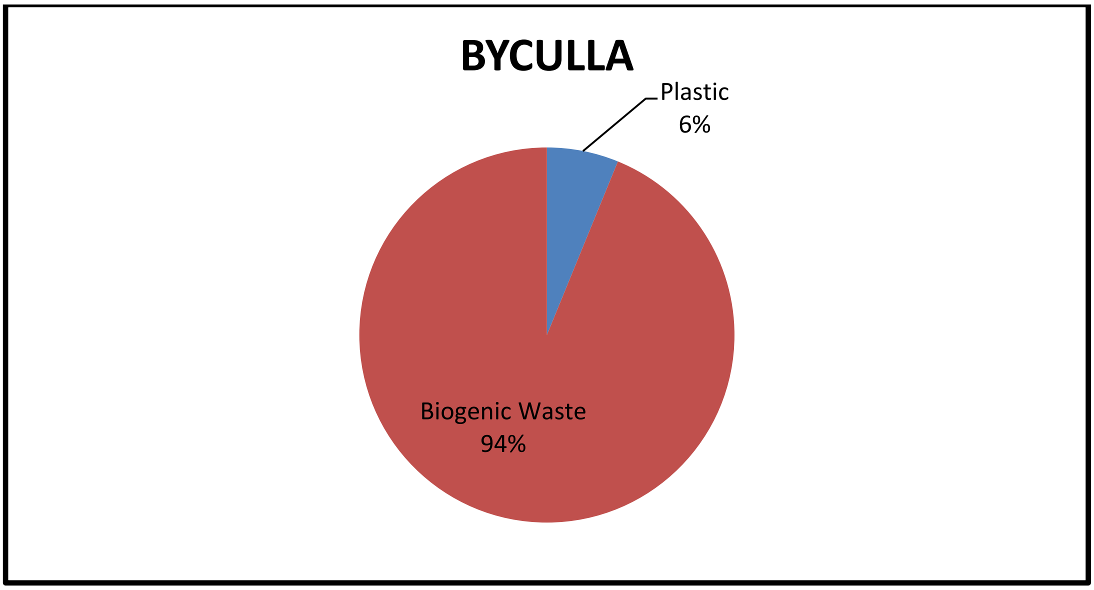


Figure 4- 35 General waste fractions in Byculla

The general and specific waste profiles for Byculla are presented in Figures 4-34 and 4-35. Recyclables which are only 6% of the total waste stream comprise of plastic. In Byculla, a large percentage of the waste stream is removed by waste pickers for the purposes of recycling. Biogenic waste forms a significant fraction of the total waste stream at 95%. Garden refuse which comprises of mostly palm leaves and flower waste, makes up 7%. Due to the many clothing factories in Byculla, 17% is cloth waste.

4.8.10 Mankhurd

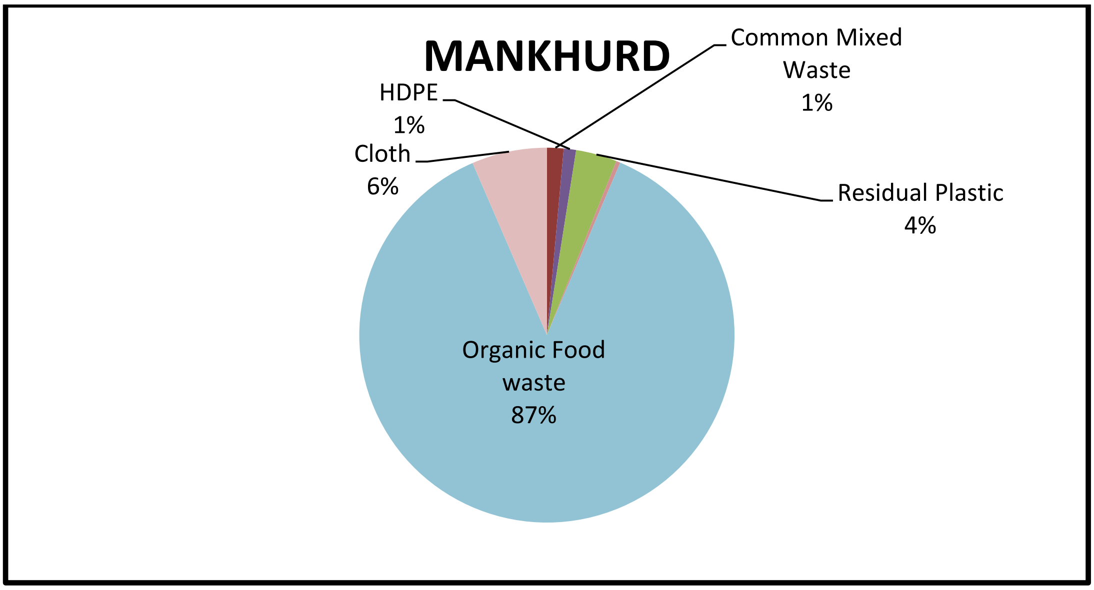


Figure 4- 36 Specific waste fractions in Mankhurd

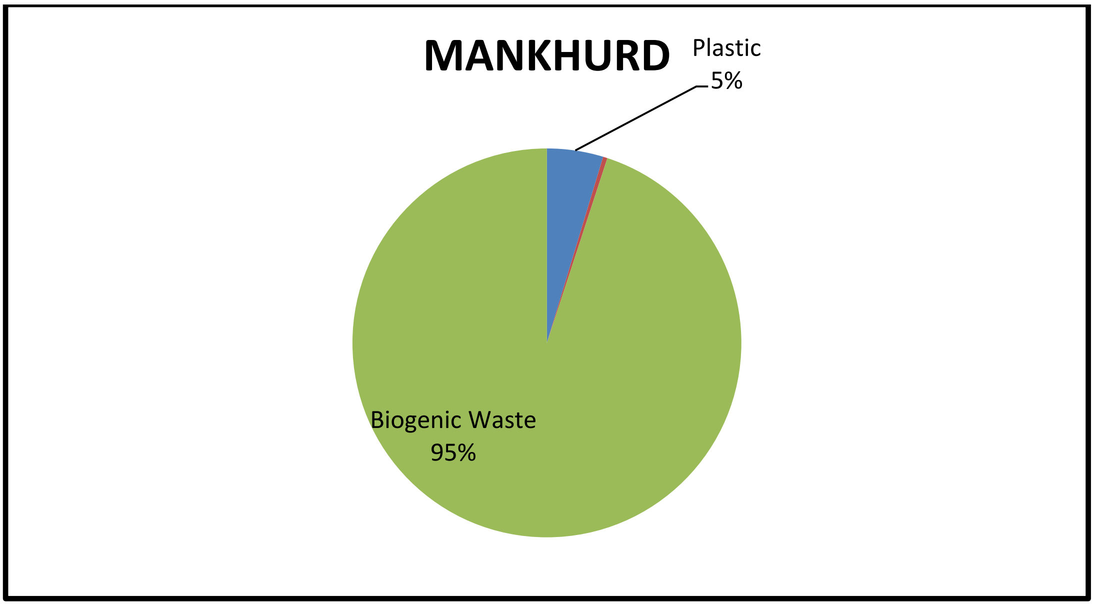


Figure 4- 37 General waste fractions in Mankhurd

The general and specific waste profiles for Mankhurd are presented in Figures 4.36 and 4-37. Recyclables which are only 5% of the total waste stream comprise of 5% plastic. In Mankhurd, a large percentage of the waste stream is removed by waste pickers for the purposes of recycling. Biogenic waste forms a significant fraction of the total waste stream at 95%. Garden refuse which comprises of mostly palm leaves and flower waste makes up 7%. Due to the many clothing factories in Mankhurd, 6% is cloth waste.

4.8.11 Bandra

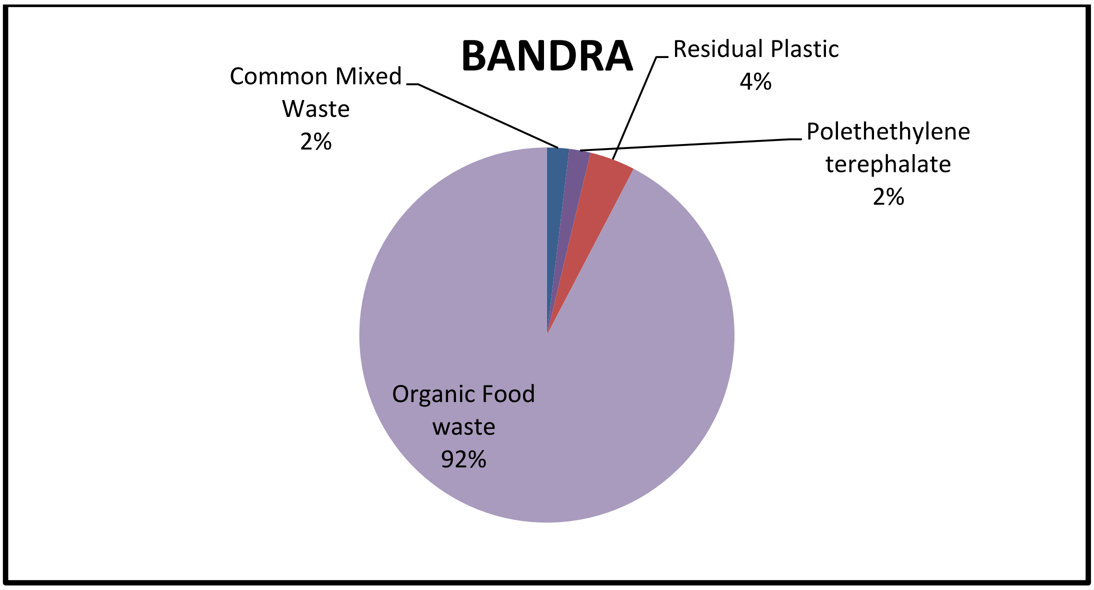


Figure 4- 38 Specific waste fractions in Bandra

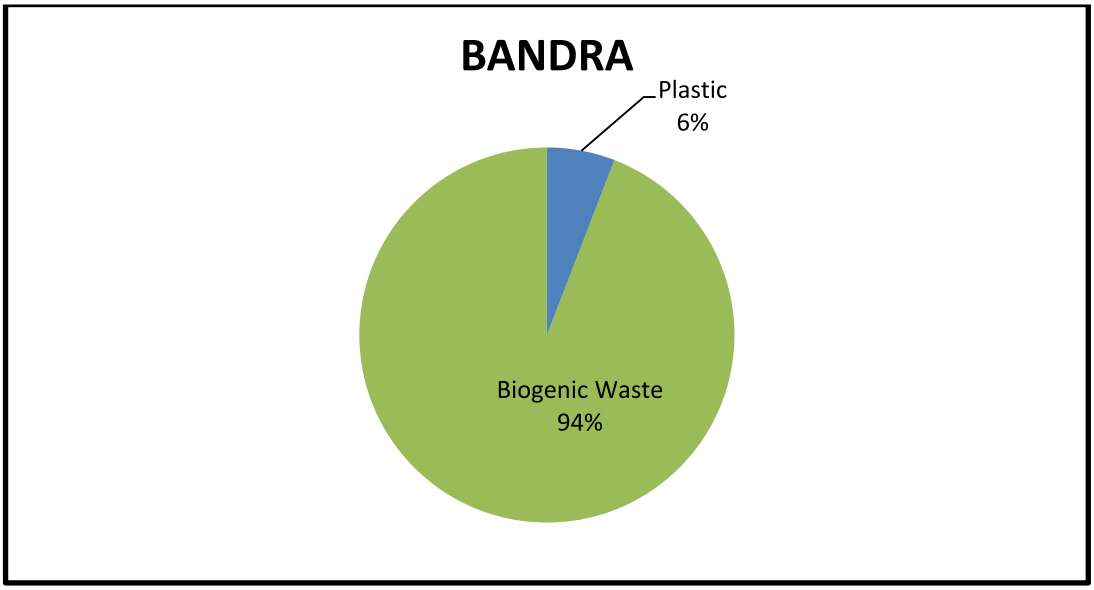


Figure 4- 39 General waste fractions in Bandra

The general and specific waste profiles for Bandra are presented in Figures 4-38 and 4-39. Recyclables which are only 6% of the total waste stream comprise of 6% plastic. In Bandra, a large percentage of the waste stream is removed by waste pickers for the purposes of recycling. Biogenic waste forms a significant fraction of the total waste stream at 94%.

4.8.12 Mahaluxmi

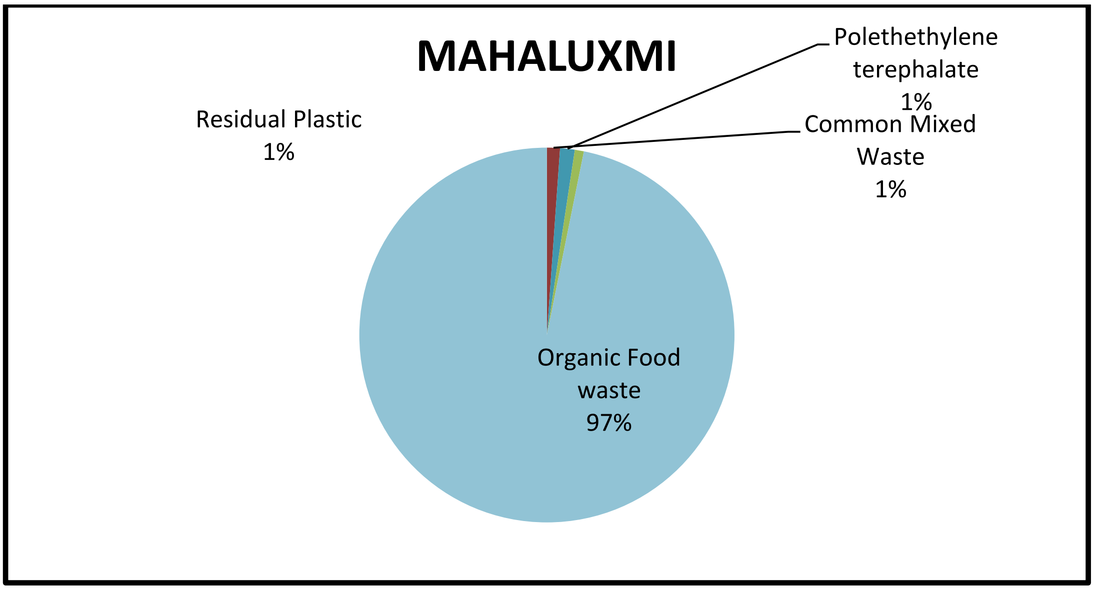


Figure 4- 40 Specific waste fractions in Mahaluxmi

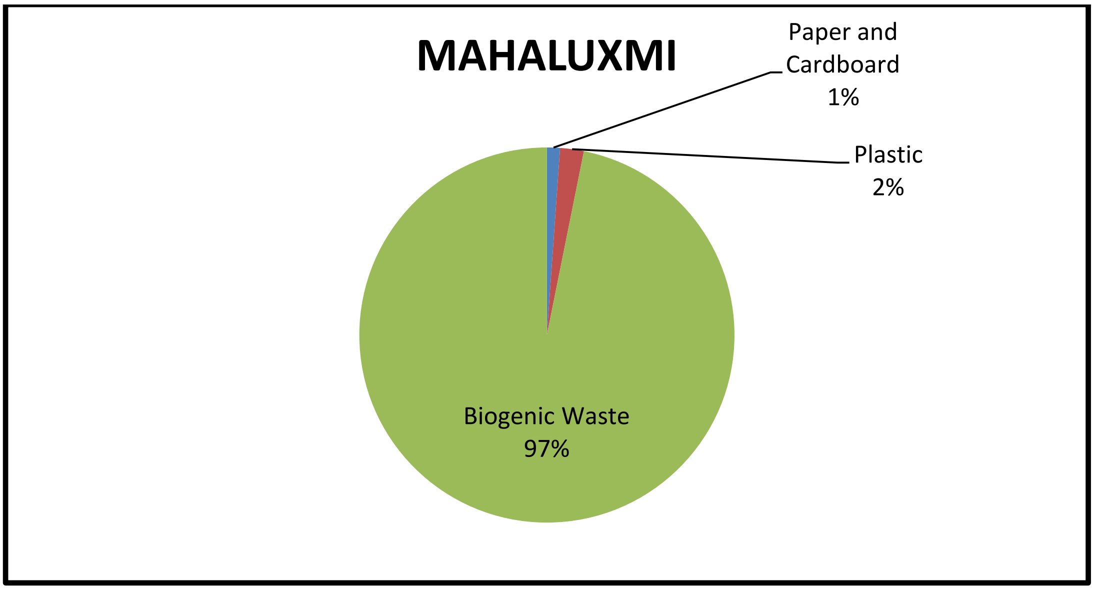


Figure 4- 41 General waste fractions in Mahaluxmi

The general and specific waste profiles for Mahaluxmi are presented in Figures 4-40 and 4-41. Recyclables which are only 3% of the total waste stream comprise of 3% plastic. In Mahaluxmi, a large percentage of the waste stream is removed by waste pickers for the purposes of recycling. Biogenic waste forms a significant fraction of the total waste stream at 97%.

4.8.13 Colaba

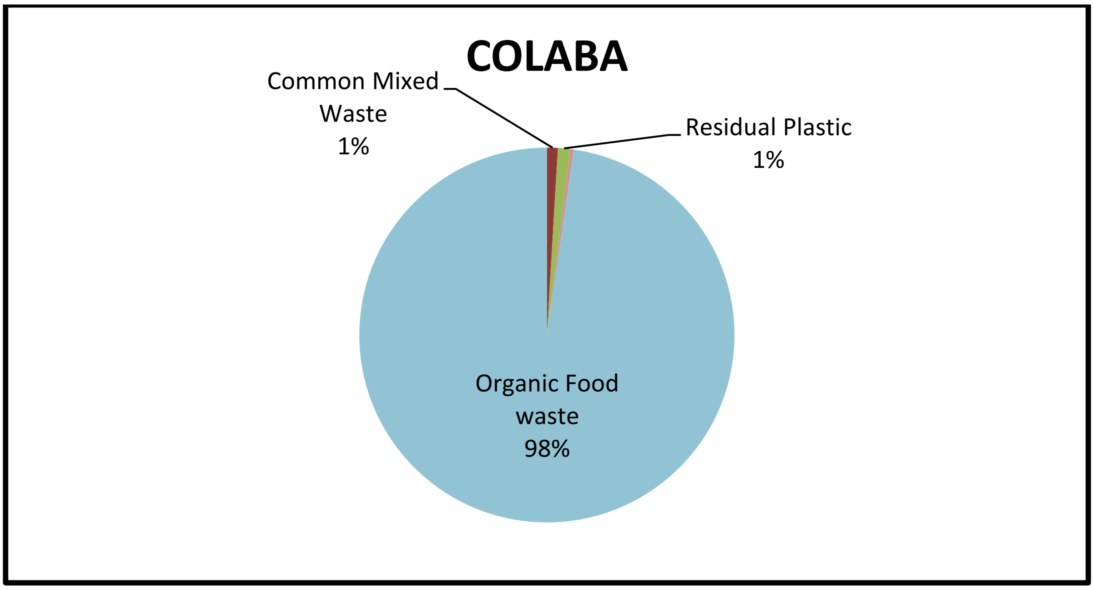


Figure 4- 42 Specific waste fractions in Colaba

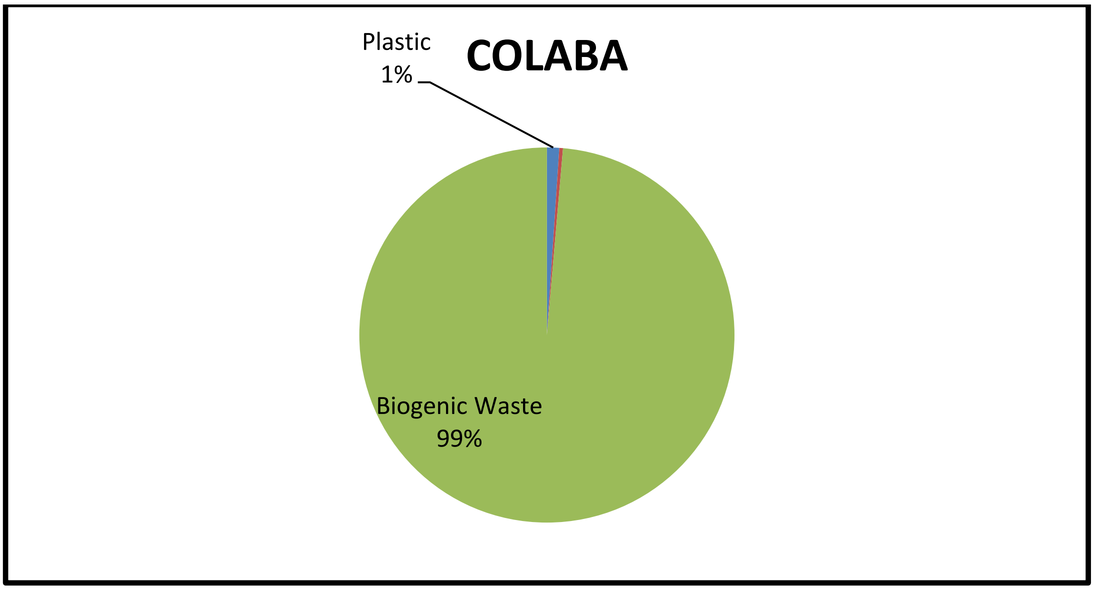


Figure 4- 43 General waste fractions in Colaba

The general and specific waste profiles for Colaba are presented in Figures 4-42 and 4-43. Recyclables which are only 1% of the total waste stream comprise of 1% plastic. In Colaba, a large percentage of the waste stream is removed by waste pickers for the purposes of recycling. Biogenic waste forms a significant fraction of the total waste stream at 99%.

4.8.14 Dharavi

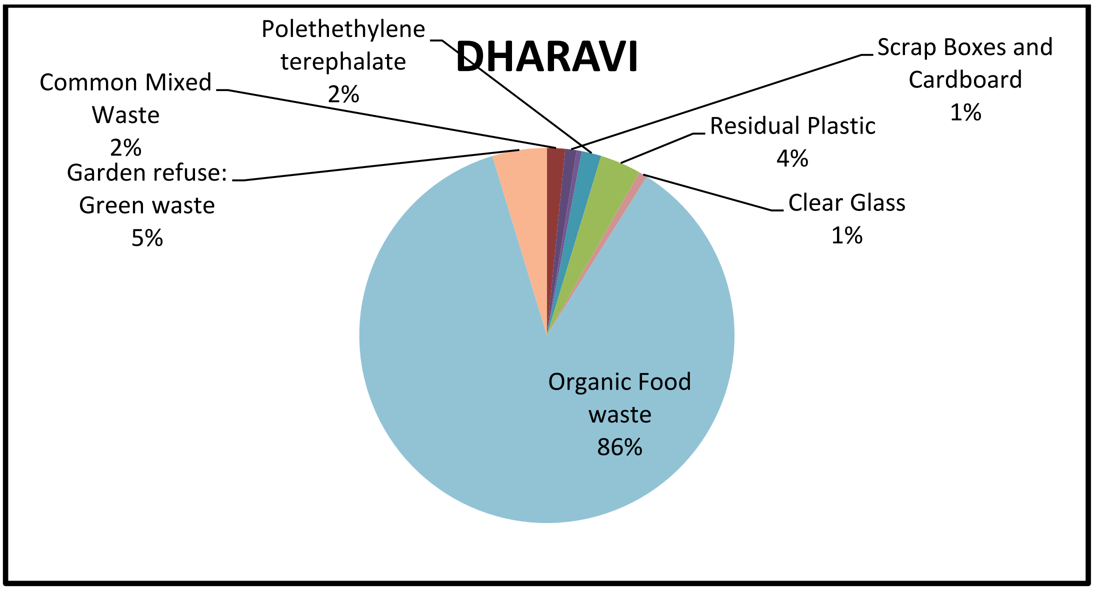


Figure 4- 44 Specific waste fractions in Dharavi

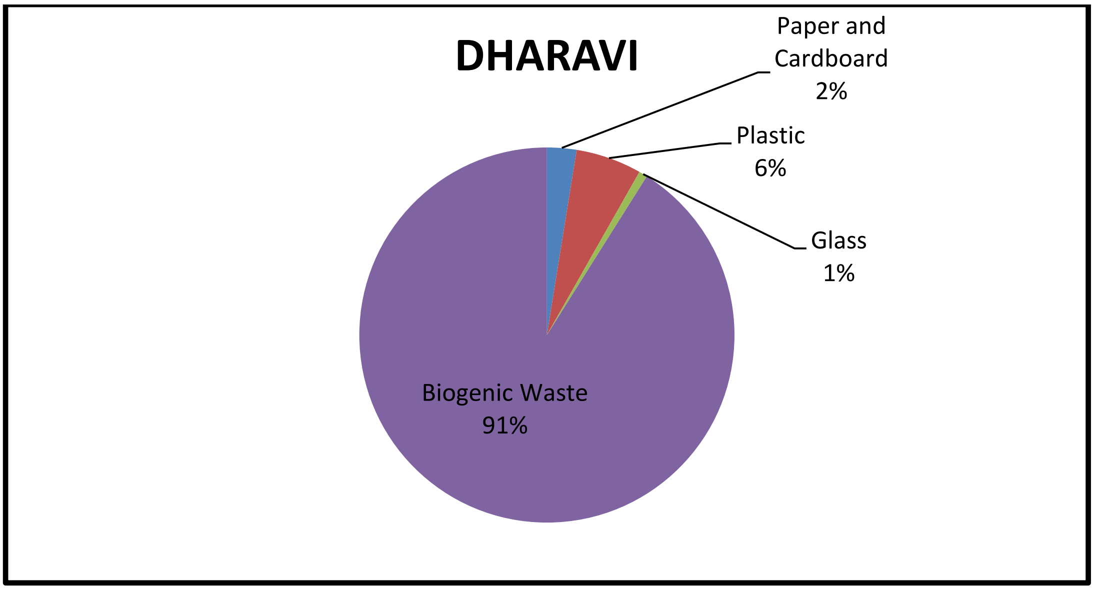


Figure 4- 45 General waste fractions in Dharavi

The general and specific waste profiles for Dharavi are presented in Figures 4-44 and 4-45. Recyclables which are only 9% of the total waste stream comprise of 2% paper and cardboard, 6% plastic and 1% glass. In Dharavi, a large percentage of the waste stream is removed by waste pickers for the purposes of recycling. Biogenic waste forms a significant fraction of the total waste stream at 91%. Garden refuse, which comprises of mostly palm leaves and flower waste, makes up 5%.

4.8.15 Govindi

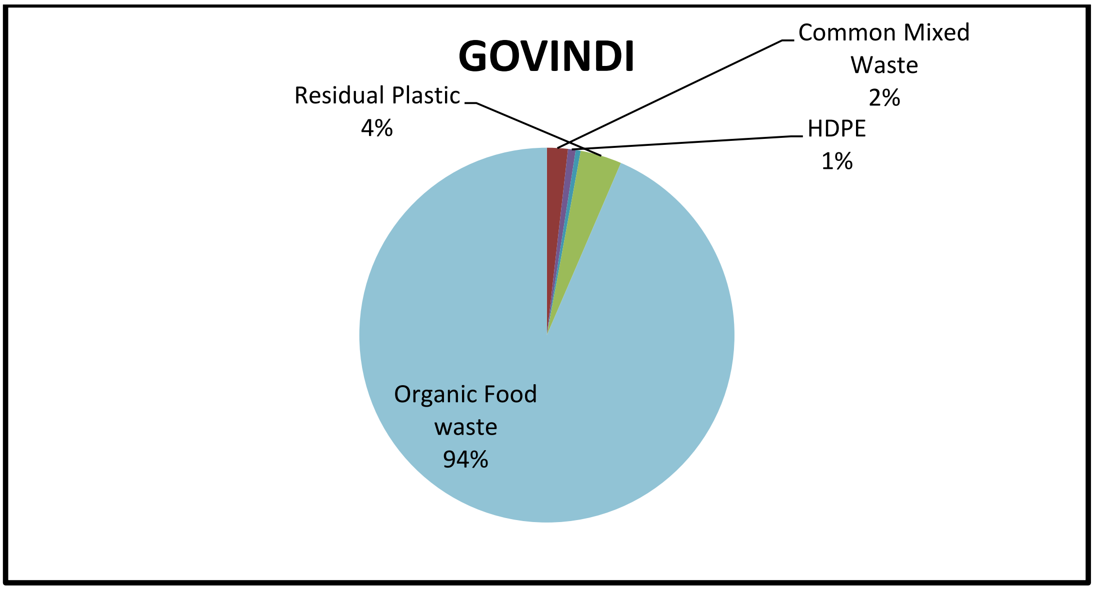


Figure 4- 46 Specific waste fractions in Govindi

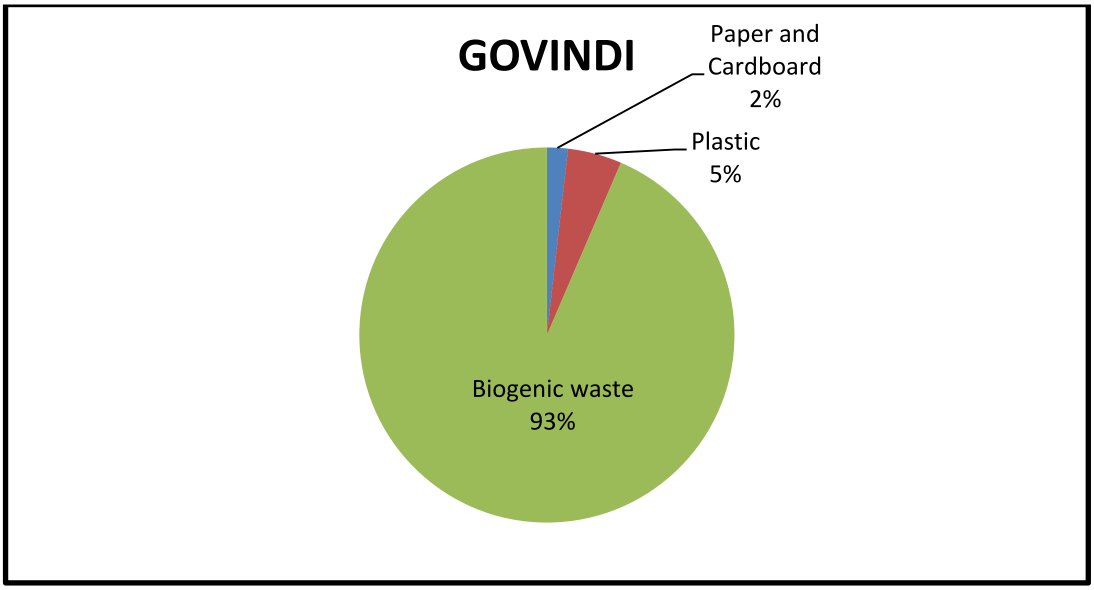


Figure 4- 47 General waste fractions in Govindi

The general and specific waste profiles for Govindi are presented in Figures 4-46 and 4-47. Recyclables which are only 7% of the total waste stream comprise of 5% plastic and 2% paper and cardboard. In Govindi, a large percentage of the waste stream is removed by waste pickers for the purposes of recycling. Biogenic waste forms a significant fraction of the total waste stream at 93%.

4.8.16 JJ Hospital

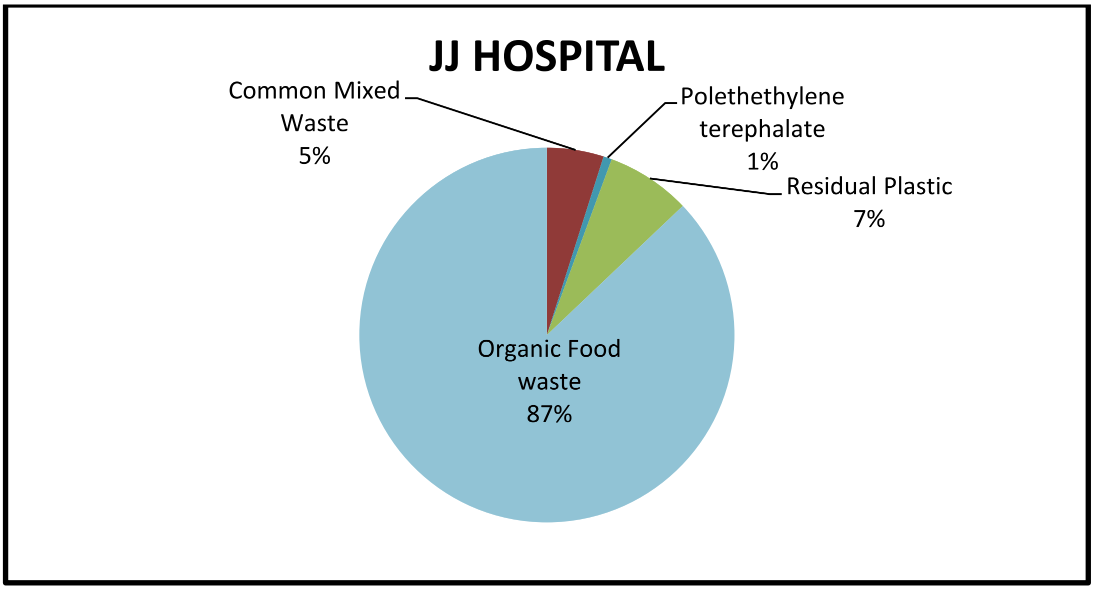


Figure 4- 48 Specific waste fractions in JJ Hospital

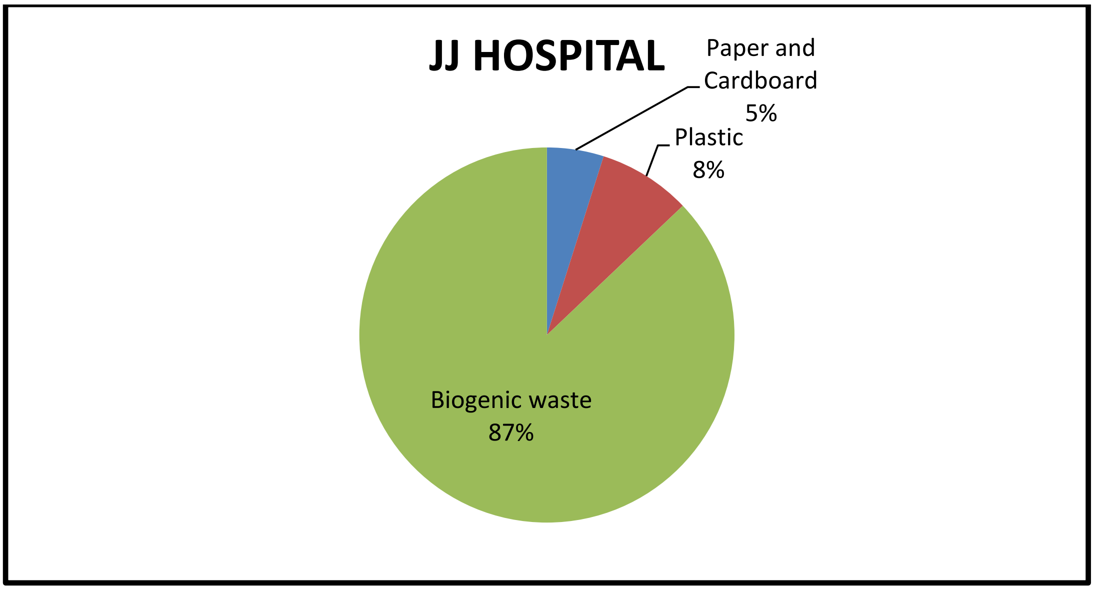


Figure 4- 49 General waste fractions in JJ Hospital

The general and specific waste profiles of JJ Hospital are presented in Figures 4-48 and 4-49. Recyclables which are only 13% of the total waste stream comprise of 5% paper and cardboard, and 8% plastic. In JJ Hospital, a large percentage of the waste stream is removed by waste pickers for the purposes of recycling. Biogenic waste forms a significant fraction of the total waste stream at 87%.

4.8.17 Nagpada

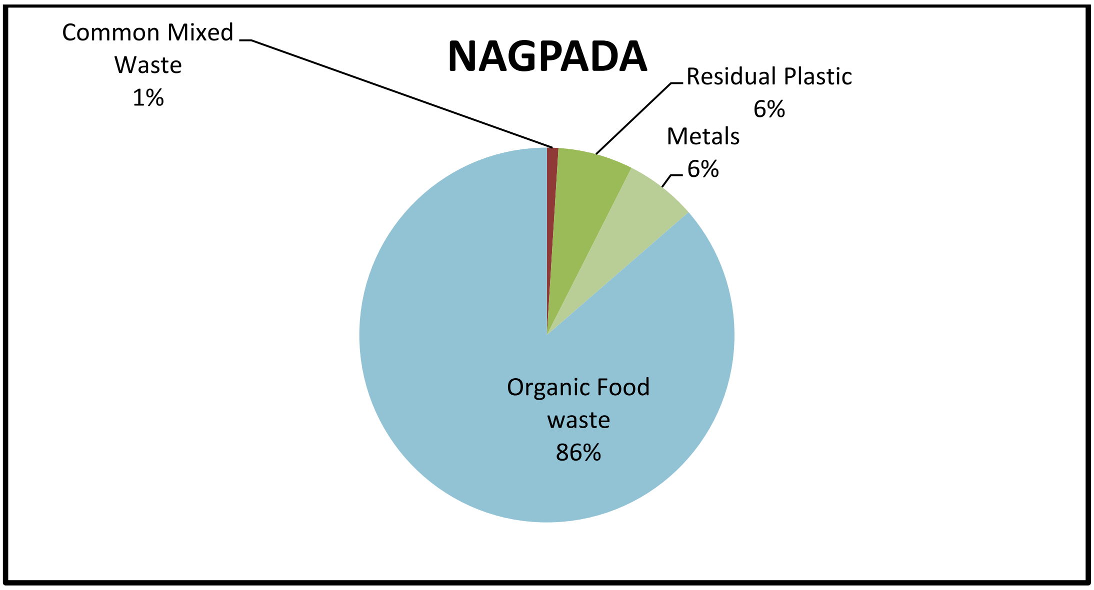


Figure 4- 50 Specific waste fractions in Nagpada

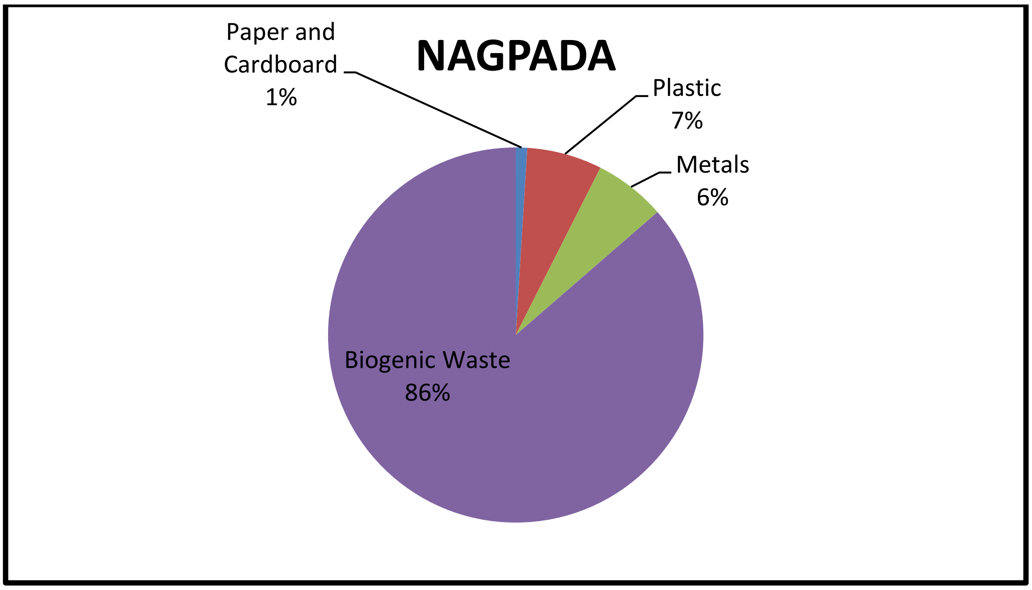


Figure 4- 51 General waste fractions in Nagpada

The general and specific waste profiles for Nagpada are presented in Figures 4-50 and 4-51. Recyclables which are only 14% of the total waste stream comprise of 1% paper and cardboard, 7% plastic and 6% metals. In Nagpada, a large percentage of the waste stream is removed by waste pickers for the purposes of recycling. Biogenic waste forms a significant fraction of the total waste stream at 86%.

4.8.18 Ranibharg

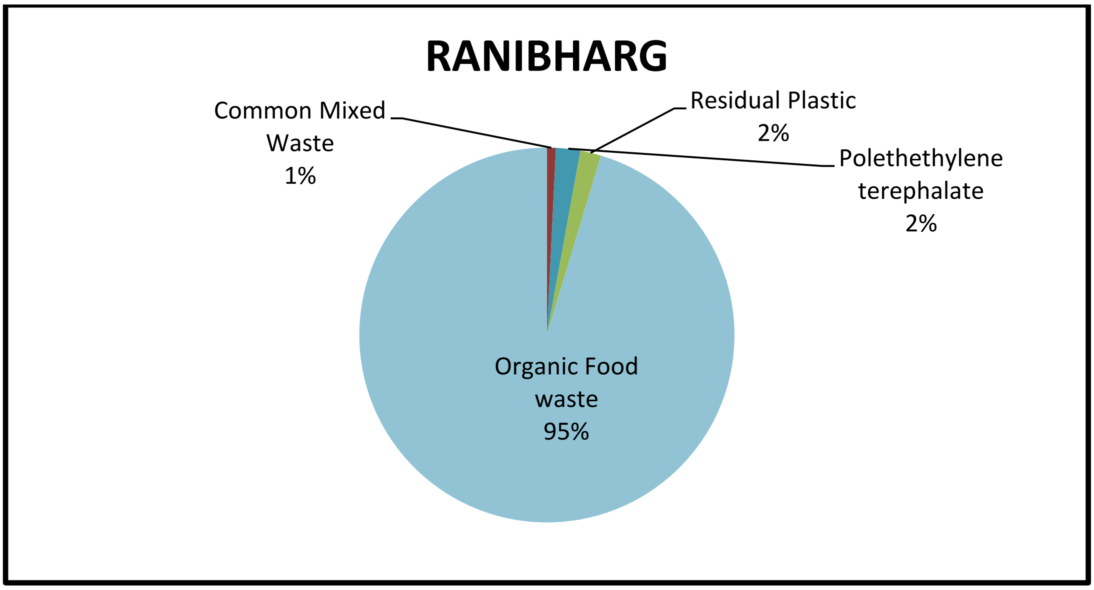


Figure 4- 52 Specific waste fractions in Ranibharg

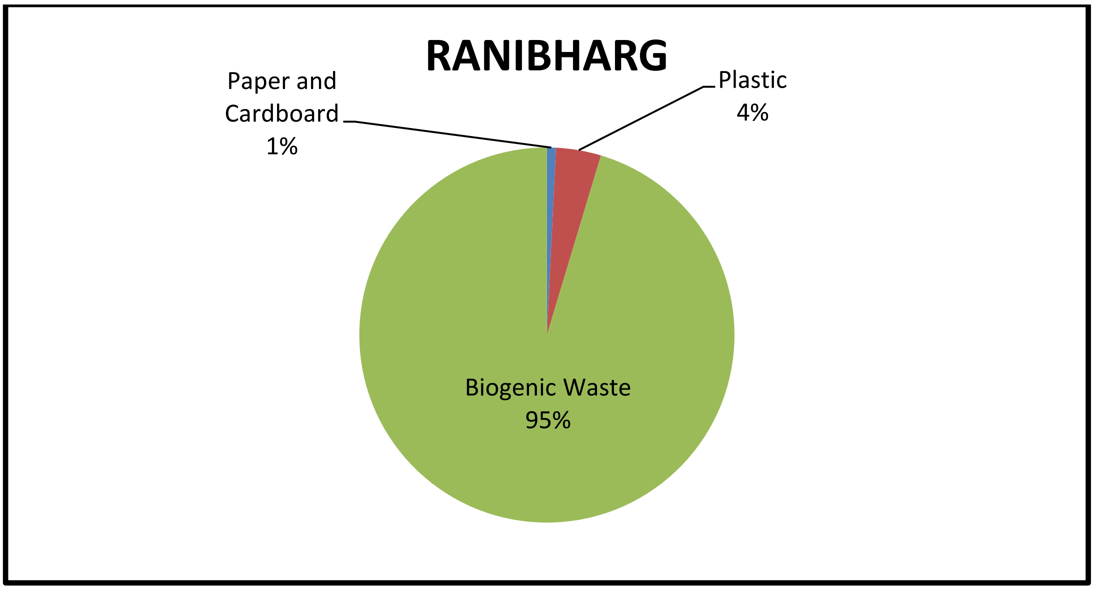


Figure 4- 53 General waste fractions in Ranibharg

The general and specific waste profiles for Ranibharg are presented in Figures 4-52 and 4-53. Recyclables which are only 9% of the total waste stream comprise of 1% paper and cardboard, and 4% plastic. In Ranibharg, a large percentage of the waste stream is removed by waste pickers for the purposes of recycling. Biogenic waste forms a significant fraction of the total waste stream at 95%.

4.8 19 Nanachowk

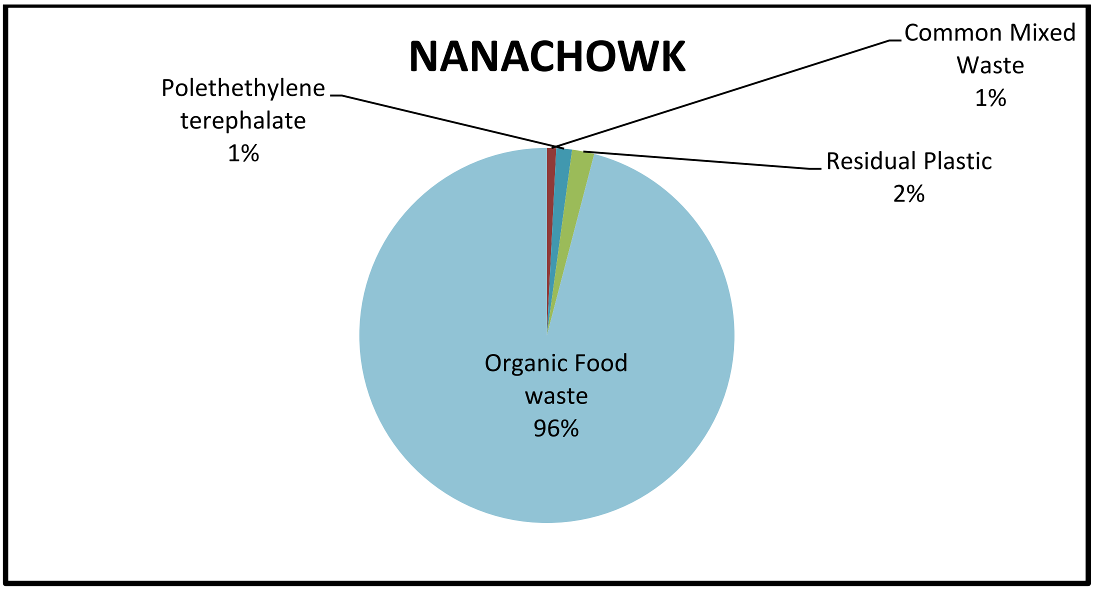


Figure 4- 54 Specific waste fractions in Nanachowk

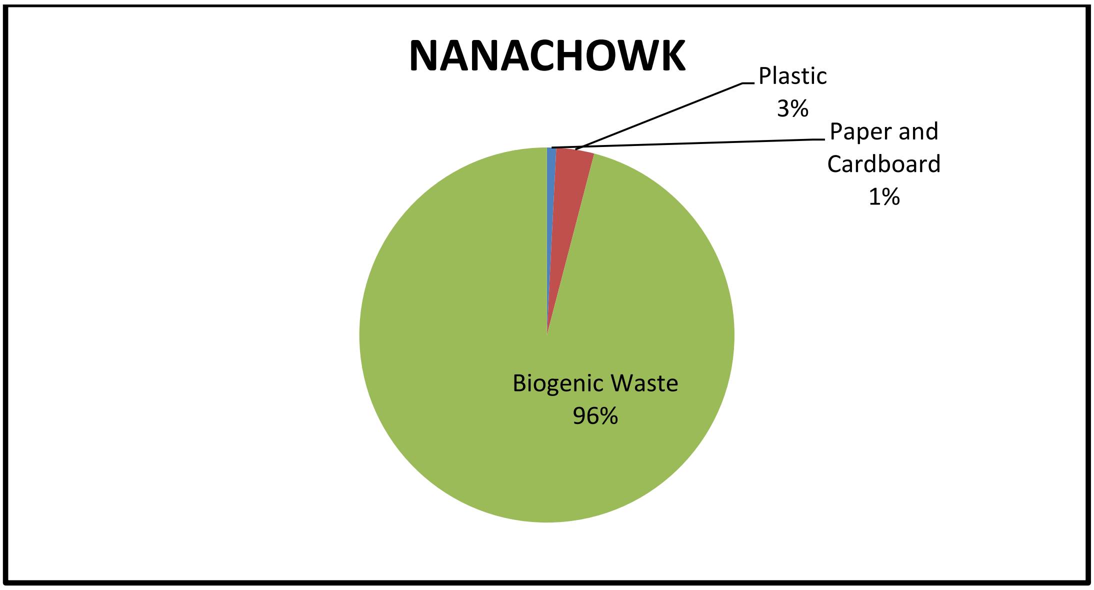


Figure 4- 55 General waste fractions in Nanachowk

The general and specific waste profiles for Nanachowk are presented in Figures 4-54 and 4-55. Recyclables which are only 4% of the total waste stream comprise of 1% paper and cardboard, and 3% plastic. In Nanachowk, a large percentage of the waste stream is removed by waste pickers for the purposes of recycling. Biogenic waste forms a significant fraction of the total waste stream at 96%.

4.8.20 Dadar

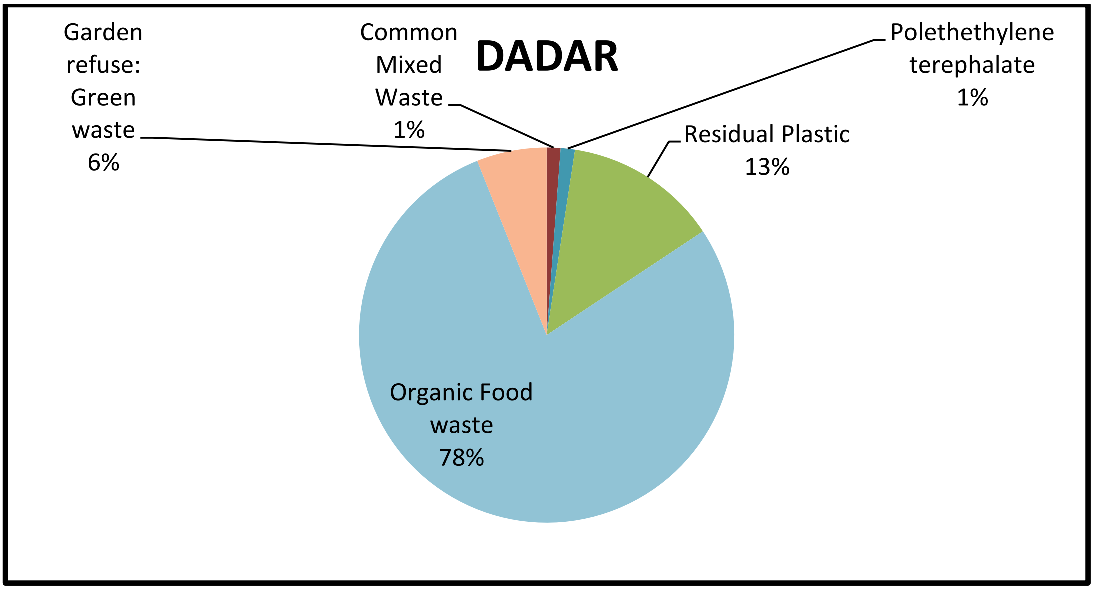


Figure 4- 56 Specific waste fractions in Dadar

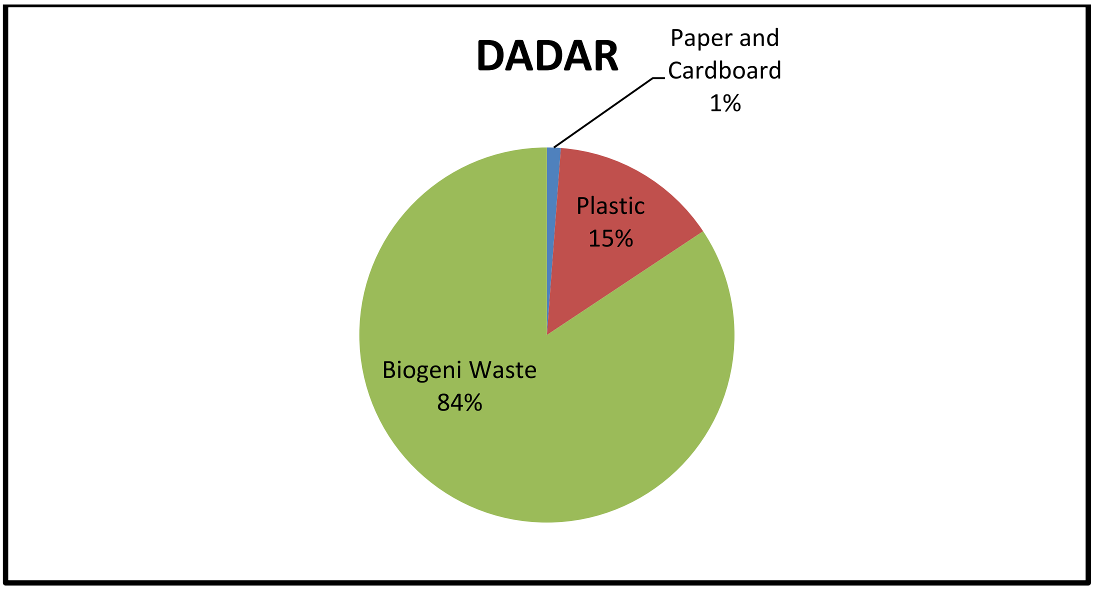


Figure 4- 57 General waste fractions in Dadar

The general and specific waste profiles for Dadar are presented in Figures 4-57 and 4-58. Recyclables which are only 16% of the total waste stream comprise of 15% plastic and 1% paper and cardboard. In Dadar, a large percentage of the waste stream is removed by waste pickers for the purposes of recycling. Biogenic waste forms a significant fraction of the total waste stream at 84%. Garden refuse which comprises of mostly palm leaves and flower waste makes up 6%.

4.8.21 CST

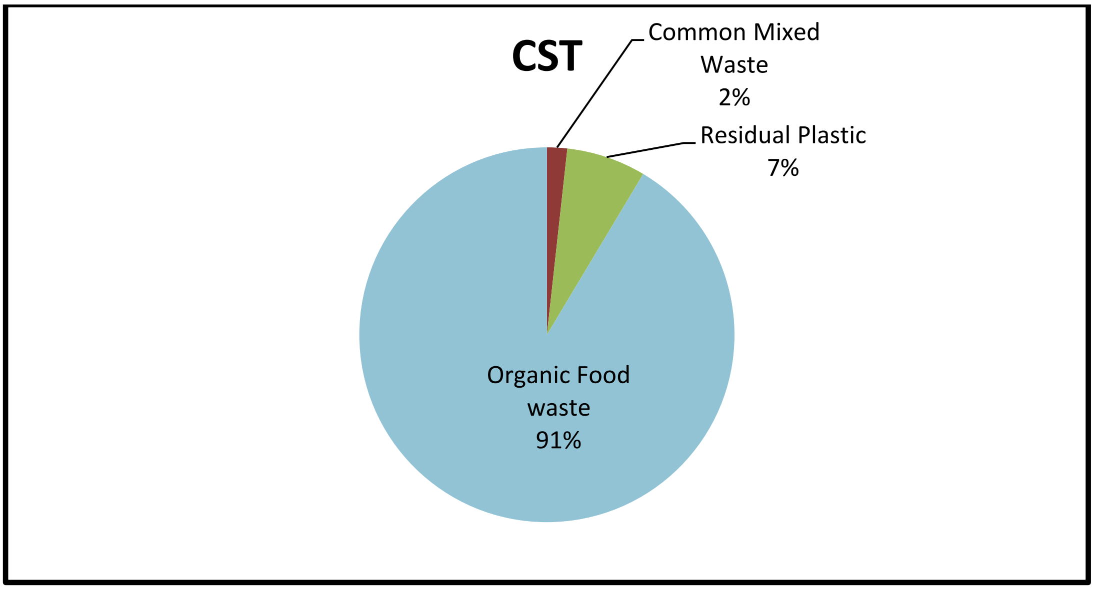


Figure 4- 58 Specific waste fractions in CST

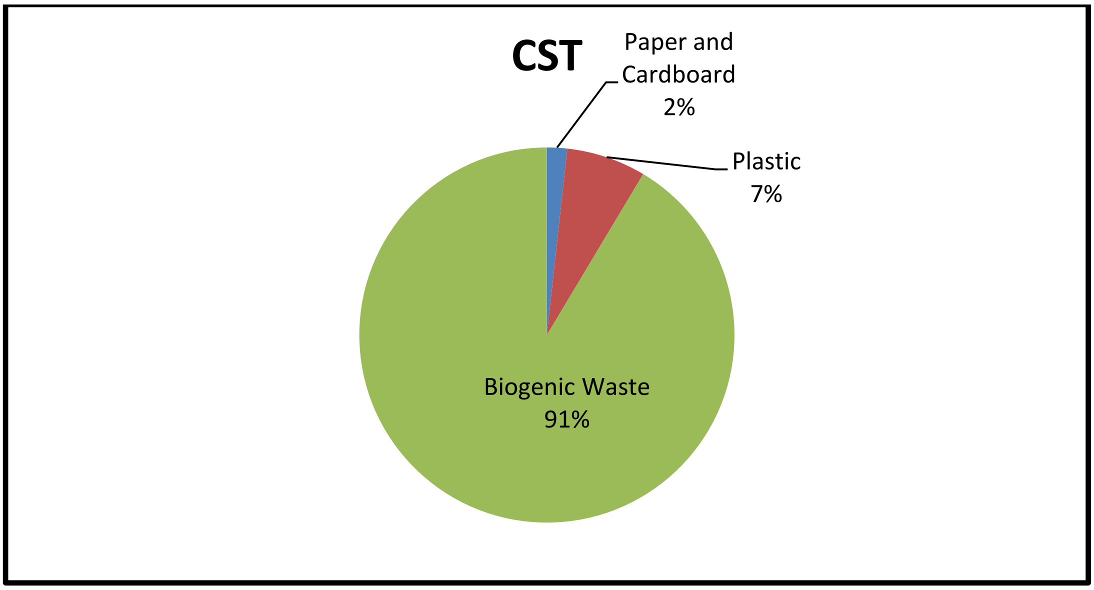


Figure 4- 59 General waste fractions in CST

The general and specific waste profiles for Chatrapat Sivaji Terminus (CST) are presented in Figures 4-58 and 4-59. Recyclables which are only 9% of the total waste stream comprise of 7% plastic and 2% paper and cardboard. In CST, a large percentage of the waste stream is removed by waste pickers for the purpose of recycling. Biogenic waste forms a significant fraction of the total waste stream at 91%.

4.8.22 Grand Road

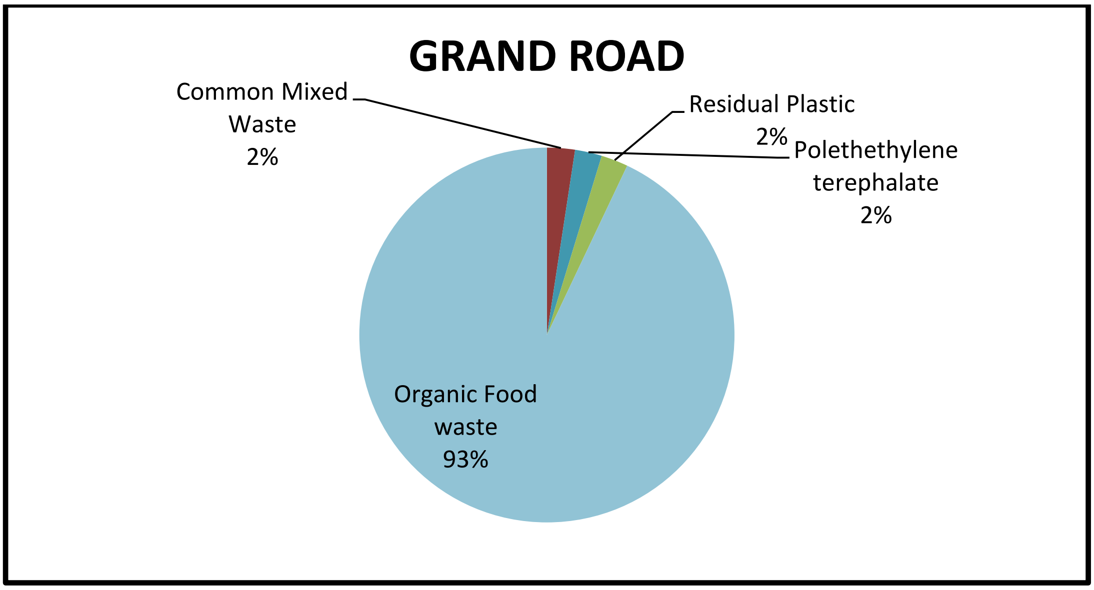


Figure 4- 60 Specific waste fractions in Grand Road

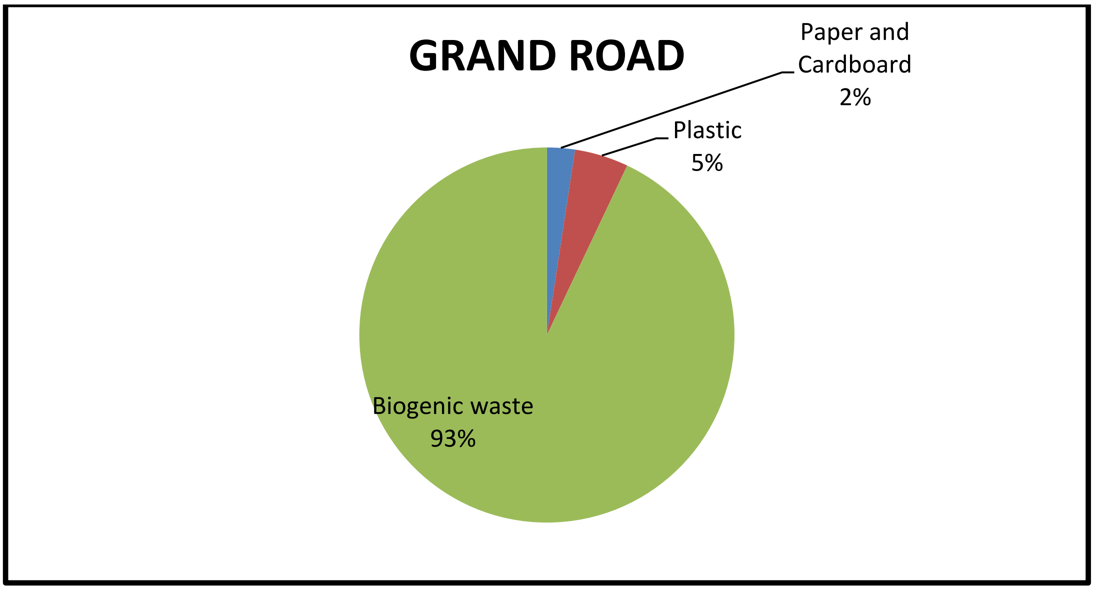


Figure 4- 61 General waste fractions in Grand Road

The general and specific waste profiles for Grand Road are presented in Figures 4-60 and 4-61. Recyclables which are only 7% of the total waste stream comprise of 5% plastic and 2% paper and cardboard. In Grand Road, a large percentage of the waste stream is removed by waste pickers for the purposes of recycling. Biogenic waste forms a significant fraction of the total waste stream at 93%.

4.8.23 Worli

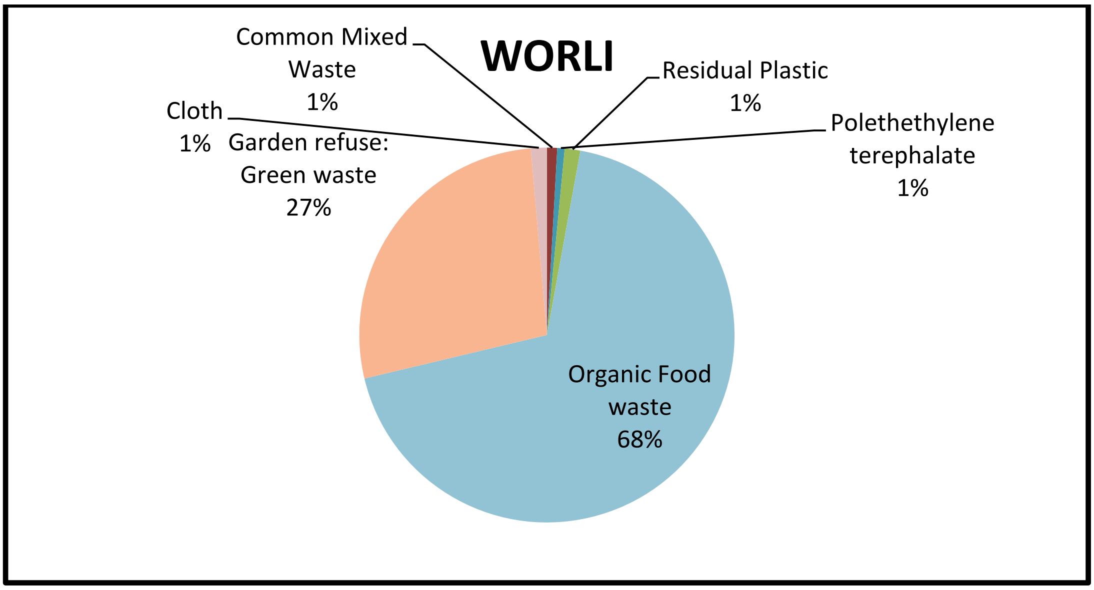


Figure 4- 62 Specific waste fractions in Worli

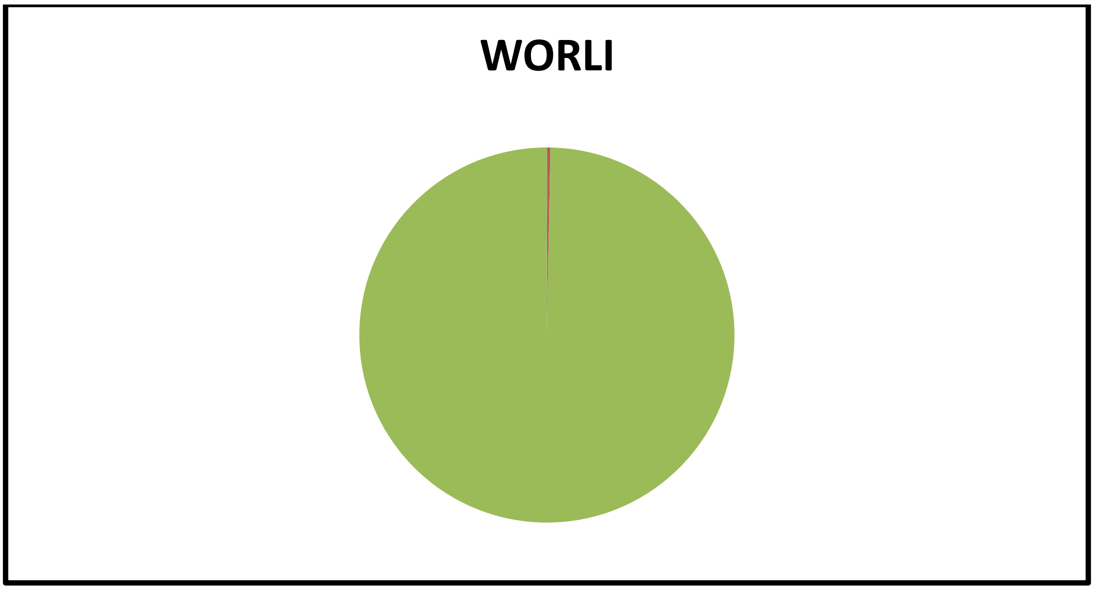


Figure 4- 63 General waste fractions in Worli

The general and specific waste profiles for Worli are presented in Figures 4-62 and 4-63. No recyclables could be identified from the waste streams received. In Worli, a large percentage of the waste stream is removed by waste pickers for the purposes of recycling. Biogenic waste forms a significant fraction of the total waste stream at 100% Organic food waste is 68%. Garden refuse which comprises of mostly palm leaves and flower waste makes up 27%. As a result of the number of clothing factories operating in Worli, 1% is cloth waste.

4.8.24 Sehwag

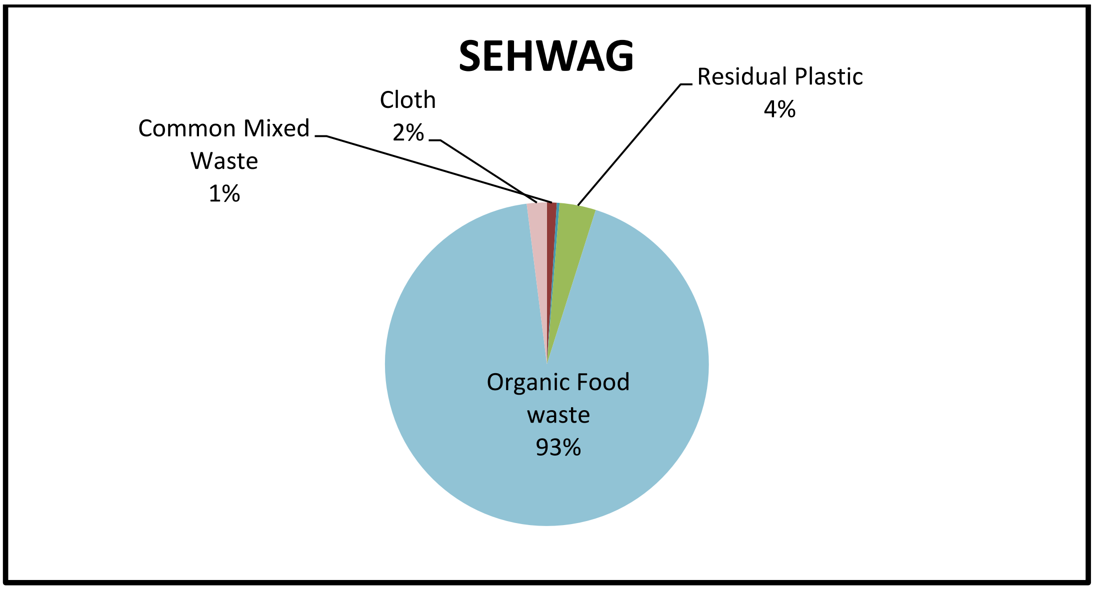


Figure 4- 64 Specific waste fractions in Sehwag

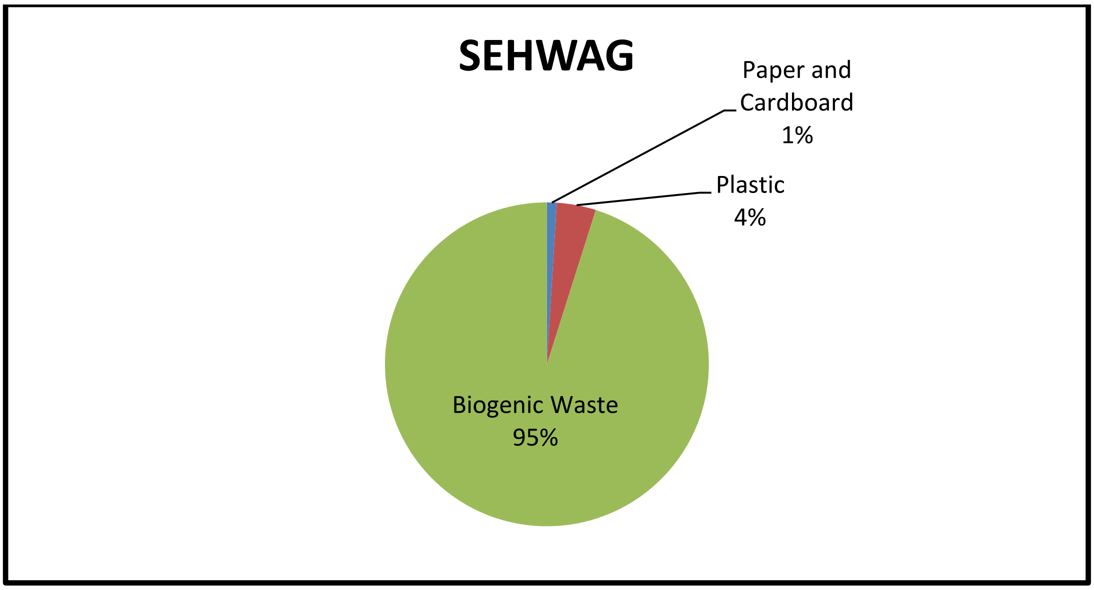


Figure 4- 65 General waste fractions in Sehwag

The general and specific waste profiles for Sehwag are presented in Figures 4-64 and 4-65. Recyclables which are only 5% of the total waste stream comprise of 4% plastic and 1% paper and cardboard. In Sehwag, a large percentage of the waste stream is removed by waste pickers for the purposes of recycling. Biogenic waste forms a significant fraction of the total waste stream at 95%.

4.8.25 Sitachem

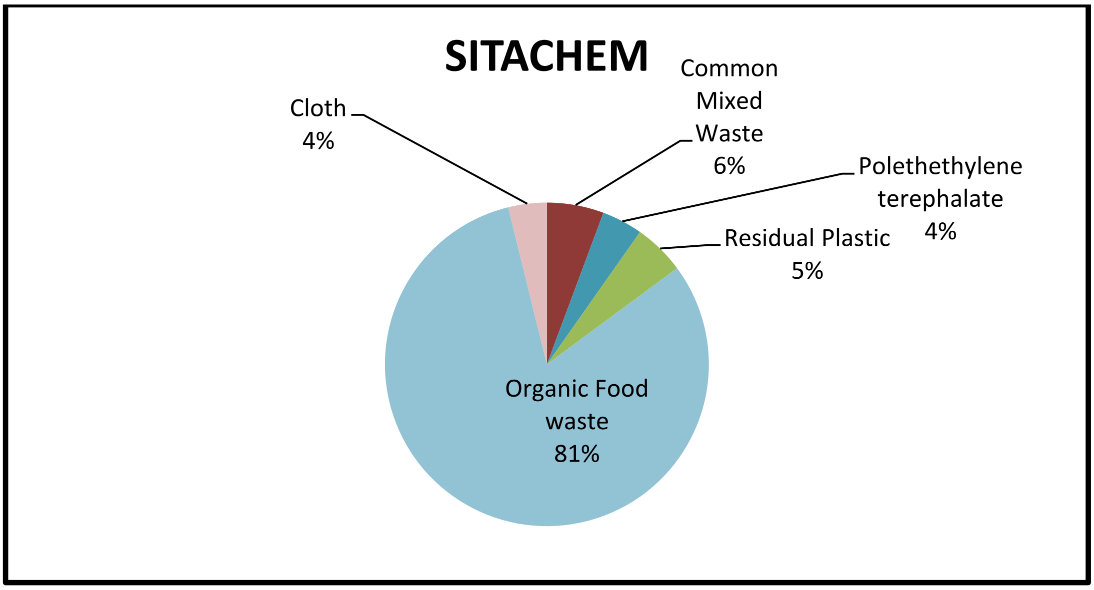


Figure 4- 66 Specific waste fractions in Sitachem

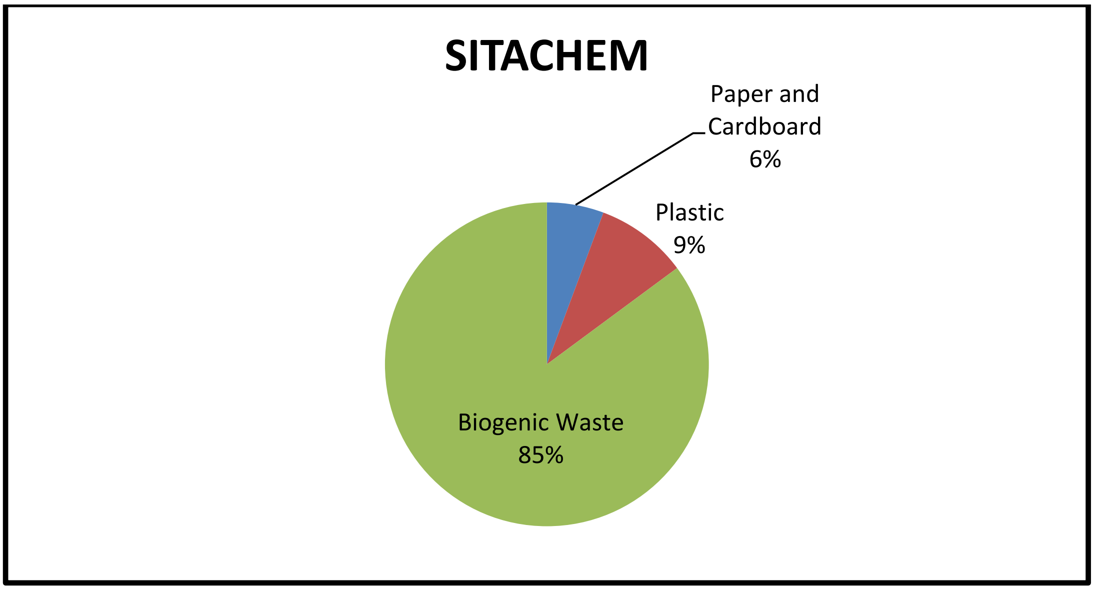


Figure 4- 67 General waste fractions in Sitachem

The general and specific waste profiles for Sitachem are presented in Figures 4-66 and 4-67. Recyclables which are only 15% of the total waste stream comprise of 9% plastic and 6% paper and cardboard. In Sitachem, a large percentage of the waste stream is removed by waste pickers for the purposes of recycling. Biogenic waste forms a significant fraction of the total waste stream at 85%. As a result of the number of clothing factories in Masjid, 4% is cloth waste.

4.8.26 Sandhurst

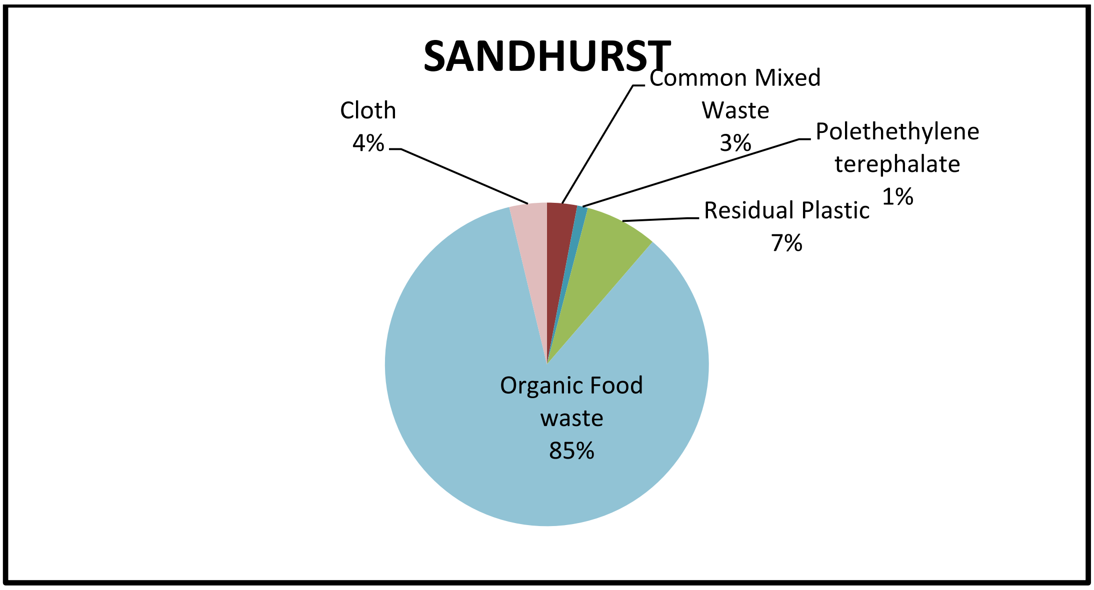


Figure 4- 68 Specific waste fractions in Sandhurst

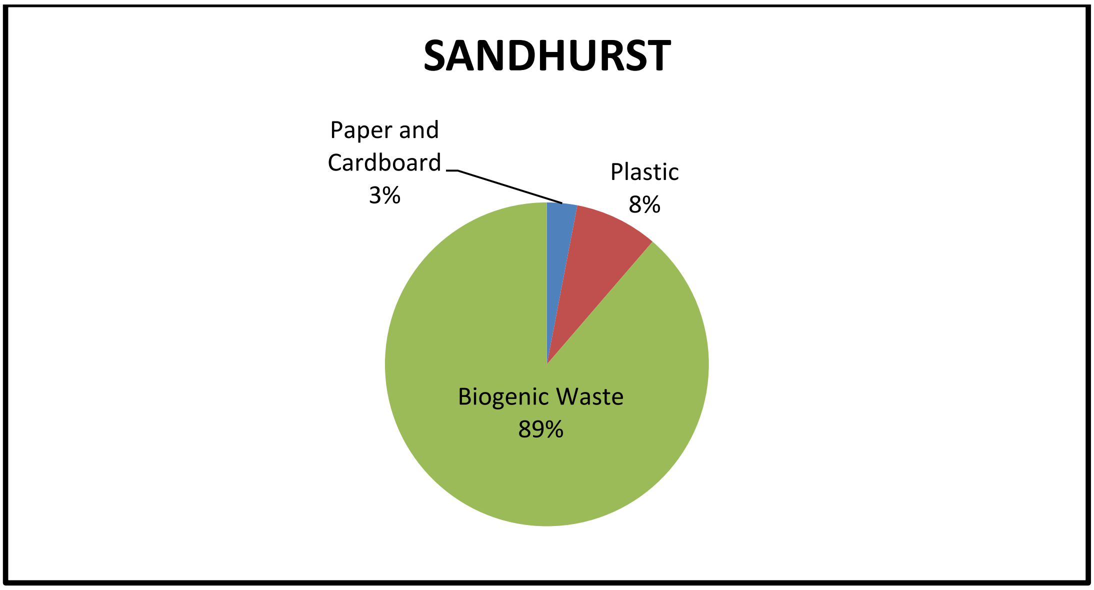


Figure 4- 69 General waste fractions in Sandhurst

The general and specific waste profiles for Sandhurst are presented in Figure 4.69. Recyclables which are only 11% of the total waste stream comprise of 8% plastic and 3% paper and cardboard. In Sandhurst, a large percentage of the waste stream is removed by waste pickers for the purposes of recycling. Biogenic waste forms a significant fraction of the total waste stream at 89%. As a result of the number of clothing factories based in Sandhurst, 4% is cloth waste.

Table 4- 6 Areas and Composition of waste in the Municipal Corporation of Greater Mumbai

Area	Biogenic Waste	Paper and Cardboard	Plastic	Glass	Metal
Chembur	93	2	5		
Andheri	94		6		
Ghatkopar	95		5		
Shivaji Nagar	95		5		
Byculla	94		6		
Mankhurd	95		5		
Kanjur Marg	97		3		
Sewri /Shivdi	92		8		
Bandra	94		6		
Mahaluxmi	97	1	2		
Colaba	99	1			
Dharavi	91	2	6	1	
Govindi	93	2	5		
Malvani/ Malad	92	2	6		
Kamitikura	92	2	6		
Kurla	92	2	6		
JJ Hospital	87	5	8		
Nagpada	86	1	7		6
Ranibharg	95	1	4		
Nanachowk	96	1	3		
Dadar	84	1	15		
CST	91	2	7		
Grand Road	93	2	5		
Worli	100				
Sehwag	95	1	4		
Sitachem	85	6	9		
Sandhurst	89	3	8		

The total quantity of 7 025 tonnes of solid waste received by the Deonar landfill site is recorded as the waste received at landfill; however this is not a reflection of the waste generated in Mumbai. Waste is being collected off the dry recyclable fraction; a considerable amount of waste is removed by so-called rag pickers, who sort it and sell it to those who deal in recyclables such as paper, plastic and metal. Table 4-6 illustrates that from that the dorminant waste classification is biogenic waste which ranges from 85% to 100% of waste. Minimal inorganic waste reaches the landfill site.

4. 9 Chapter Summary

This chapter outlined the case study area of Mumbai, India. It established that there are varying service standards in respect of the waste service. The methodological approach to the Waste Stream Assessment was discussed in chapter 3 and a scenario analysis is completed in the Institutional Framework which led to the WTE options.

This chapter determined the fraction of the waste stream generated at household level that can be diverted from landfill. It was evident that large amounts of the inorganic fraction of waste that is generated at households do not reach the landfill site. It was also evident that the biogenic waste generated at households is skewed from the sample as a greater percentage of the biogenic waste is received at landfill. It also highlighted the types and quantities of waste generated by households and what percentage of this waste is received at the landfill site. The survey also revealed households' perspectives of the services rendered by MCGM. A detailed waste stream assessment was conducted at the Deonar landfill site, detailing the specific waste stream by types and characteristics of waste.

5. CASE STUDY: NEWCASTLE LOCAL MUNICIPALITY

5.1 Introduction

This study's objectives were achieved through a comprehensive study of NLM. This municipality includes urban and rural areas, formal and informal households, and low, medium and high income groups. These characteristics are common in South African municipalities (Matete, 2009; and Purnell, 2009). Socio-economic factors are pivotal when one considers a population's waste stream.

This chapter describes the case study of NLM. This municipality is part of the Amajuba District which is representative of South African municipalities due to the socio-economic differences among the local municipalities within the district. There is inequitable service delivery, as well current and future projects for long term growth and sustainability with regard to waste management.

Newcastle Municipality is located in the inland region on the northwest corner of KwaZulu-Natal, a few kilometres south of the Free State and Mpumalanga provincial borders, in the foothills of the Drakensberg.

The municipality covers an area of 1 855km^2, has a population of 332 980 in terms of Census 2001 and is made up of 31 wards. The Newcastle municipal area is the most densely populated municipality in the district and constitutes 71% of the total population of the Amajuba District Municipality, and 3.5% of the total population of KwaZulu-Natal. (Newcastle Municipality IDP, 2013)

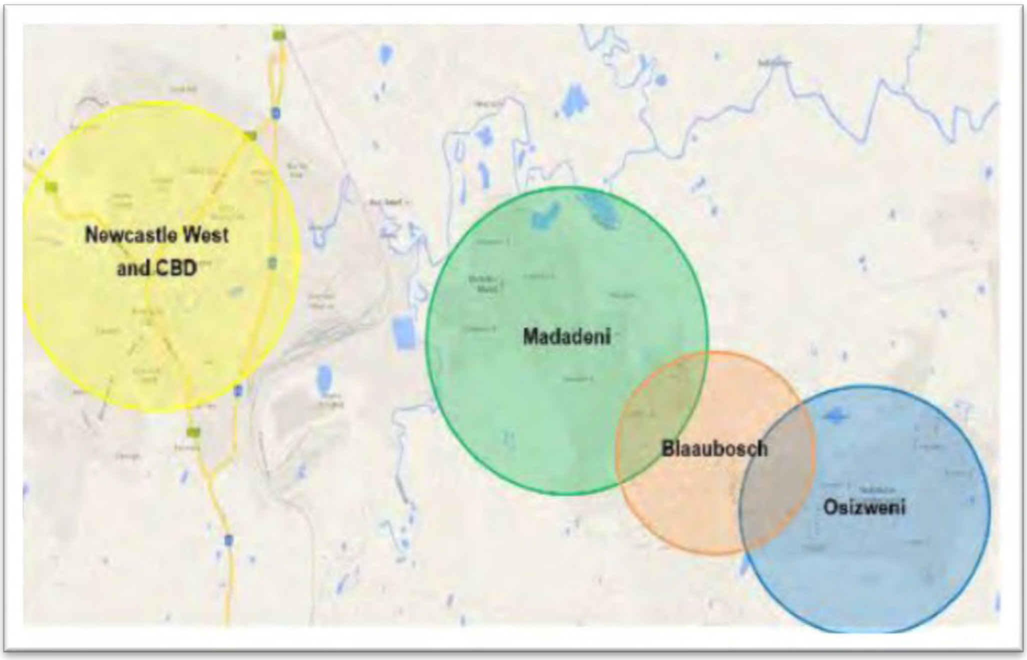


Figure 5- 1 Study Area of Newcastle (Source: Newcastle IDP, 2013)

Census 2001 shows that Newcastle has a very young population with most inhabitants falling into the 15 to 34 year age group. This implies that the majority of the population is economically active; hence, planning is required for more employment opportunities. This calls for a strategic approach in light of the general economic dynamics of the district as a whole. (Newcastle Municipality, IDP, 2013)

There are limited formal employment opportunities in the area. More than 60% of the population has an income of less than R1 500 a month and more than 48% live on less than R1 000 per month. The number of people with no income has trebled since the 1996 census. The indigent population increased from 220 in March 2005 to approximately 19 500. Sixty percent of the population of Newcastle is mainly urban with 59 423 living in formal housing, 6 851 in informal settlements and 4 649 in traditional housing. (Newcastle Municipality, IDP, 2013)

Newcastle is a secondary city offering employment opportunities to the surrounding rural hinterland and acts as the district's urban core. It therefore provides employment opportunities for the whole district. The greatest challenge is to provide housing and essential services to meet increasing demand especially around the urban core where many informal settlements have mushroomed. The demographics of Newcastle provide information on unemployment, population, access to services and piped water. (Newcastle Municipality, IDP, 2013)

Table 5- 1 Demographics of Newcastle (Source: Newcastle Municipality IDP, 2013)

Criteria	**Newcastle %**
Unemployment rate	54
Population employed	27
Population unemployed	32
Population not economically active	40
Access to electricity for lighting	84
Access to refuse removal	71
Piped water inside dwelling	58
Population with toilet connected to sewer	56

5.2 Population and Densities

The Newcastle municipality is composed of approximately 77 784 households as per the 2007 Community Service Data. The 2007 IDP also indicates an urbanized population with over 95% living in urban or mining settlements and the remaining 5% living on farms within the municipality.

There are no accurate records of the waste generated with NLM or of the waste disposed at the Newcastle landfill site. However, the quantities of waste have been estimated by other authors, and it is also possible to project waste production based on per capita rates.

A 2004 survey of landfill sites conducted by SiVEST from the Amajuba District Municipality (IWMP – 2009), on behalf of the Provincial Planning Development Commission (PPDC, 2004) estimated that approximately 4 460 tonnes of waste was being disposed of to landfill every month, or approximately **53 520 tonnes/year.** This was based on estimates provided by NLM.

The integrated waste management master plan for the district (2003) estimates that approximately 103.3 tonnes and 79.6 tonnes of waste were generated for Newcastle West and Newcastle East, respectively, per day in 2005. This represents a total of **182.9 tonnes** per day for the combined area or approximately **66 758.5 tonnes** for the whole of 2005.

It is possible to project the total amount of waste generated within an area based on per capita waste projection rates. This is set out below.

Due to the lack of data on the amounts of waste generated, a per capita projection was estimated in line with the KwaZulu-Natal Department of Agriculture and Environmental Affairs (IWMP) Guidelines Document (2003). In terms of section 3 of this document the listed waste generation rates are used for NLM. These relate to the broad income groups in section 3.3 of the IWMP document. The following rates are assumed as per the above report.

- Very poor areas (farm lands) - 0.03 Kg/Person/day
- Middle Income - 0.35 Kg/person/day
- Middle to High income - 0.61 Kg/person/day

For the segments of the population that failed to provide a response on income levels or are designated as institutions, an average waste generation rate of 0.35 Kg/Person/day, is assumed.

Table 5- 2 Households serviced in Newcastle (Source: Courtesy of Newcastle Municipality, 2013)

Newcastle Local Municipality	**No. of Households**
Removed by the local authority at least once a week	47685
Newcastle West	12545
Madadeni	19465
Osizweni	15297
Ngagane/Kilbarchan	378
TOTAL	**47685**

5.3 The Newcastle Landfill Site

The Newcastle Waste Disposal Site (WDS) is nearing the end of its lifespan. A process to identify and authorize a new disposal site is underway and it is expected that the existing site will close in 2017. The site has been in operation since 1971, and commenced its operations on an undeveloped portion of the site on receipt of a permit to operate from the Department of Water Affairs and Forestry (DWAF) in 1994. According to the permit, the site is a Class 2 disposal site. The DWAF Minimum Requirements for Waste Disposal by Landfill (2nd Edition) came into effect in 1998 and are applicable to the proposed closure of the Newcastle WDS; hence, it was necessary to classify the site in accordance with the Minimum Requirements.

The classification of the proposed waste site as per the DWAF Minimum Requirements relates to the following criteria:

- The composition of the waste stream;
- The quantity of the waste stream; and
- The leachate generating potential of the site.

Once these three criteria are established the potential site is assigned a classification which determines site development parameters/regulations which must be met in the development of the site.

The existing Newcastle site has been classified as a **G: M: B+** site where,

G=General Waste (composition of the waste stream is General waste);

M=Medium Site (the size of the site determined by the quantity of the waste stream); and

B+= Positive Climatic Water Balance (Potential leaching producing site-Positive).

5.4 Waste Stream Composition

Currently the Newcastle WDS accepts the following waste streams:

- Domestic waste;
- Garden waste;
- Building waste; and
- Commercial waste.

Commercial waste includes the waste produced by retail outlets and other similar establishments. In terms of the operating permit for the site, the site is classified as a Class 2 waste disposal site accepting general waste. At time hazardous waste is discarded as part of the general waste stream in the form of oil cans from petrol stations, batteries, weed killers, etc. However, the relatively small quantity of this type of waste, and its co-disposal with general waste, reduces its concentration and consequently its significance. The waste stream can therefore be classified as General Waste.

The existing Newcastle WDS uses the trench method whereby waste is deposited in large excavations specially excavated for landfilling purposes. Daily cover material of 150mm depth is spread over the waste and compacted. According to the motivation report for the operating permit application, each cell is covered with 1m depth of soil after it is filled with waste. The size of the trench is 50x100m.

There is no formal pipework for leachate collection within each cell. Polluted and unpolluted storm water runoff is collected in a cut off trench downstream of the waste pile. The cut off trench is unlined, and flows to a retention pond at the southern end of the site. The pond is not fenced off and is also unlined. Due to the existence of Osizweni Road along the south-eastern boundary of the site and the prevailing ground topography, unpolluted storm water emanating upstream of the site is collected via the road drainage system and does not flow onto the site. Three existing groundwater monitoring boreholes are present on the site. Two are operable whilst one is not functional.

5.5 Waste Collection


Figure 5- 2 Waste collection with a Compactor Trucks and Skip trucks (Source:Courtesy of Newcastle Municipality, 2012)

The waste is collected by means of a waste compactor which carries 19 cubic meters of waste. Five compactors serve Newcastle West with ± 12 000 households and 10 compactor units serve Newcastle East. Skip trucks are used to service garden skips deployed in and around Newcastle. Newcastle East has four skip trucks that serve Madadeni and Osizweni.

Table 5- 3 Weighbridge data recorded (Source: Newcastle Municipality:South African Waste Information data, 2014)

YEAR	DEA no	SOURCE	SOURCE GENERATOR	WASTE CLASS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
2014	D00324-01	Newcastle (KZN252)	D00324-01	GW01 General: Municipal waste				2354	2354	1940	2453	2375	2189		2527	3466
2014	D00324-01	Newcastle (KZN252)	D00324-01	GW10 General: Commercial and industrial waste				204	198	109	297	1545	287		148	84
2014	D00324-01	Newcastle (KZN252)	D00324-01	GW30 General: Construction and demolition waste				544	318	2159	458	533	795		334	1910

In Table 5-3 provides statistics of the weighbridge data recorded of municipal solid waste, commercial and industrial waste and construction and demolition waste in tonnage.

5.6 Objectives of the Waste Stream Analysis

The waste stream analysis for NLM was conducted as part of the feasibility study for alternative technologies for waste reduction to landfill, requested by NLM's Solid Waste Management Division.

The primary objective of the study was to establish the composition of the waste stream entering the landfill and generate a general waste profile for NLM in order to estimate the annual quantities of each fraction (recyclables, biogenic and inert waste) which will in turn be used as input data for the carbon emissions reduction potential of various waste strategies in the municipality.

5.6.1 Selection of the waste streams and focus areas

The following waste streams/sources categories were sampled and characterized:

- High, medium and low income residential waste streams;
- Commercial and industrial waste streams.

5.6.2 These waste streams were classified using the following three strata:

i) The type of waste source or activity from residential/household, commercial and industrial waste.

ii) Area classification: rural and urban settings.

iii) Income group (in the case of residential/household waste): low, medium and high income groups.

Residential waste comprises all MSW originating from households. Commercial waste refers to waste generated through commercial activities from businesses, shopping centres, restaurants and similar sources. Industrial waste comprises of waste from light industrial activities such as goods and manufacturing.

Table 5- 4 Socio-economic status of areas serviced (Source: Courtesy of Newcastle Municipality, 2012)

Newcastle Local Municipality	Schuinhoogte	Urban High Income
	Aviary Hill	
	Paradise	
	Hutten Heights	
	Signal Hill	
	CBD	
	Central	
	Vlam Industrial Park	
	Osizweni Section E	Upper Income
	Ngagane	Urban High Income
	Pioneer park	Urban Medium Income
	Sunnyridge	
	Barry Hertzog	
	Amajuba Park	
	Ncandu Park	
	Amiel Park	
	Lennoxton	
	Sunset View	
	Richview	
	Arbor Park	
	Ghandi Park	
	Madadeni Section 1	
	Madadeni Section 2	
	Madadeni Section 3	
	Madadeni Section 4	
	Madadeni Section 5	
	Madadeni Section 6	
	Osizweni Section C	
	Osizweni Section D	
	Fernwood	Urban Low Income
	Fairleigh	
	Madadeni Section 7	
	Osizweni Section F	

This chapter outlines the case study area of NLM. It notes that there are varying service standards in respect of waste services. The methodological approach to the waste stream assessment and the remainder of the study is discussed in the following chapter.

5.7 RESULTS AND ANALYSIS:

Waste Stream Analysis, NLM

5.7.1 Introduction

Data for each of waste streams was captured in three ways:

- Firstly, a waste profile is presented of the general fractions of the waste streams (recyclables; biogenic and other waste) to immediately differentiate between the proportions of dry, wet and residual waste fractions.
- A pie chart of general waste fractions is then presented to determine the contribution of the individual recyclable waste material groups - paper and cardboard, glass, metal and plastic.
- Finally, the specific fractions of each waste material group as defined in the waste classification system are examined.

The interpretation of the results derived from the waste stream analysis will reveal trends, inconsistencies and correlation with the anticipated results. Waste streams will be compared with the source/activity of the waste generated, income group and type of area.

5.7.2. Waste Stream Analysis

There was no socio-economic analysis conducted for Newcastle as the areas are layed out according to Income.

5.7.2.1 Newcastle High Income Waste stream

The general and specific waste profile for each waste stream is present in the Figure 5.3 below. A high percentage of recyclable waste (60%) is present in the waste stream. Biogenic waste makes up 36% and other waste comprises 4%. The recyclable fraction is made up of paper (26%), plastic (23%), metal (7%) and glass (5%).

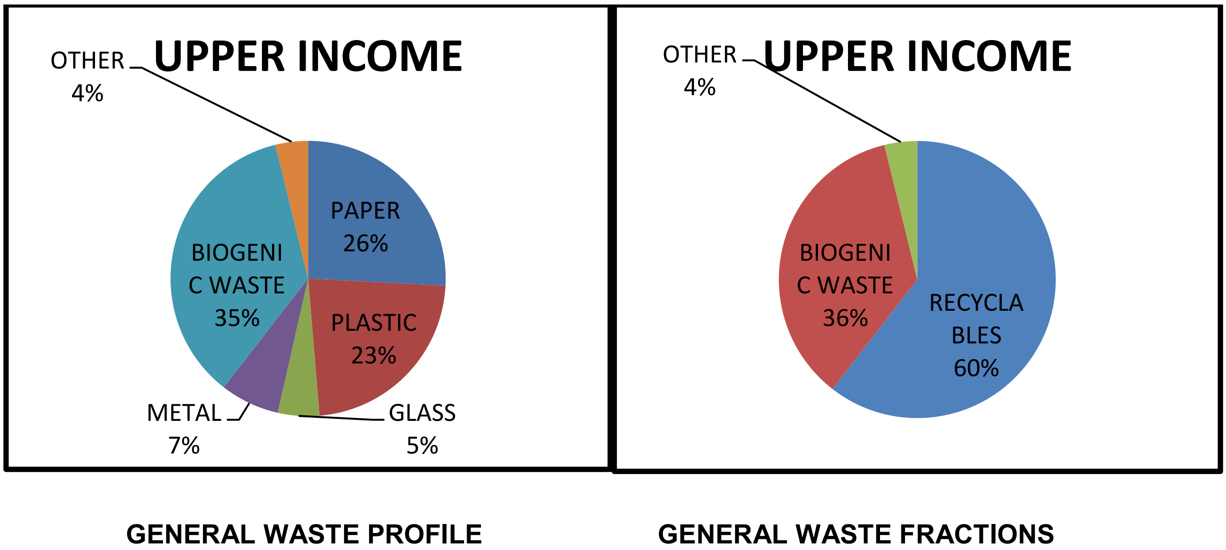


Figure 5- 3 General Waste Profile and General Waste Fractions

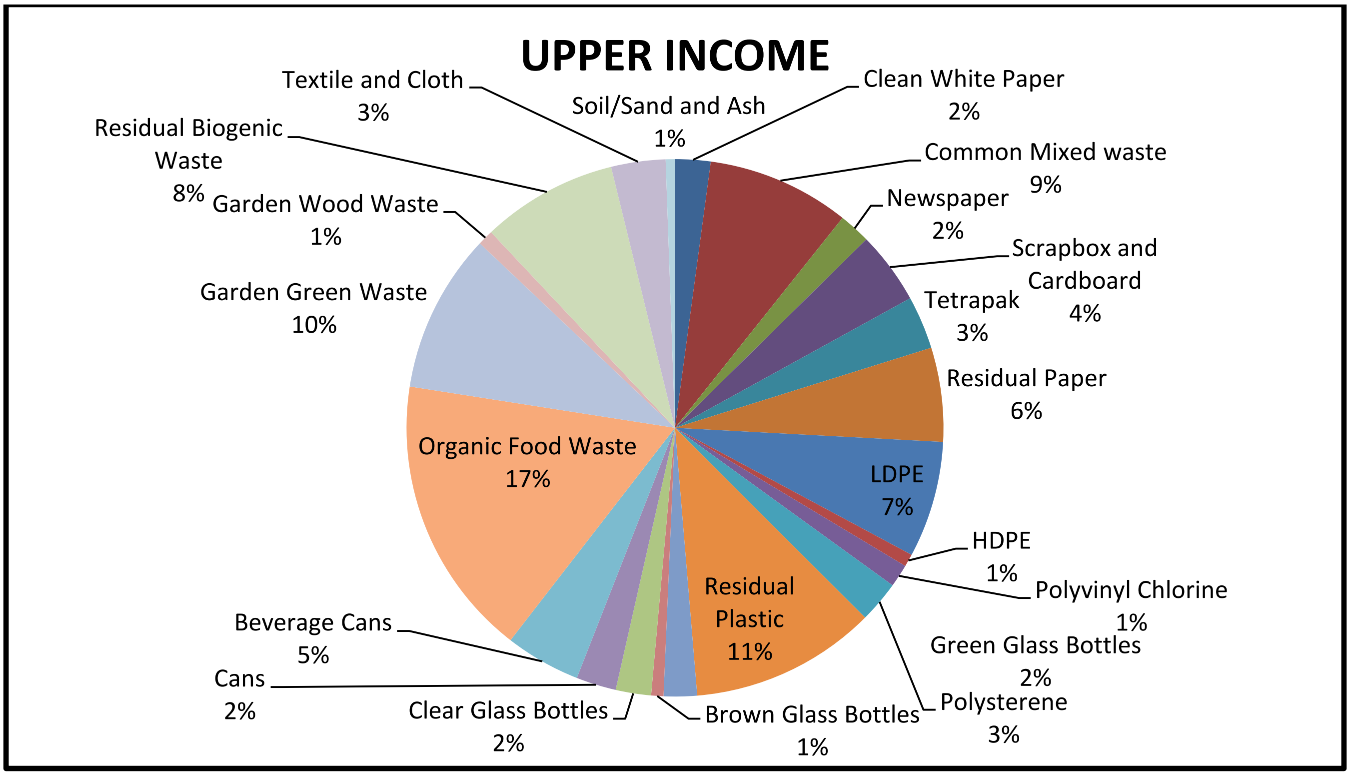
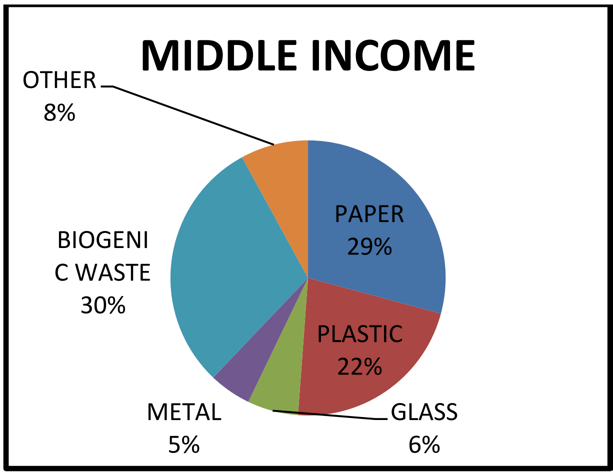
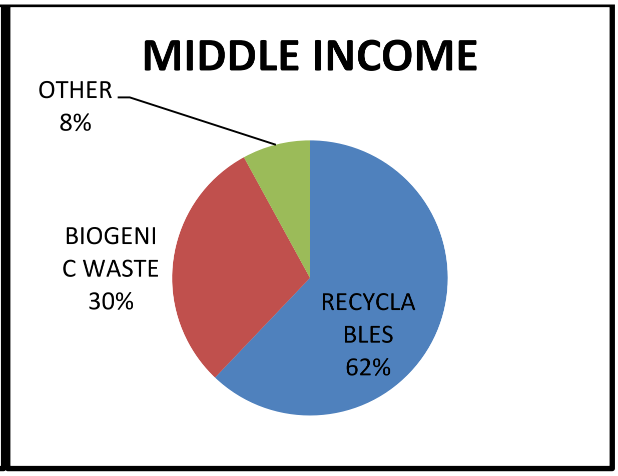


Figure 5- 4 Graph illustrating specific waste fractions in high income areas in Newcastle

5.7.2.2 Newcastle's Medium Income Waste Stream

The general and specific waste profiles for the Medium Income Waste Stream are presented in the Figure 5.5 below. There is a high percentage of recyclables (62%). Paper comprises 29%, Plastic 22%, Glass 6%, Metal 5%, Biogenic waste 30% and other waste 8%.





GENERAL WASTE PROFILE **GENERAL WASTE FRACTIONS**

Figure 5- 5 General Waste Profile and General Waste Fractions

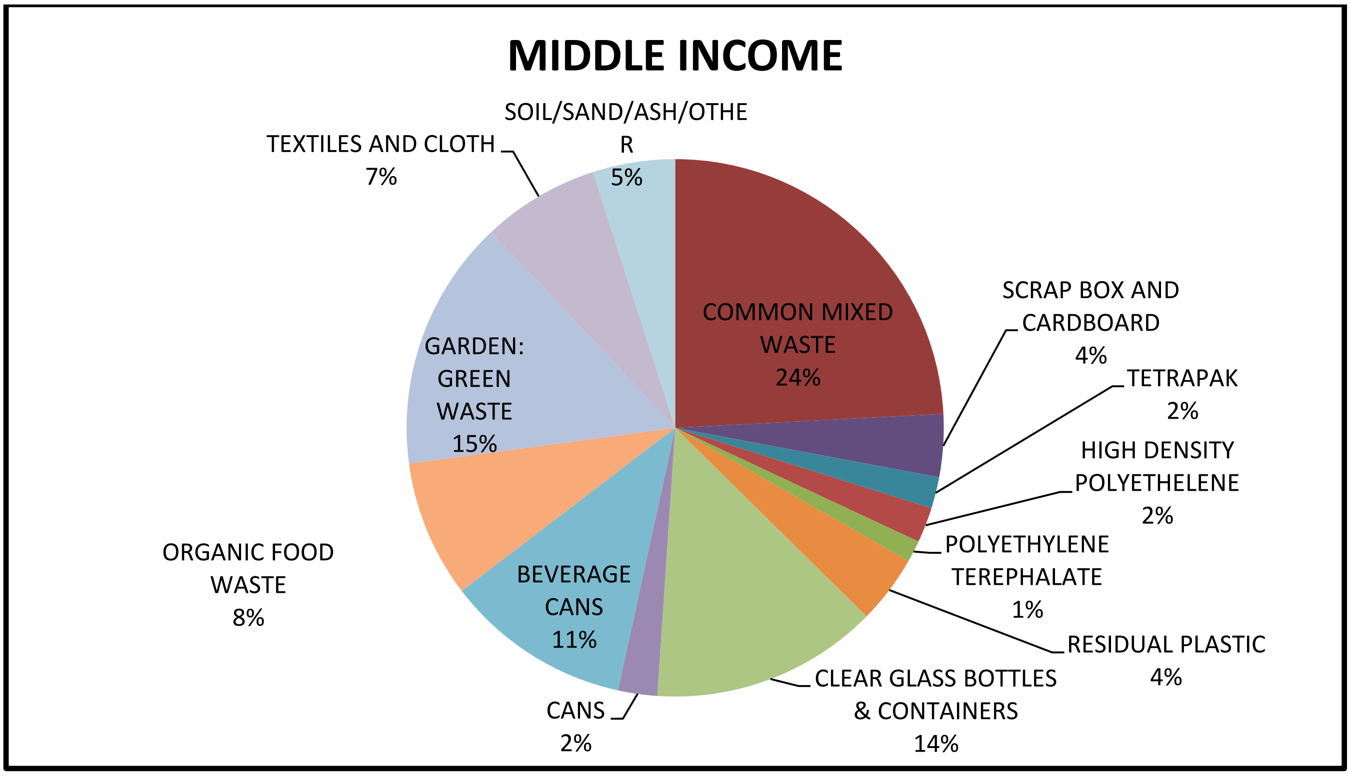
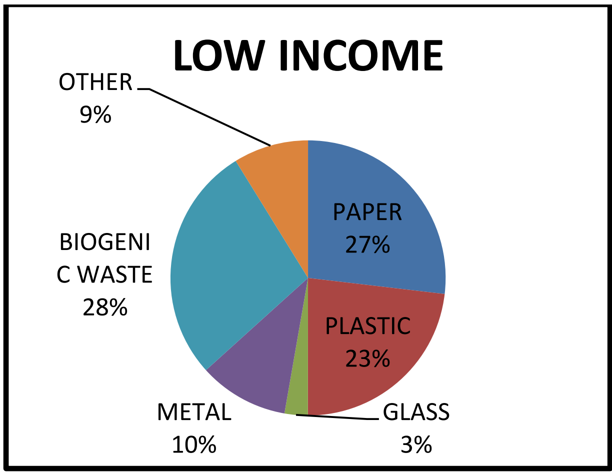
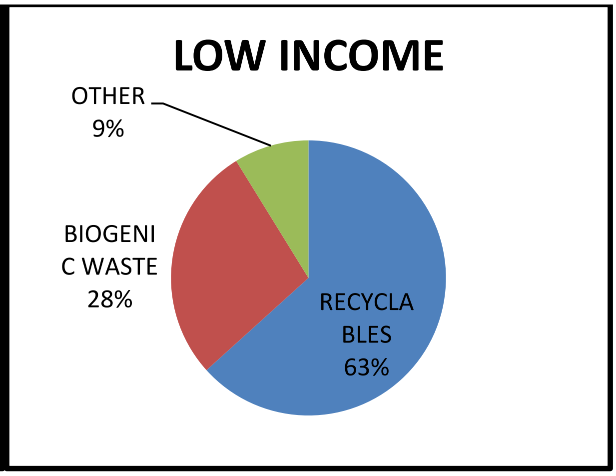


Figure 5- 6 Graph illustrating specific waste fraction in middle income areas in Newcastle

5.7.2.3 Newcastle's Low Income Waste Stream

The general and specific waste profiles for the Low Income Waste Stream are presented in the Figure 5.7 below. Recyclables make up 63%, with paper at 27%, plastic 23%, metal 10% and glass 3%. The biogenic fraction is 28% and 9% is other waste





GENERAL WASTE PROFILE **GENERAL WASTE FRACTIONS**

Figure 5- 7 General Waste Profile and General Waste Fractions

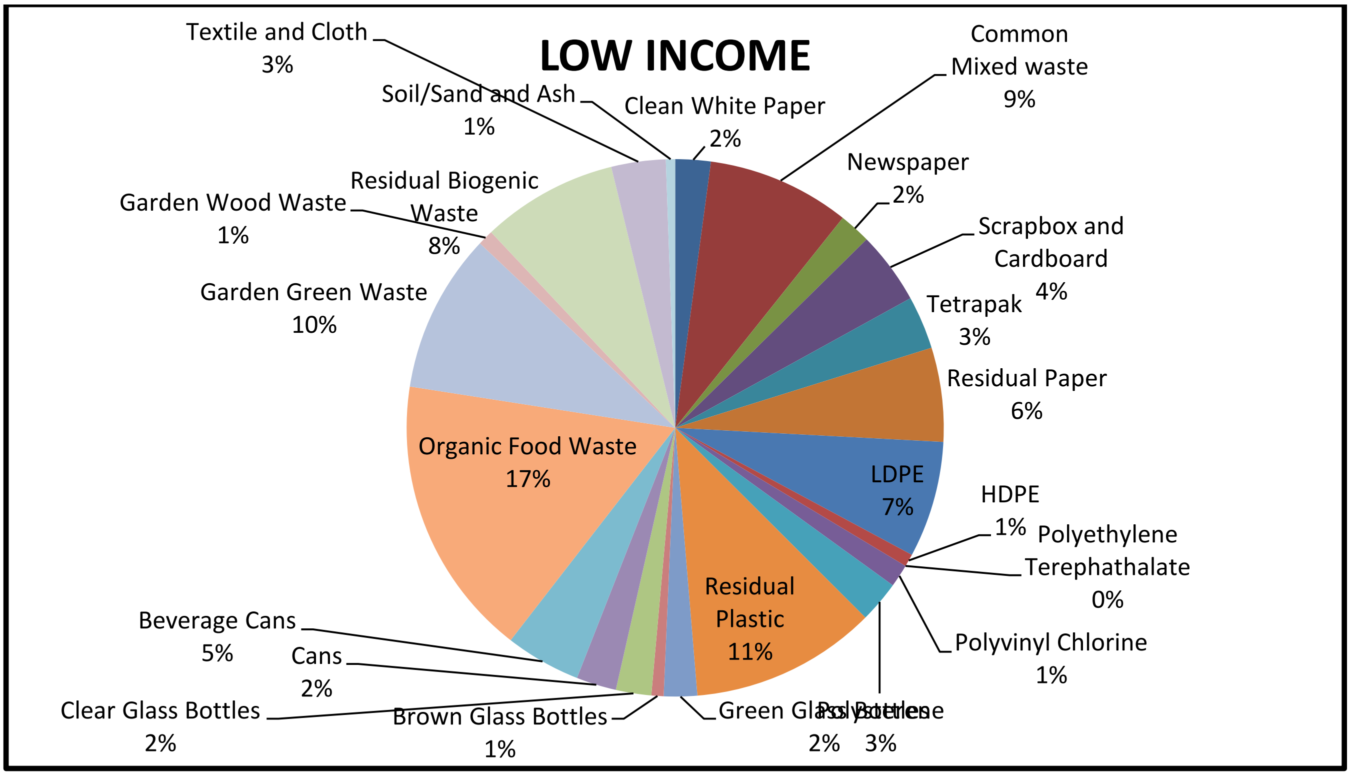


Figure 5- 8 Graph illustrating specific waste fractions in low income areas in Newcastle

5.7.3 Interpretation of waste stream analysis results

Table 5- 5 Summary of the waste fractions received from all income areas

Individual Waste Stream	**Waste Fractions (%)**					
	Plastic	**Paper**	**Metal**	**Glass**	**Biogenic**	**Other**
High Income	23	26	7	5	35	4
Medium Income	22	29	5	6	30	8
Low Income	23	27	10	3	28	9

The recyclable fractions are generally consistent across all income groups. General household waste stream fractions (recyclables and other waste) are also generally consistent across all income groups. The overall results suggest that waste composition does not differ greatly on the basis of the type of source/area or income group. A relatively high percentage of recyclables can be recovered from the specific categories of waste. Amongst all income groups, there is a no Polyethylene Terephthalate going to landfill. The reason is that there is a material processing factory in the area which converts PET to hollow woven fibre. There is also extensive participation in recycling schemes.

Like all methods of waste disposal, landfilling imposes both financial and external costs on society. Financial costs refer to the financial outlays associated with the establishment, operation and end-of-life management of the landfill site. However, external benefits may be associated with landfilling. For example, the methane content of LFG can be recovered and used to generate energy (energy recovery). This is an external benefit in that the negative impact associated with conventional (e.g., fossil fuel-based) energy, including GHG emissions and other air pollutants is displaced (European Commission, 2000a; b; Fiehn and Ball, 2005).

5.8 Processing of PET plastic into woven fibre

Background

A PET bottle recycling factory was established to process three-dimensional hollow short fibre. This is used, *inter alia*, in the bedding and toy industry as stuffing. The establishment of the factory was intended to contribute to environmental protection as plastic bottles are now recycled. Furthermore, the company has created approximately 150 new direct job opportunities in the Newcastle area. It was also an opportunity for community-based organizations to collect plastic bottles which are in turn purchased by Sen-Lida which is a the name of the PET processing company, thus contributing to poverty alleviation. The capital investment in the project was R80 million which makes it one of the largest investments from China in South Africa.

The factory is in the Madadeni industrial area. It consists of an existing factory of 10 500 square meters that was previously used by Nantex as a clothing factory employing 1 600 people. Nantex had a boiler on site which was removed when they ceased operations. A large portion of the site has been concreted to enable trucks to offload the plastic bottles.

5.8.1 Production Principles

First Part of Production

The polyester regenerated bottle chips are dried to rid them of moisture and they are then sent to spiral drums where they are heated and changed into fused mass. Impurities are removed by filters and then it enters the spinning assembly in which it is filtered, assigned and extruded into spinnerets which become thin silk bunches. The silk bunches are cooled and solidified by a wind blower from the side, where after they drop down and enter the coil machine. They then pass through the rollers and to a feeding device. The silk bunches are then sent to containers on the to-and-fro device**.** The polyester regenerated bottle chips are physically changed through these procedures and no chemicals are used in the process.

Second part of Production

The container loading silk bunches are arranged according to the total *Dens* of silk that will be extended. The heads of the silk bunches passing though the collection shelf are rearranged; the bunches are divided into three streams and then spread into three even layers on the guiding machine rollers. The layers of silk are extended by the extension machine rollers, passing through a soak trough, a water shower extension trough, and a steaming heat box. The silk is packed into blocks after being curled, cut and dried to become finished products. In this process, the semi-manufactured product from the first part of production becomes a very thin diameter silk product through physical extension.

Production Technique:

Bottle Chip Process

Consumption of raw PET bottles: 25-30 Ton/per day.

Frame Diagram of the Technical process:

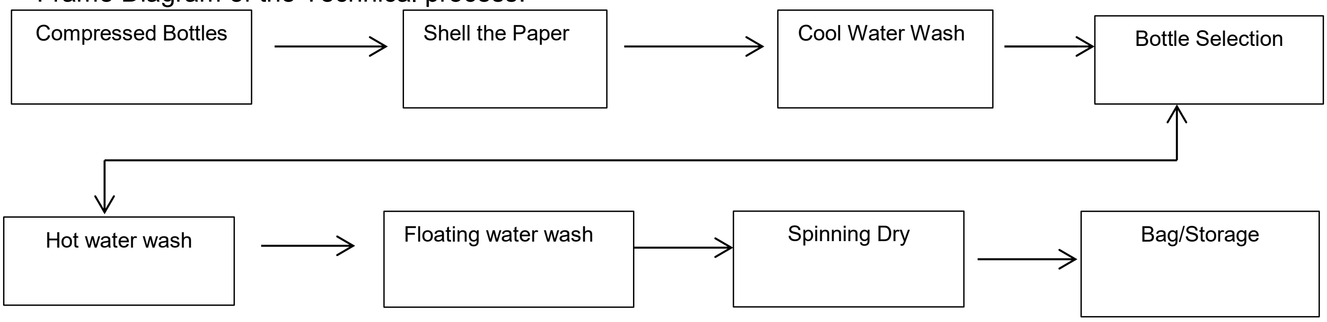


Figure 5- 9 Frame diagram of the technical processes of the PET plant (Source: Courtesy of SenLida, 2012)

5.8.2 Unit Operations of the technical plant

Bottles input and wash

Compressed bottles are sent on the conveyer to the washing workshop. Workers cut off the iron wires wrapped around the compressed bottles and the bottles are then sent to a washing machine by conveyer. PET bottles are washed according to the technical requirement that the machine removes silt and dirt etc., whilst it also removes most PE paper labels and some sticky PVC labels on the PET bottles.

Buffer and blow off the labels

After the PET bottles have been washed they enter buffer troughs to filter water; and are then sent to the blower along the conveyer to remove any remaining labels and rubbish.

Manual selection

The heterogeneous label bits and rubbish in PET bottles, etc., are removed by means of manual selection in the washing workshop to ensure that only clean PET bottles are sent to the next operating section.

PET bottles smash

The clean PET bottles are smashed to chips by a pulverizer machine.

Floating water wash

The chip mixture after crush should have a specific gravity between (~ 1.3 / ~ 0.8) among different plastics, under the float separating machine PET bottles are deposited to the bottom but the lids and fragments of the bottle chips go up separately to be purified.

Hot water wash, rubbing and rinse

This section mainly uses mechanical force and heating power. The chips are washed in a hot water wash machine, and move to a high-speed rubbing machine and fresh water rinse machine to totally remove the impurity in the PET chips.

Spin-drier and storage

In this workshop section, the washed PET chips are dried by a spin-drier and the PET chips are sent to storage.

Table 5- 6 Key equipment used at the plant (Source: Courtesy of SenLida, 2012)

Number	*Name*	*Unit*	*Quantity*
1	Belt transmission conveyer	Set	2
2	Bottle wash machine	Set	1
3	Double spiral conveyer	Set	2
4	Buffer trough	Set	1
5	Label container	Set	1
6	Blower (for labels)	Set	1
7	Wind blower (for labels)	Set	1
8	Screen belt transmission conveyer	Set	2
9	Selection platform	Set	1
10	Pulverizer	Set	2
11	Spiral feeder	Set	4
12	Float separating machine	Set	1
13	Hot water wash & rubbing machine	Set	2
14	Heat washing circulatory system	Set	2
15	Spin-dryer	Set	4
16	Rinsing machine	Set	2

Main raw materials and acceessories

The main raw material is only the PET. Recycled beverage bottles, edible oil bottles, and plastics like PVC and PP are not mainly used as materials as well as bottles with mud, grit and glue.

Polyester chip cleaner TF-131A

Principal ingredients Surfactant

Technical specification Yellow color powder of appearance; PH (1‰ aqueous solution) >8.0

5.8.3 Dacron short fibre production

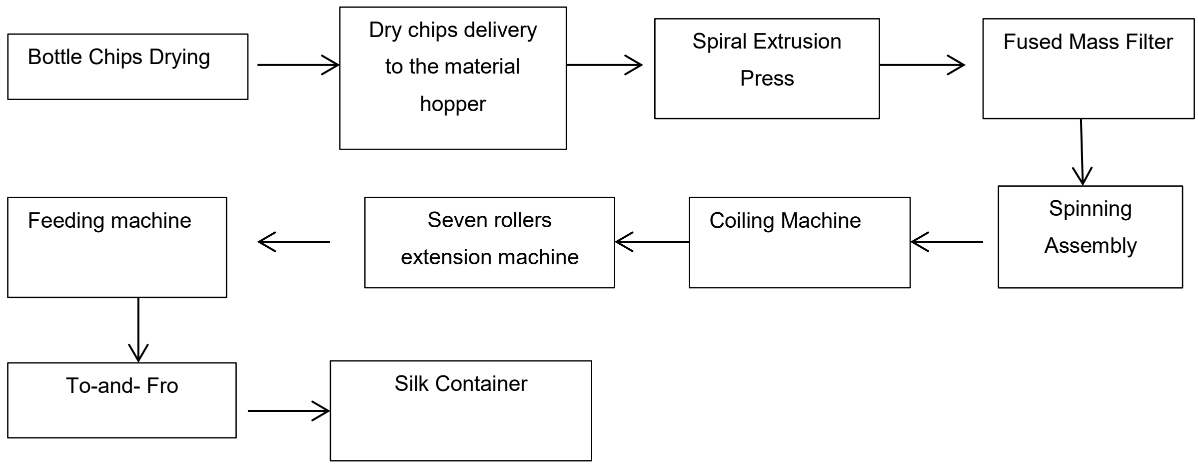


Figure 5- 10 Dacron Production process in the PET plant (Source: Courtesy of SenLida, 2012)

Dry system

Place the clean chips in rotary drums to dry them, and then deliver to material hoppers. Fused mass conveyer system. Chips are released from material hoppers and fed into augers. Spiral extrusion press squeezes the fused mass into dividing pipers of spinning cases through the change valve and filter.

Spinning system

Including spinning case, controlled volume gear spinning pump, spinning assembly, blowing wind system and oiling system.

a) Spinning case

The fused mass is distributed into each spinning location. The body structure of the case guarantees a constant temperature.

b) Controlled volume gear spinning pump

The fused mass from each spinning location is measured and controlled by an accurate gear spinning pump, and then the gear pump sends the fused mass into the spinning assembly to form the fiber, gushing through silk holes after filtering.

c) Spinning assembly

The assembly includes the support board, distributing board, spinneret and filter materials, etc. The fused mass is filtered by sand and a filter net. The assembly is installed from upstairs workshops to the factory floor.

d) Surround blowing and cooling device

The fused mass is pushed out from the spinneret and cooled by the device which blows a laminar flow of cooling wind. The pace of blow, temperature and humidity are all regulated to meet the requirements of the techniques. The amount of blowing wind can be controlled in the best pressure range by the regulating valve to ensure that fibers are evenly solidified.

Coiling, hauling, feeding and the silk barrel to-and-fro

Coiling and oiling system:

Silk bunches are evenly oiled by the two-sided oiling wheel after the spinning corridor.

Silk combination:

Silk from each unit is combined into a bunch through the guiding rollers.

Hauling and feeding device:

After converging, the silk bunch is led by the guiding machine with six rollers and to the silk barrel.

Silk barrel to-and-fro:

The silk barrel is a two-ways movement controlled by the servomotor.

Table 5- 7 Main raw material PET bottle slice and accessories (Source: Courtesy of SenLida, 2012)

Appearance	White or blue
Moisture content (ppm)	<100
Relatively viscosity	0.7 ± 0.05
Impurity content (%)	<0.02
PVC content (%)	<0.02

Main accessories

Spinning silicon oil

Appearance	Brown even liquid
PH (20 ℃, 1% of the cream)	6-8
Ion type	Cation type

Packing materials

Material	Polypropylene (PP)
Wrapping up type size	1120mm × 670mm ×950 ～ 1150mm
Bale weight	250 ± 20kg

<u>Boiler replacement in the main boiler room</u>

A new boiler has been installed in the old boiler room. The new boiler’s rated thermal power is 3 500 Kw. The boiler produces heat by burning coal to heat the conduct oil which is transmitted to the positions where energy is needed in the workshop, such as the rotary drums and the drying cabinet. A compound water desulfurizing dust scrubber has been installed for the boiler smoking treatment. The scrubber has an 18 000 m3/ hour disposal capacity of exhaust gas by making use of water showering technology, which delivers dust filtering efficiency ≥ 98% and desulfurizing efficiency ≥ 80%. The new boiler will cause less pollution than the previous one.

Boiler Replacement

The boiler will heat conduction oil and this is sent through a circulation oil pump system to the areas in the factory where heating is required. The oil is led to the return pipe after releasing heat to the heating equipment and back to the mail machine to be reheated again by the circulation pump, thus going round and beginning again to achieve heating conduction circulation.

The boiler's characteristics and the heat conduction is a direct current type special boiler developed on the basis of the circulation of force design thinking. The electric energy is regarded as the energy; there is no noise and is pollution free. The electric heat pipe and controls the reliable work and the service life of the boiler. The closed circulation heating model lengthens the service life of the boiler. The heat energy is sent in the liquid phase state, the loss of heat is small, conserving energy and protecting the environment. The boiler system adopts a three backward coil pipe design and straight current type structure to ensure there is a high level of safety. The adoption of the backward coil pipe design and straight current type structure is obtained from the boiler to achieve high thermal efficiency.The prominent characteristic of the conduction heat oil boiler is the adverse current heat exchange that achieves the difference of temperature between smoke emission and a thermal conductance oil outlet under 30℃. The structure of the conduction heat oil boiler results means that the boiler can run at lower pressure to easily obtain a working temperature under 450℃; it therefore has both low-pressure and high-temperature characteristics. It can achieve steady heating and accurate temperature control, meeting different requirements. In changing the hot load, the boiler can maintain thermal efficiency at the optimal level.

The advantage of conduction heat oil is the design of the heat surface layout; the oil has a longer service life. The discharge of exhaust gas meets environmental protection standards. Accurate and reliable temperature control is ensured by complete operation control and the safety measurement system, which is automatic and low laboring.

Table 5- 8 Unit Operation and Processes of Circulation Heating Model (Source: Courtesy of SenLida, 2012)

Number	*Name*	*Unit*	*Quantity*
Burning system			
1	Chain raft combustion room	set	1
1a	Coal lifter	set	1
2	Air-blower	set	1
3	Air inhaler	set	1
4	Water curtain dust catcher	set	1
5	Gear box	set	1
6	Spiral cinder scavenger	set	1
7	Square wrench	set	1
8	Ash fall collector case	set	1
9	Natural ventilation door	set	1
10	Air pre-heater	set	1
Circulation system			
11	Boiler main body assembly	set	1
12	High-temperature circulation oil pump	set	2
13	Gear injection oil pump	set	1
14	Y model filter	set	1
15	Y model oil filter	set	2
16	Oil gas separator	set	1

16a	Inflation trough	set	1
16b	Oil storage	set	1
Instrument control system - *electric switch cabinet*			
17	Glass plate height-finding instrument	set	1
18	Glass plate height-finding instrument	set	1
19	Ball float level controller	set	1
20	Thermal platinum resistance	set	2
21	Thermal platinum resistance	set	3
22	Duplex metal thermometers	set	2
23	Thermal resistance Interface	set	2
24	Thermometer interface	set	2
25	Manometer stop valve	set	2
26	Distant reading manometer	set	2

Table 5- 9 Boiler index parameter (Source: Courtesy of SenLida, 2012)

Number	*Parameter name*	*Unit*	*Assessment criteria*	*Required standard*	*Real data*
1	Smoke and dust density of discharge	Mg/Nm^3	GB13271	200	93.16
2	SO_2 density of discharge	Mg/Nm^3	GB13271	900	318.79
3	Dust remover resistance	Pa	HCRJ040	<1200	996.42
4	Air leaking rate	%	HCRJ040	<7	4.28
5	Liquid gasification	L/m3	HCRJ040	<1	0.52
6	Dust remove efficiency	%	HCRJ040	≥ 94	95.29
7	Desulphurization efficiency	%	HCRJ040	>60	74.01
8	Moisture rate in exhaust gas	%	HCRJ040	≥8	7.3
9	Rate of reuse of recycle water	%	HCRJ040	≥85	>90
10	Smoke black	Grade	GB13271	<1	<1

Coal

South Africa local soft coal will be used as fuel. The average daily coal usage is around three tonnes and less than 20 tonnes of coal is carried to the covered coal room by supplier transport.

Table 5- 10 Synthesis of the environmental protection offered by heat conduction oil (Source: Courtesy of SenLida, 2012)

Appearance	Light yellow Transparent liquid
Component	Synthetic hydrocarbon mixture
Flash point(ASTMD-92)	201 ℃
Movement viscosity	40℃ 23.92mm2/s (c.s.t.) 100℃ 4.113mm2/s (c.s.t.)
Density (20℃)	876.4kg/m^3
Specific gravity index API	29.2
Neutralization value mg Kou/g	<0.01
Remnant charcoal % (m/m)	<0.01
Incline point ℃	- 38℃

The old coal storage area for the previous boiler will be used again.

5.8.4 Emission of waste water, waste material and pretreated bottle storage

Waste water:

The waste water comes from several workshops, but mainly from the washing workshop, the boiler and the storage of pretreated bottles;

The average discharge of sewage from the bottle washing is 30 - 50 m3/per day;

The average discharge of oil sewage is 0.5 - 1 m3/ per day;

The average discharge of boiler sewage is 10 - 20 m3/ per day;

Average COD value: 500-970mg/l.

All of the above-mentioned sewages enter the sewage treatment system. The system can handle 50 m^3/ per hour and the treated water is reused in production. There is no discharge of effluent to the municipal sewage system as, once treated, the water is reused.

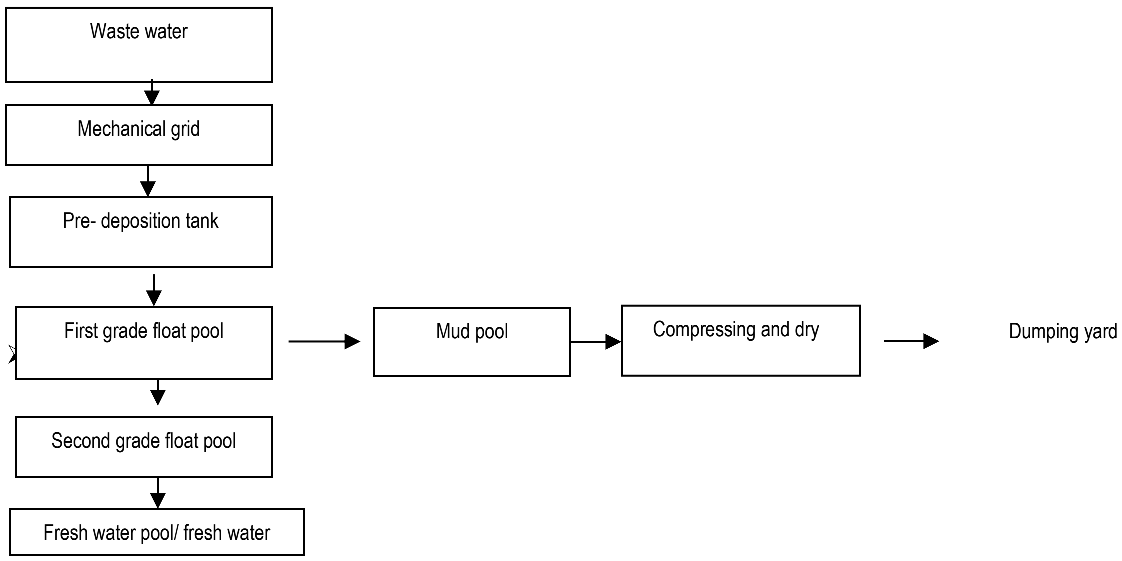


Figure 5- 11 Frame diagram of waste water treatment at the PET plant (Source: Courtesy of SenLida, 2012)

The waste water discharged from the workshop enters the waste water treatment station through the waste water piping system. Big particle impurities in the waste water are first removed by the mechanical grid by adding caustic soda to balance it to about PH 8.5, then the waste water enters the pre-deposition tank to remove the suspended substance and impurities.

After deposition, the water in the pre-deposition tank is lifted by pump and enters the first stage air-water floating pool where alumina is added. Floating adopts partial reflux air pressure mingling to dissolve air with water by using water from the clear water pond, mixing compressed air with water in the air-water mixing tank, under pressure to saturate the dissolved air-water. On releasing the air-water into the air-water floating pool, the excessive air rises and appears on the surface of water in the form of micro-bubbles. The alumina in the waste water absorbs the micro-bubbles with the impurities and uses its buoyancy to float to the top of the water, thus isolating the impurities from the water. The impurities on the surface can be disposed of regularly but the mud under the pool is pressed into the mud drying pool and compressed to form blocks. The water enters the second stage air-water floating pool after passing through the first stage for further COD and suspended substance elimination. After the second stage, the water in the air-water floating pool is clean and enters the clean water pool ready for production. The solution is that the waste is recycled in the hallow fibre production process or recannot be recycled and is then dumped.

Table 5- 11 Waste material (Solid and liquid) (estimate) (Source: Courtesy of SenLida, 2012)

Number	*Area*	*Waste material*	*Quantity (kg/d)*	*Composition*	*Solution*
1	Spinning	Fused mass	60	PET	Produces retrieval and utilization
2	Spinning	None oil silk	300	PET	Produces retrieval and utilization
3	Coiling	Oil silk	200	PET	Produces retrieval and utilization
4	Silk bunch collection	Remnant silk in Barrel	100	PET	Produces retrieval and utilization
5	Extension	Silk	200	PET	Produces retrieval and utilization
6	Curling	Oil silk	100	PET	Produces retrieval and utilization
7	Cutting	Oil silk	50	PET	Produces retrieval and utilization
8	Wash bottle	PP, PVC	500		Retrieval utilization or sale
9	Boiler	Cinder			Dumping yard

Illustration of the PET processing plant

Waste PET received at the processing plant then stores before auto washing of PET and removal of PVC labels

All PET bottles are washed and PVC labels removed and bagged, there is then sorting of hetrogenous plastic. The PET is then chipped. It is then stored in bags before thermal processing

All chips processed into an oven and passed through a funnel, and a revolving cooling barrel/shower

The crossing of the fibre through a grid network, stretching of the fibre, it is then curled and gathered in silicon oil and the end product of hollow fibre

Figure 5- 12 Illustration of the PET processing plant Photo's: Kelly T, (2012)

5.9 Chapter Summary

This case study of Newcastle, South Africa was unique in the sense that not much research has been conducted on the waste project activities of medium or small sized municipalities. The detailed waste stream analysis provides insight into potential project activities that lead to WTE options.

The South African government has committed to GHG mitigation across all sectors including the waste sector; however, landfill disposal of MSW remains the predominant waste management strategy in the country (DEAT, 2009a). Many studies have suggested that zero waste and waste diversion strategies could result in significant GHG/carbon reductions (Smith et al., 2001; Mohareb et al., 2008; Couth and Trois, 2010). This study sought to identify integrated waste management strategies that could be utilized at municipal level in South Africa and assess the potential for MSW diversion and GHG mitigation. The greatest climate change impacts of carbon dioxide, methane and nitrous oxide are as a result from GHG emissions, all of which are produced from landfilling of municipal solid waste.

An alternative technological process for waste stream management was also examined in this chapter with particular focus on PET that is being diverted from the landfill, resulting in zero PET in the Newcastle Landfill site. The study details the actual process involved of converting PET in woven fibre that is used to stuff pillows, bedding and furniture. Due to the quantity of the pretreated bottles, storage reaches about 30 tonnes/per day, requiring a large storage area. Consumption of pretreated bottles is also about 30 tonnes/per day. The storage ground drainage pipeline is connected to the internal effluent treatment system. Even rainwater from the bottles storage ground is drained to the effluent treatment system, so there is no pollution from the storage ground.

6. INSTITUTIONAL FRAMEWORK FOR WASTE MANAGEMENT AT MUNICIPALITIES IN SOUTH AFRICA

6.1 Introduction

An institutional framework refers to a formal organisation structure of rules and informal norms for service provision. Amongst municipalities in South Africa and observations from India there is no framework which is a precondition for successful implementation of waste management projects.

The development of an institutional framework involves outlining responsibilities of municipalities with regard to waste management strategies in considering any technology or process inline with legislation and policy. The need for an instituitional framework for waste management is to avoid the root causes of many failures in service delivery. Such institutional weakness often result from the lack of clear institutional planning and management together with limited capacity within institutions to co ordinate and manage initiatives.

The DEA is leading the Waste Management Flagship, as defined under the National Climate Change Response Policy, which includes a Waste-to-Energy Flagship sub-programme intended at examining waste to energy opportunities in the solid, semi-solid and liquid-waste management sectors, especially the generation, capture, conversion and/or use of methane emissions (SANEDI, 2013).

The key outputs of the flagship programme are a flagship framework and action plan that will, amongst other things, detail the development and implementation of any policy or legislation and /or the regulations essential to facilitate the implementation of the plan (SANEDI, 2013).

A feasibility study comprises a detailed analysis of the waste stream and its characteristics. It outlines waste data and assesses the various waste management technologies that are available for municipalities to include in their IWMS. Waste treatment technologies were investigated to identify the most appropriate application to maximise GHG reductions. While a number of zero waste models have been developed, the objective was to identify one that would suit municipalities in developing countries, bearing in mind technical feasibility and most importantly, environmental benefits.

In this context the entire waste management system needs to be considered to best evaluate the most appropriate strategies to reduce greenhouse gas and to assess how different waste management processes can be considered to maximise for the purpose of developing an institutional framework.

This chapter also details the standardised IWMP for municipalities which should be in line with National Waste Management strategies. Municipal service delivery targets and indicators are measure against institutional, environmental, social, economic and technical sustainability. The institutional framework will provide information that will lead to an assessment of appropriate technologies that municipalities can consider, in line with the feasibility study as well as a road map of any potential waste-to-energy projects. The study further assessed the level of importance of each step on the road to institutional, environmental, social, economic and technical sustainability. These are the essential components that develop this framework.

6.2 Municipalities' Feasibility study process

To determine the most appropriate and standardized IWMP for municipalities to invest in, a feasibility study was undertaken to identify and develop an IWMS that will comply with the Waste Act and Municipal systems Act, suing the case study on the detailed waste stream analysis and waste management characteristics and composition.

6.2.1 Management of Projects and the relevant Legislation

LFGTE projects should be regarded as a competent activity that is part of the municipality's strategic vision. The municipality should explore the available service delivery mechanisms in terms of the relevant National Treasury regulations to the Municipal Finance Management Act, 2003 (MFMA), the Municipal Systems Act (MSA) and, where appropriate, the National Treasury's Municipal PPP manual, all of which potential advisors are required to be familiar with.

6.2. 2 Management of Projects and Municipalities' Procurement Process

The management of waste projects with the municipal procurement process requires expertise which is scarce within the municipality. These terms of reference invite proposals from bidders representing teams of suitably qualified and experienced financial, technical and legal advisors to assist the municipality. The following schematic diagram illustrates the sequence of procurement process. Figure 6-1 details the procurement plan in municipalities with regard to waste project activities.

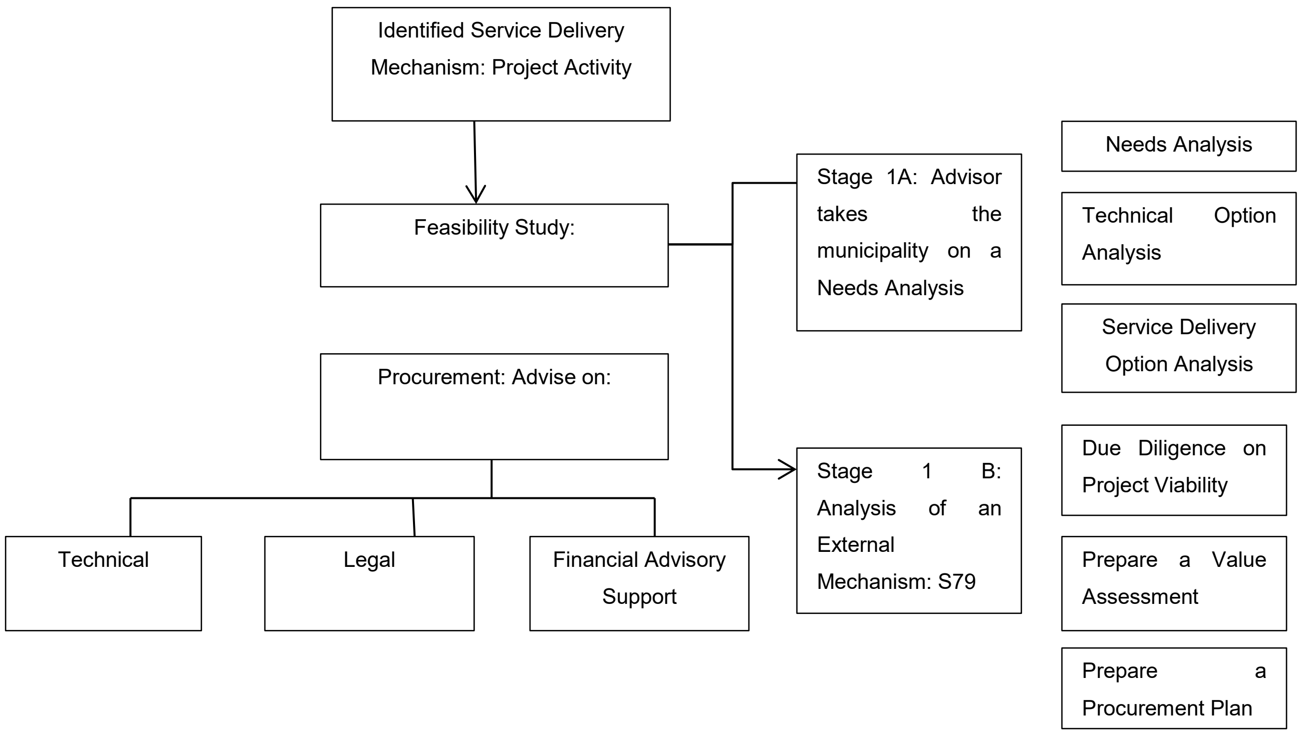


Figure 6- 1 The schematic layout of the procurement process to undertake a feasibility study

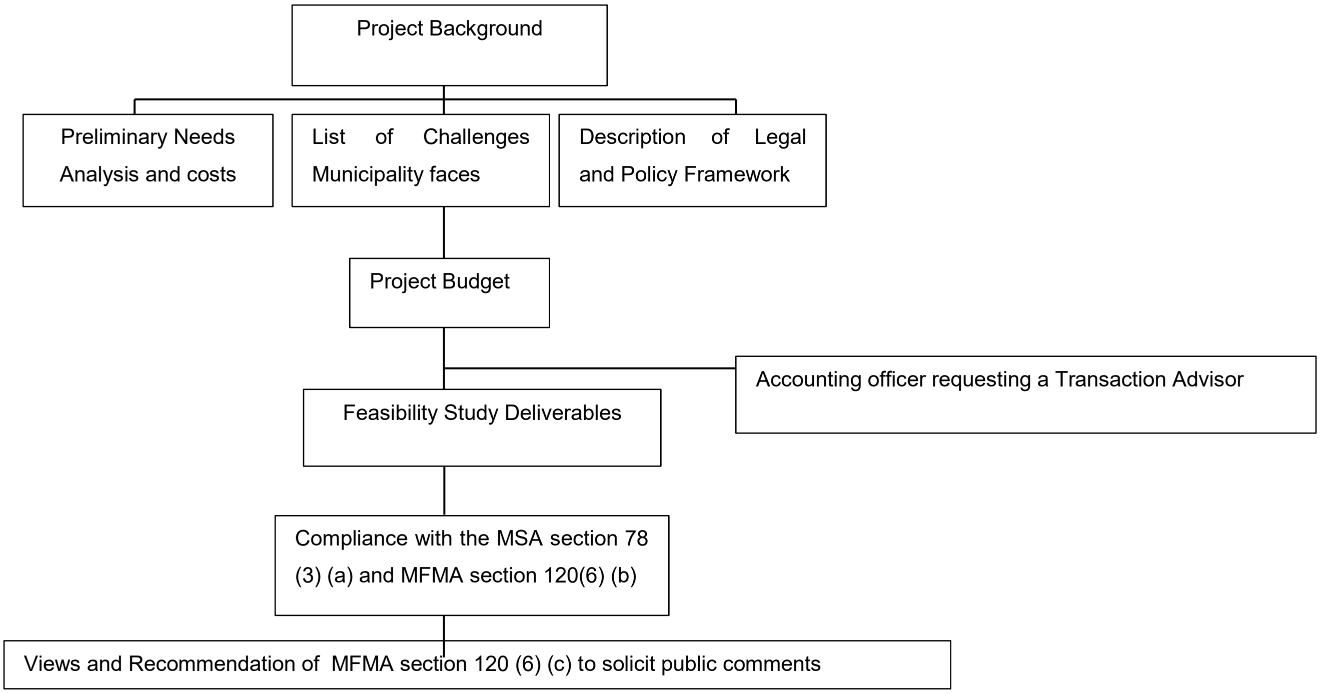


Figure 6- 2 Schematic layout of the Procurement Process - Detailing a Feasibility study deliverables

6.2.2 Stage 1: Feasibility Study

The feasibility study compromises of two stages. The first stage, the advisor takes the municipality through a needs analysis. There is also a technical option analysis and service delivery analysis. At this point if the municipality decides on an internal operation then the municipality may opt to review the advisor's contract or it is either terminated in compliance with MSA S79. Should the option of analysing an external mechanism in more detail, then stage 1B proceeds where an in-depth assessment is undertaken. The municipality will decide on the option to proceed with the procurement of an external option.

6.2.3 Stage 2: Procurement

If a municipality decides on the option of an external mechanism, the advisor will provide the necessary technical, legal and financial advisory support to the municipality for the procurement. The feasibility stage 1A and 1B and procurement will be included in the terms of reference as prescribed in compliance with MSA S79. The advisor's work may be terminated at the end of any stage without any additional remuneration either that that was specified for that particular stage.

6.2.4 Feasibility Study Stage 1A:

The advisor will be required to produce a comprehensive analysis in compliance of MSA S79 to determine the:

Needs analysis which is the status quo of the current situation that is part of the Integrated Waste Management Plan; this plan is also a sector plan which is part of the IDP. The IDP is the municipality's strategic document that outlines the strategic objectives of short term, medium term and long term projects. These strategic objectives have budget estimates or approved budgeted projects over a multi-year period. The IDP also highlights the institutional analysis and output specifications and scope of all projects.

Technical options analysis offers a technical evaluation of the options that need to be considered. Each technical option is evaluated and assessed and a summary report is presented with recommendations.

Service delivery options analysis is a list of all the deliverables with specific timelines and evaluation and assessment of each service delivery option. A summary report on all delivery options is prepared and recommendations are made on the preferred delivery option.

6.2.5 Feasibility Study Stage 1B:

The advisor will be required to:

Undertake **Project Due Diligence** that considers the legal aspects of the project. The rights of all parties are considered and contractual documentation is presented. Regulatory matters in terms of the project and site enablement are considered in the due diligence exercise. Socio-economic factors and black economic empowerment should also be considered.

Prepare a **value assessment** which is a determination of the need to undertake an internal assessment. Technical definition of the project as well as a discussion of costs (direct and indirect) and assumptions made in terms of the cost estimates are conducted. The value assessment should include a discussion on revenue (if relevant) and the assumptions made in revenue estimates and black economic empowerment targets. It should also include all assumptions made in the construction of the model, including the inflation rate, discount rate, depreciation, tax and VAT, and budgets. It should discuss public-private partnerships and sources of funding and a detailed discussion of the payment mechanism. Finally, it should present a summary of results from the external reference model on the net present value.

6.3 A standardized integrated waste management plan

The framework below is essential for the management of MSW. The implementation of the plan outlined details the different waste technologies that can be implemented by municipalities. This framework is part of the strategic document in line with the legislation.

Legislation regulating waste management in South Africa is prolific and highly fragmented. Previous legislation did not comprehensively regulate waste management. The National Environmental: Waste Act, 2008 ("the Act") aimed to provide a comprehensive framework to regulate waste management practice. The Act is based on the following approaches:

a) The need to give effect to environmental rights contained in Sect. 24 of the Constitution in general, and the waste management hierarchy in particular.

b) Alignment with international and national trends.

c) Avoidance of regulatory over boarders.

d) Framework legislation that enables appropriate flexibility in regulating different aspects of waste management.

e) Regulation of waste throughout the life cycle.

f) Performance-based regulation.

g) Opportunities to encourage best environmental practice.

6.3.1 Institutional and planning matters

The Waste Act is legislation which is structured around providing a guideline within the waste management hierarchy, which is the overall approach to waste management in South Africa. The various aspects of the Act detail the obligations to uphold norms and standards, integrated waste management plans, and industry management plans.

According to Chapter 3 Section 11 of the Act, each Municipality must:

i. Submit its integrated waste management plan to the MEC for approval;

ii. Include the approved integrated waste management plan in its IDP contemplated in the Municipal Systems Act.

Section 6

In exercising the power to monitor and support a municipality as contemplated in Section 31 of the Municipal Systems Act, the MEC for local government, in consultation with the Minister of Executive Council, must ensure that the municipal IDP is co-ordinated and aligned with the plans, strategies and programmes of the Department and provincial departments.

Section 7

Before finalising an integrated waste management plan, the Department and every provincial department contemplated in subsection (1) must follow a consultative process in accordance with sections 72 and 73.

b) A Municipality must, before finalising its integrated waste management plan, follow the consultative process contemplated in Sect. 29 of the Municipal Systems Act either as a separate process or as part of the consultative process relating to its IDP.

(12) (I) An Integrated Waste Management Plan must:

a) Contain a situation analysis.

i) A description of the population and development profile of the area to which the plan relates.
ii) An assessment of the quantities and types of waste that are generated in the area.

iii) A description of the services that are provided or that are available for the collection, minimization, re-use, re-cycling, recovery, treatment and disposal of waste; and
iv) The number of persons in the area who are not receiving waste collection services.

- To provide for the implementation of waste minimization, and re-use, recycling and recovery initiatives.
- To address the delivery of waste management services to residential premises.
- To give effect to best environmental practice in respect of waste management.
- To implement the Republic's obligation in any relevant international agreements.
- Establish targets for collection minimization, re-use and recycling of waste.
- Planning of any new facilities for disposal and decommissioning of existing waste disposal facilities.

To indicate the financial resources that are required to give effect to the plan:

- The Annual Performance Report must contain information on the implementation of its integrated waste management plan.

  a) The extent to which the plan has been implemented during the period.

  b) Waste management initiatives that have been undertaken during the delivery of waste management services and measures taken to ensure efficient delivery, if applicable.

  c) The level of compliance with the plan.

  d) The measures taken to secure compliance with waste management standards.

  e) Waste management monitoring activities.

  f) The actual budget expended on the implementing the plan.

  g) Amendments to the plan.

  3. Description of the population and development profiles of the area to which plan relates.

6.4 Development of an Integrated Waste Management Plan

The system of Integrated Waste Management Plans in South Africa has a clear legal basis in the Waste Act. It provides an assessment of the quantities and types of waste that are generated in the area in the IWMP Situational Analysis.

The IWMP situational analysis describes the services that are provided or are available for collection, minimization, re-use, recycling, recovery treatment and disposal of waste.

The intentions of the municipality in the planning of any new facilities for disposal and decommissioning of existing waste disposal facilities (including Buy-back Centres, MRF's and waste transfer facilities) must be set out. The schematic diagram below illustrates what should be contained in the IWMP that will unfold the potential technologies that will be appropriate for the reduction of GHG emissions.

A standardized framework for waste management technology is developed for South African municipalities. Municipalities will save valuable time and money. The framework also offers municipalities an easier approach to develop a sustainable IWMP. The framework below provides a response that will be specific to each municipality’s needs. Waste management technologies should result in an appropriate solution according to various indicators in different areas.

The following schematic layout is illustrative of the structure of the IWMP which should be informed by a feasibility study and include potential project activities. It outlines key aspects that municipalities are obliged to include in the IWMP.

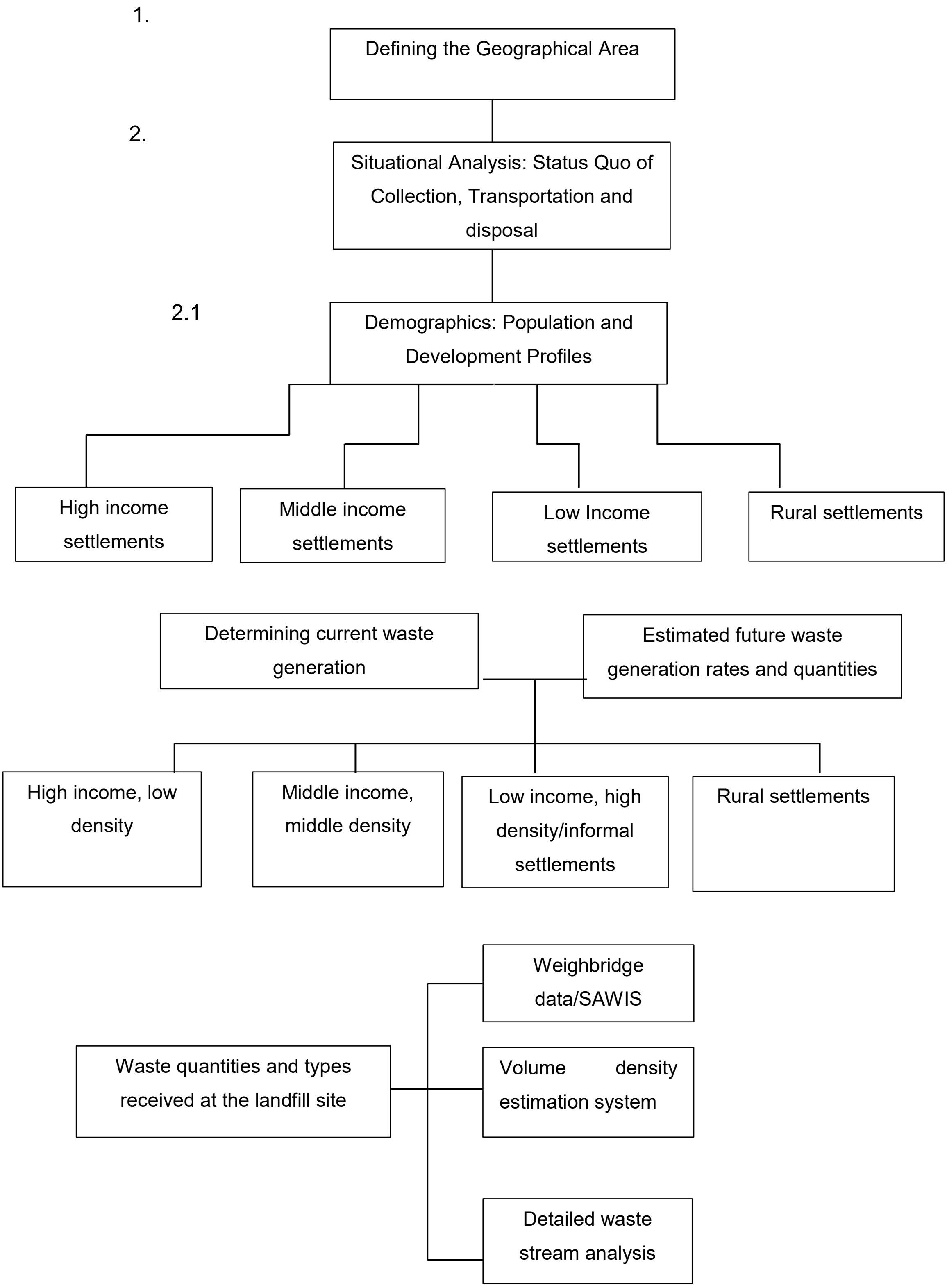


Figure 6- 3 Schematic Layout of the structure of a standardised IWMP

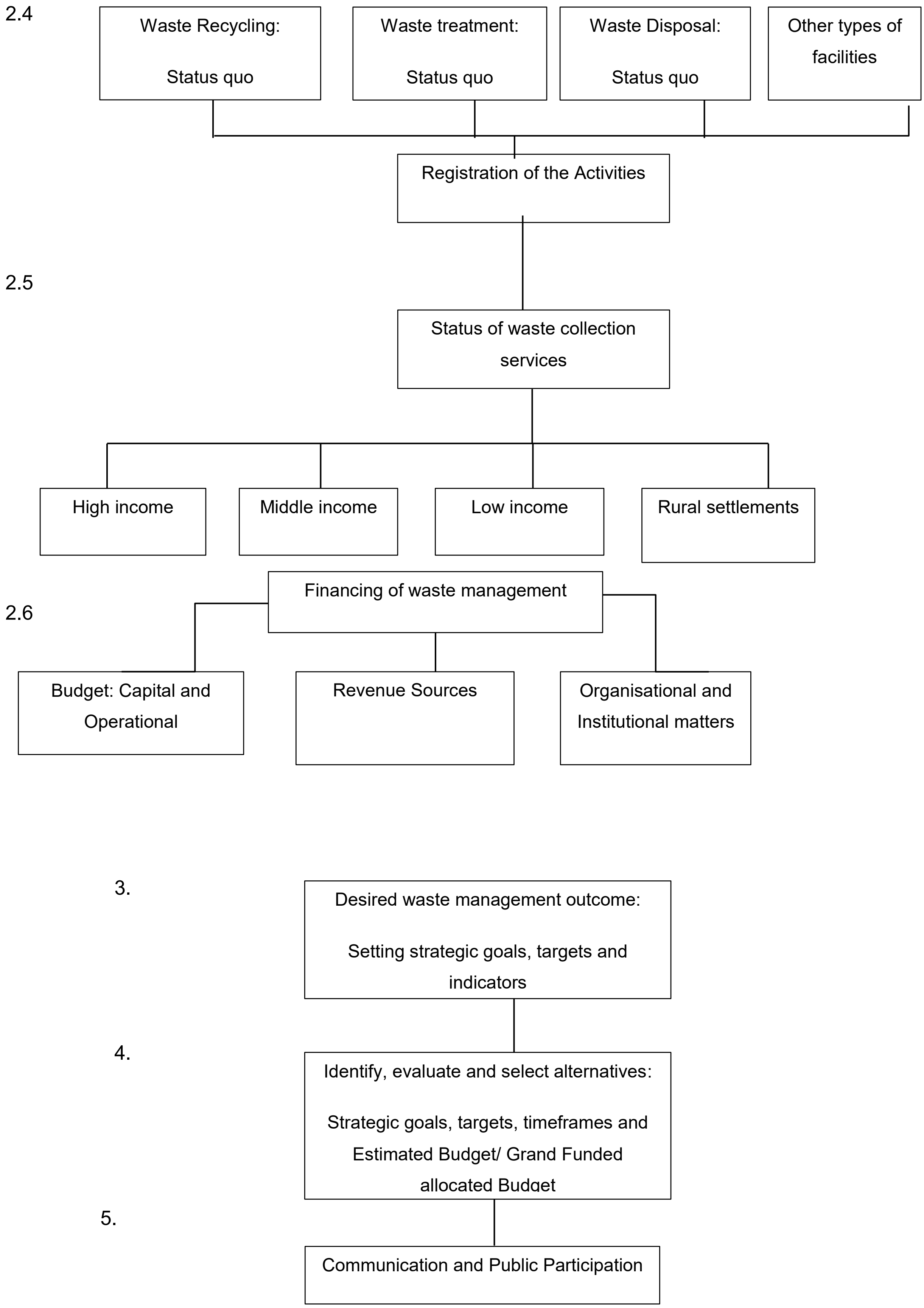


Figure 6- 4 Continued Schematic Layout of the structure of a standardised IWMP

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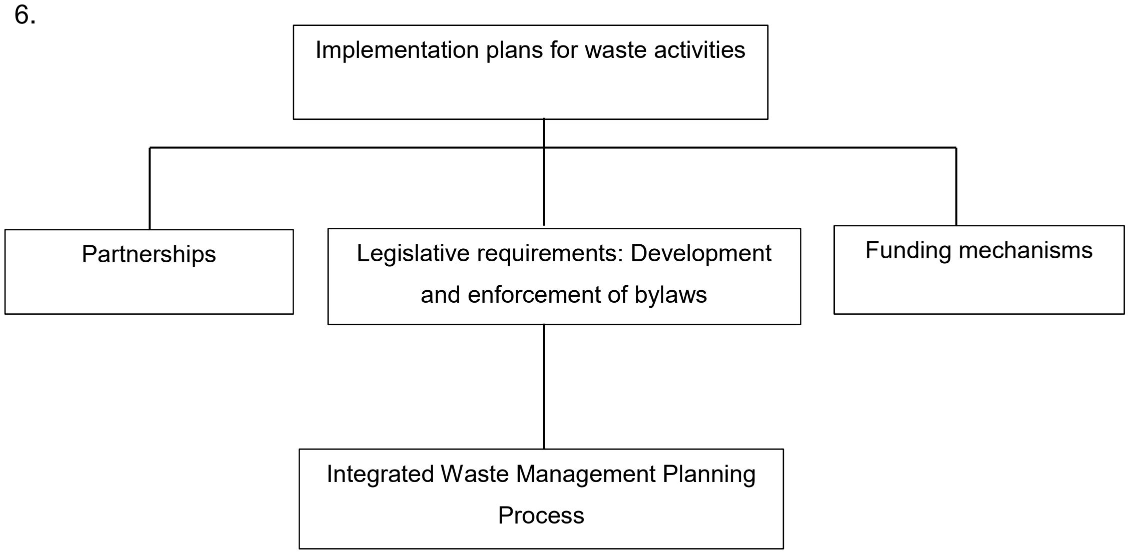

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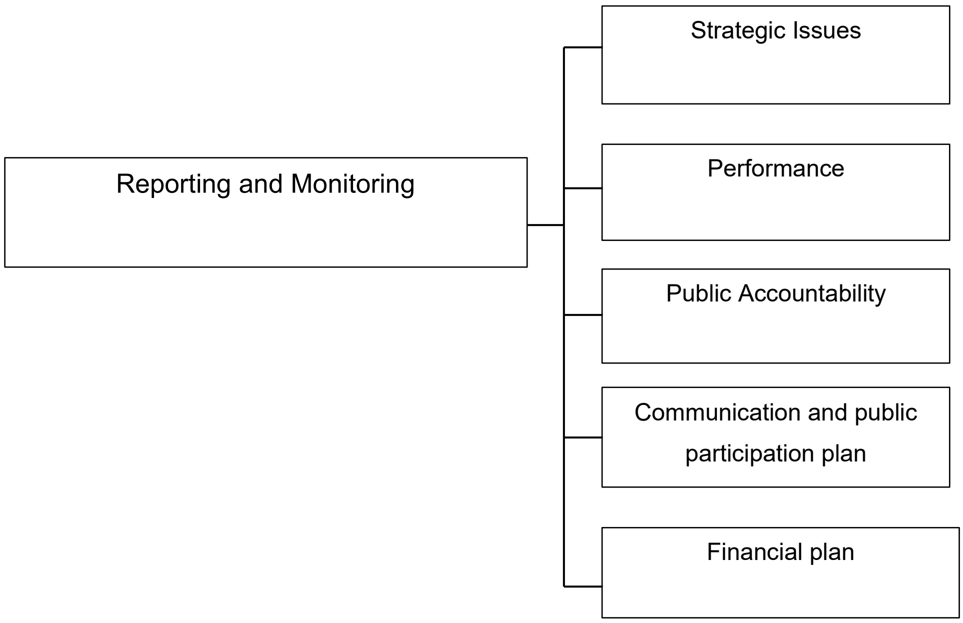

Figure 6- 5 Continued Schematic Layout of the structure of a standardised IWMP

6.5 An assement of the National Waste Management Strategy

Based on the strategic goals set out in the National Waste Management strategy, Figure 6.3 below assesses municipalities' ability to achieve these goals. The assessments by categories, which are institutional, environmental, social, economic and technical, were weighed on the level of priority from a municipal perspective, with 5 being high on the priority list and 1 low on the priority list.

The level of priority shows that institutional sustainability is ranked highest amongst municipalities, followed by environmental, economic, social and technical sustainability. The matrix illustrates each goal against performance indicators and targets that municipalities should achieve.

	Goals in terms of the NWMS	Proposed Indicators	Target	Institutional Sustainability					Environmental Sustainability					Social Sustainability					Economic Sustainability					Technical Sustainability				
				5	4	3	2	1	5	4	3	2	1	5	4	3	2	1	5	4	3	2	1	5	4	3	2	1
1	Promote waste minimisation, re-use, recycling and recovery	Targets and measure waste minimisation with the municipality	Full achievement of targets set in the IWMP				✦		✦							✦					✦					✦		
		% of recyclables diverted from the landfill site for re-use, recycling and recovery	25% of recyclables diverted from the landfill sites for re-use, recycling or recovery by 2015			✦			✦							✦					✦					✦		
		Separation of waste at source being implemented	Initiated programmes of Separation at source				✦			✦				✦							✦					✦		
2	Ensure the effective and efficient delivery of waste services	% of households receiving basic waste collection services	95% of urban households and 75% of rural households have access to adequate levels of waste collection services	✦						✦				✦							✦				✦			
	Safe Disposal of waste in licenced landfill site	% of licenced waste disposal sites	80% of waste disposal sites have licences	✦					✦								✦			✦					✦			
3	Growing the contribution of the waste sector to the green economy	No. of jobs created in the waste sector	100 new jobs were created in the waste sector			✦					✦				✦													
		No. of additional SME's and co operatives participating in the waste service delivery and recycling	new SME'sa nd co operatives participating in waste service delivery and recycling			✦					✦						✦			✦						✦		
4	Ensure that people are aware of the impact of waste on their health, well being and the environment	No of municipal campaigns raising awareness of waste mangement issues	80% of schools implementing waste management programmes with the municipality				✦				✦					✦							✦					✦
5	Achieve integrated waste management planning	Is the muncipalities integrated their IWMP into their IDPs	Municpality have met targets set in their IWMPs	✦						✦						✦					✦						✦	
6	Establish and maintain an information base on waste flow	Waste management facilities with waste quantification systems	All waste management facilities required to report to SAWIS have waste quantification systems that report to WIS	✦						✦						✦					✦						✦	
7	Ensure sound budgeting and financial management for waste services	Municipality that provides a waste service have conducted full-cost accounting for waste services	A full cost-accounting for waste services		✦								✦					✦				✦					✦	
		Implementation of cost reflective tariffs	Waste services implemented cost reflective tariffs			✦							✦					✦			✦							✦
8	Provide measure to remediate contaminated land	The % of sites reported to the contaminated land register which have site assessments performed	Assessment for 80% of sites reported are completed on the land register				✦				✦						✦					✦						✦
9	Effective compliance with enforcement of the Waste Act	% of successful enforcement actions	50% increase of successful enforcement actions against non-compliant facilities			✦					✦						✦					✦						✦
		No. of EMI dealing with the Waste Act	EMI's appointed in the sphere of govt to enforce the waste act		✦					✦								✦					✦					✦

Figure 6- 6 Matrix assessment of the NWMS against waste service delivery objectives

6.6 Assessment of Waste Treatment Technologies

Based on feasibility studies conducted by municipalities that have the resources to do so, the following technologies are assessed: sanitary landfilling, MRFs, Composting, Anaerobic Digestion, Incineration and Gasification. The six alternatives are:

Alternative 1: Sanitary Landfilling

Alternative 2: Material Recovery Facility (MRF) at the Landfill site or Disposal Facility

Alternative 3: A MRF and a Composting Treatment Plant based on the waste data

Alternative 4: A Material Recovery facility for the inorganic fraction and an Anaerobic Digestion for the organic fraction of municipal solid waste.

Alternative 5: A MRF and MBT and Refuse Derived Fuels

Alternative 6: Incineration and WTE

Most municipalities in developing countries' primary practice are Alternative 1, sanitary landfilling. The MRF and biological treatment would reduce the amount of waste going into landfill and thereby increasing the lifespan of the site. The sorted recyclable waste is often sold as well as the compost products or the compost fertilizer which can be used for cost recovery purposes. Incineration would produce ash which can be used for road construction. From the case studies presented in this research study, the possible alternatives to landfilling are presented in the table below.

Alternative 1 is the most understood and practiced technologies amongst most municipalities. However, with the changing legislation, Section 16 of NEMWA 59 of 2008 now states that holders of waste have a duty of care to reduce, re-use and recycle in terms of the new definition of waste. Another reason is that alternative 6 requires skilled personnel.

Alternative 2 (landfills) would be the most advantageous technology as it will not only create more job opportunities, but also increase the lifespan of the site. It allows for more inorganics to be diverted from landfill. It is aligned with the national waste management strategy which highlights the need to recycle. However, the costs of an MRF often pose challenges to municipalities, with priority given to other projects such as water and sanitation in line with the IDP. The cost of MRFs varies in terms of the waste stream; hence the importance of an analysis of the waste stream that would detail the design of a specific municipality. The literature review detailed how MRFs operate and the essentials of each unit operation within the MRF.

Alternative 4, an MRF and Anaerobic Digestion, are technologies that are considered the most effective in reducing GHG emissions. Anaerobic Digestion is not fully understood amongst most municipal practitioners. Funders are also skeptical about piloting these projects in municipalities with a small volume waste stream. Basically, metropolitan municipalities are considered for projects of this magnitude. No municipality in South Africa receives smaller volumes that are equipped with these technologies.

Alternative 6, incineration, offers the best technology in terms of waste to energy options in respect of reducing methane gas emissions - it also provides an alternative energy source. The difficulty with this alternative is that waste practitioners are not familiar with this technology. Procurement to acquire it is a long and tedious process.

The Table 6- 1 below assesses the alternatives listed above and current practice in the case studies presented in earlier chapters.

				Potential of Waste Technology				
Waste Technology	**Deonar: Mumbai**	**Current Practice**		**5**	**4**	**3**	**2**	**1**
		YES	**NO**					
Alternative 1	Landfilling	X						
Alternative 2	MRF at the Landfill		X	X				
Alternative 3	An MRF and Composting Treatment		X				X	
Alternative 4	An MRF and AD of the Organic Waste		X	X				
Alternative 5	MRF, MBT and RDF		X		X			
Alternative 6	Incineration and WTE		X	X				

				Potential of Waste technology				
Waste Technology	**Newcastle: South Africa**	**Current Practice**		**5**	**4**	**3**	**2**	**1**
		YES	**NO**					
Alternative 1	Landfilling	X						
Alternative 2	MRF at the Landfill		X	X				
Alternative 3	An MRF or Composting Treatment	X		X				
Alternative 4	An MRF and AD of the Organic Waste		X	X				
Alternative 5	MRF, MBT and RDF		X				X	
Alternative 6	Incineration and WTE		X	X				

The assessment outlines the various scenarios for waste management based on the case studies of Deonar in Mumbai and Newcastle South Africa as well as the literature review and key informant interviews. The MRFs, Anaerobic Digestion, Composting and Landfill Gas to Energy are the potential waste technologies that are mainly under consideration.

Table 6- 2 The four alternatives are unpacked in four scenarios:

Scenario	Scenario Titles	Brief Description
1	MRFs and Composting	Waste recyclables are sorted, where most inorganic waste is removed from a clean or dirty MRF and the organic matter is composted e.g., garden waste, wood waste. It is impossible to obtain good recyclable material without separated collection at source will never produce an agronomic compost because too many impurities; the same for paper, it will never be of good quality to be recycled as secondary raw material to produce new paper.
2	MRF and Anaerobic Digestion	Waste is sorted in organic and inorganic fractions. The inorganic fraction is diverted from landfill for recycling and the organic matter is anaerobically digested.
3	Landfilling and LFGTE	All waste is sent to a landfill. Methane gas is extracted and converted as an energy source from the organic fraction of the MSW.
4	MRF and Gasification/Pyrolysis	Waste such as metal and glass are removed from the waste stream, all other waste is placed into a waste bin, syngas is extracted and converted into electricity.

Scenario 1: MRF and Composting

Waste is either collected from households, through daily door to door collection which was the case in Mumbai. In South Africa, waste is collected once a week from the curbside of households and taken to a transfer station or a landfill. Depending on the distance, waste is transported to a MRF at a Waste Transfer Station or to a landfill site. Recyclable material, such as plastic, paper and cardboard, glass and metals is diverted from the waste stream and sold to potential reclaimers for recycling or to make new products. The organic waste fraction is diverted for composting on the landfill site. There is mixed waste in the compost due to inefficiency in sorting and removing all inorganic waste from the waste stream.

Scenario 1:

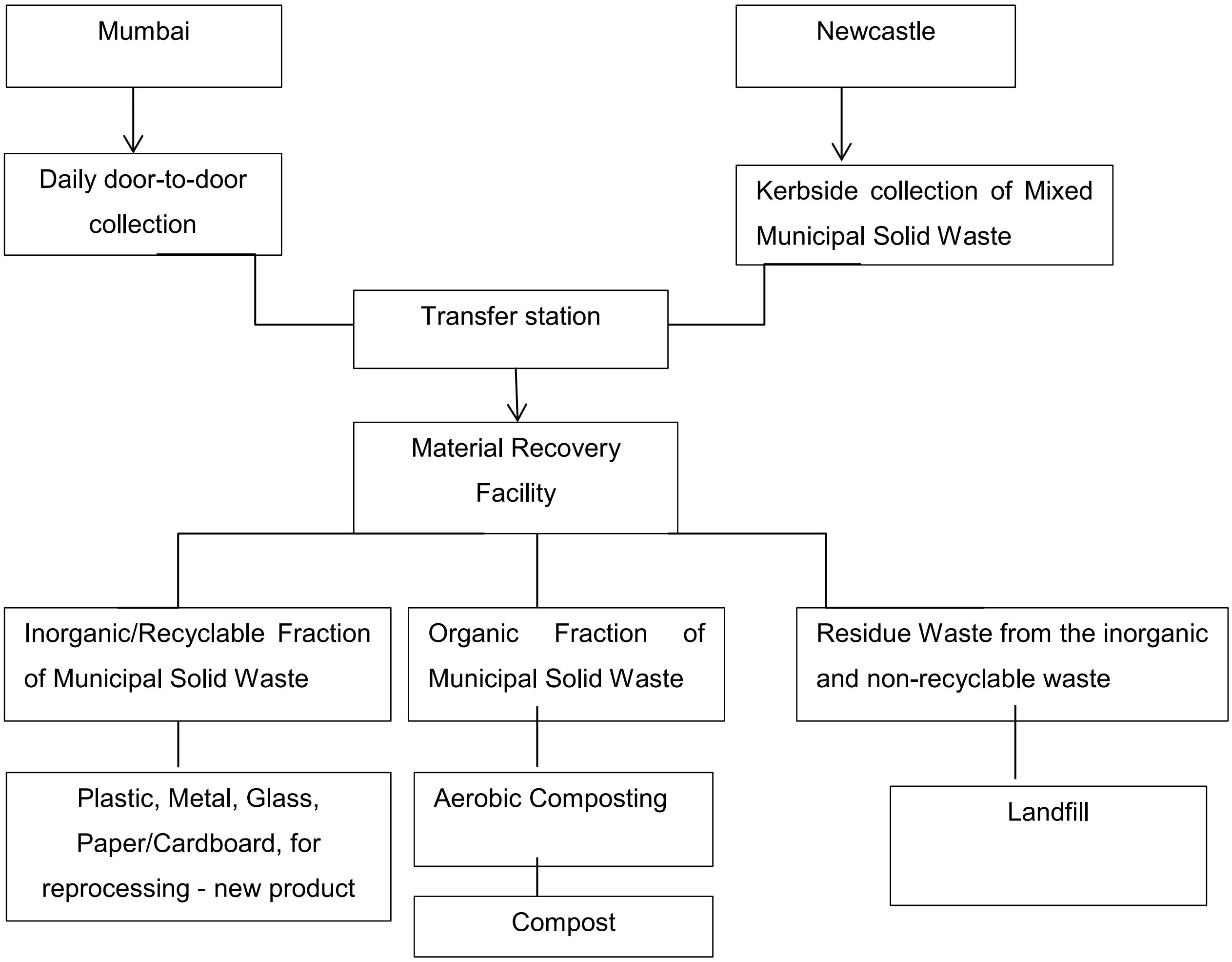

Figure 6- 7 Schematic layout of Scenario 1

Scenario 2: Material Recovery Facility and Anaerobic Digestion

Waste is collected either from the curbside of households or through daily to-to door collection and transported to a transfer station then, to a MRF. The MRF will recover the recyclable inorganic fraction. The organic fraction is sent to the Anaerobic Digestion Plant site to generate methane gas for electricity production. The digestate will be utilized for fertilizer from the nutrient recovery.

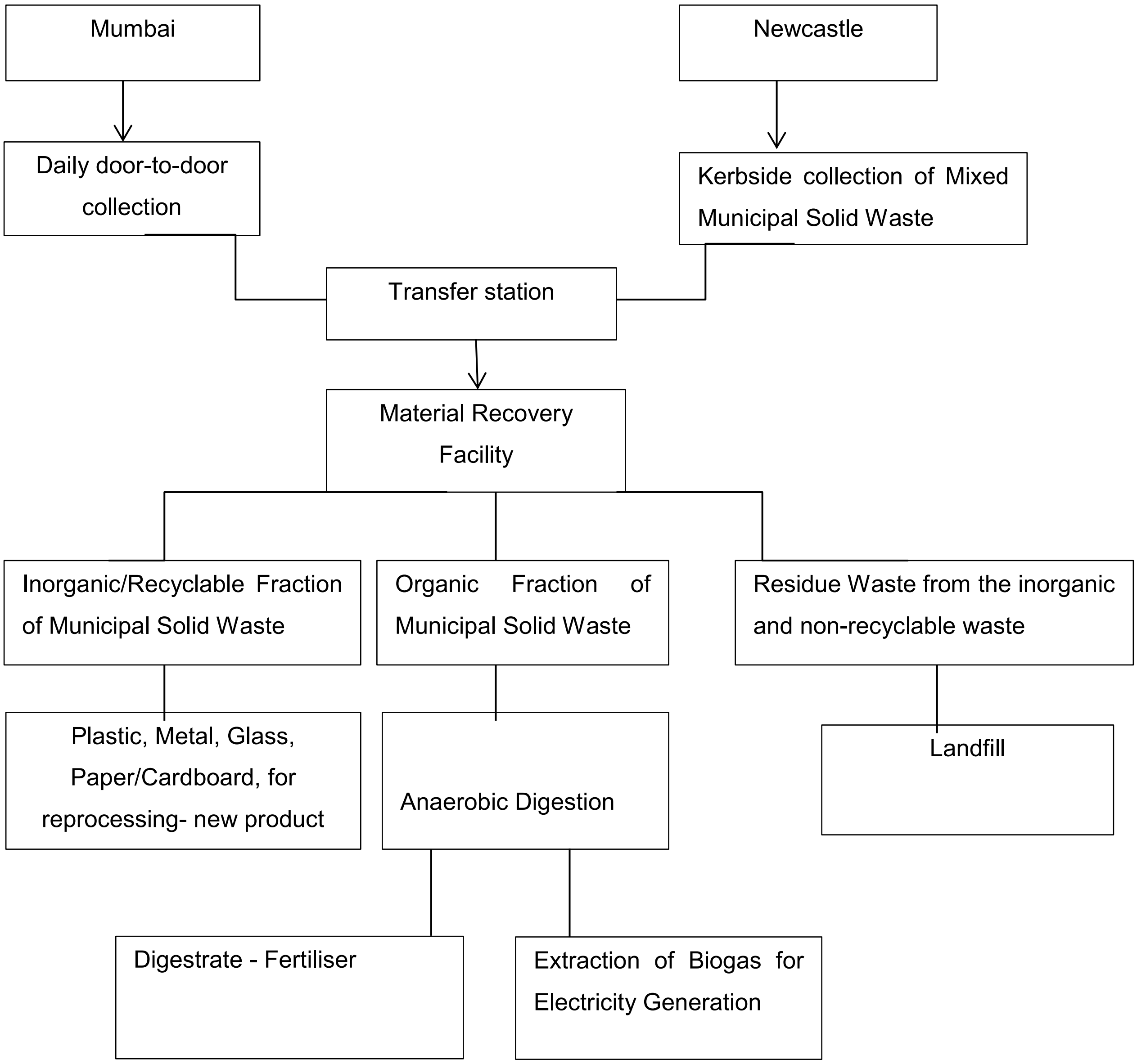

Figure 6- 8 Schematic layout of Scenario 2

Scenario 3

Scenario 3 outlines waste management technologies that are implemented at Gorai Landfill site in Mumbai, India and at Marainnhill and Bisasar landfills in South Africa. Waste is collected and taken either to a transfer station or directly to a landfill site. The inorganic fraction of waste is not recovered. Waste in Gorai, Marainhill and Bisasar are landfilled. There is extraction of LFG to electricity.

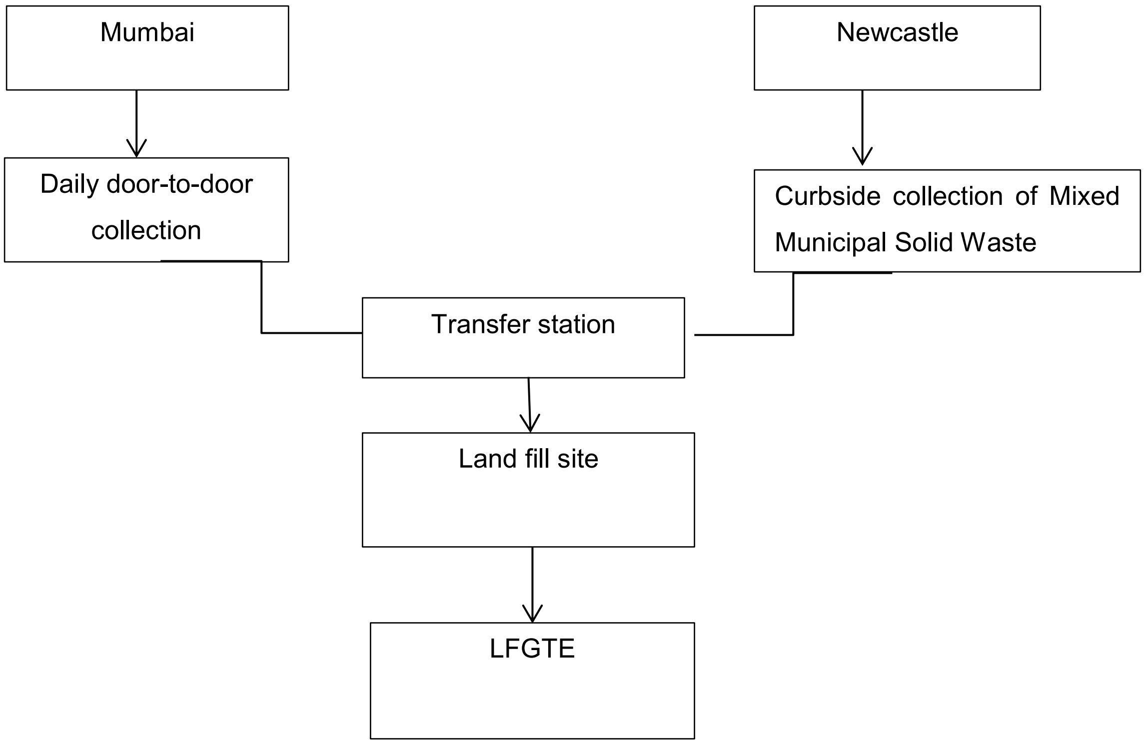

Figure 6- 9 Schematic layout of Scenario 3

Scenario 4

In Scenario 4, waste is collected either from weekly curbside collection from households or daily door-to-door collection and transported to a waste transfer station and an MRF which is nearby or on a landfill site. Recyclable material such as plastic, glass, metal and paper is recovered. The rest of the waste which is organic, inert and some inorganic waste that cannot be recycled are fed into a gasification unit under anaerobic conditions. Energy is then recovered. Gasification is considered an expensive treatment process. It has environmental benefits and it an option for municipalities. It can be modified to handle waste streams according to the size and classification of the municipality. These technologies are usually funded to developing countries by funders from the developed countries. Some setbacks are tipping fees (often dollars and pounds) for receiving of waste as municipalities would usually landfill far exceeds the costs of collection and disposal of waste. The currencies of developing countries are usually weak and would not be able to sustain the tipping fees.

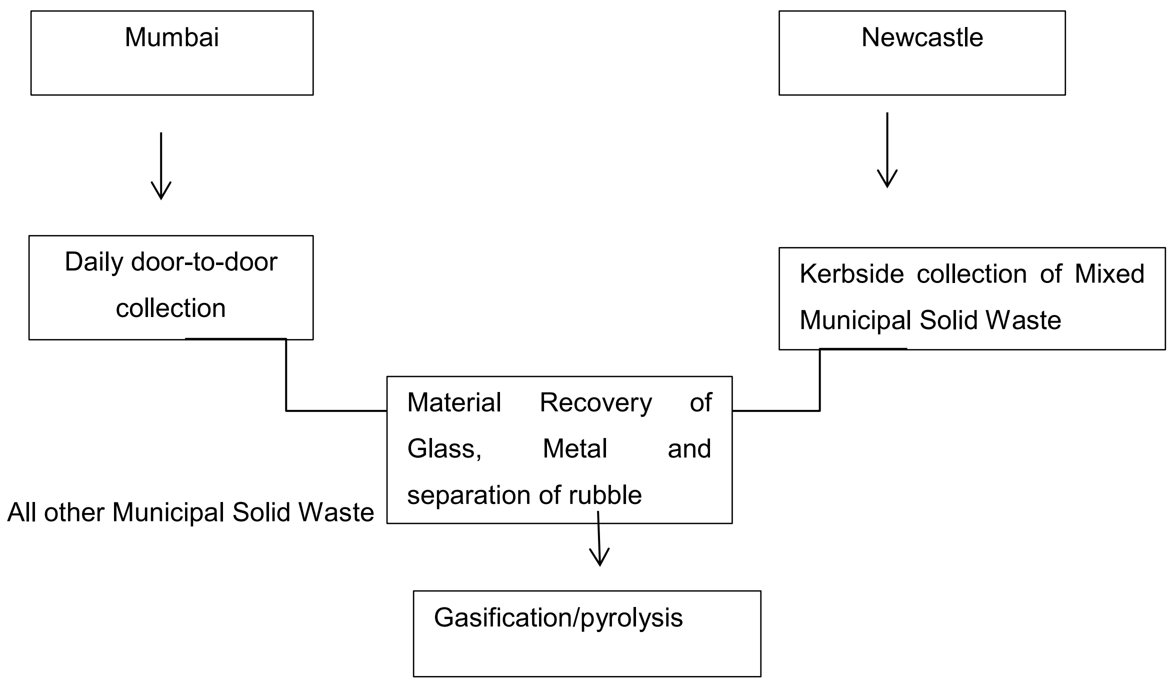

Figure 6- 10 Schematic layout of Scenario 4

The scenario analysis clearly depicts the waste technologies and the current status quo of Mumbai, India and in South Africa. Scenarios 1 and 2 are referred to mechanical biological treatment, with a material recovery facility with mechanical sorting. They also provide for biological treatment such as composting and anaerobic digestion. Scenarios 3 and 4 offer energy recovery opportunities. Scenarios 1-3 waste is still being landfilled, however with Scenario 4, there is no need for landfilling. Construction and demolition material can be pulverized and reused as subbase material for construction. The following section unpacks the process or roadmap for energy recovery projects.

6.6 Criteria for Energy Recovery Projects and Potential risks

6.6.1 Road Map to determine the Technical Feasibility of Emission Reduction Benefits

Waste composition is the most important factor in determining energy generation potential that can be derived from municipal solid waste. A successful LFGTE project requires a feasibility study. Above all, it should be included in the IWMP which is an institutional requirement for project monitoring and performance. LFG generation assessments are based on a variety of LFG modelling techniques and pumping field testing programs. LFG modelling is reliant on the model input including data such as annual waste-in-place quantities, the maximum rate of deposition, moisture and climate. All LFG utilisation facilities require an effectively designed and operated LFG collection system that provides a reliable fuel supply, however not all municipalities have a reliable fuel supply.

Landfill management projects are typically expected to operate between 20 and 30 years to enable the financial viability of the project. Each project must be examined individually to determine the particular circumstances of the potential project site. Expanding and developing a well field and piping to collect the gas is an on-going responsibility that should be clearly defined in order to protect and secure the revenue streams.

The accelerated development of LFGTE projects over the past decade has increased investor confidence in LFGTE projects in South Africa. However, energy recovery from LFG is still not considered economically viable in developing countries. The engineering knowledge with non-economic incentives driving some project developments is also risky.

These risks are the generation rate of waste and the potential of landfill gas that will be accessible, the technology that will be utilised to collect the landfill gas and potential sources of revenue.

6.6.2 Road Map of WTE project in municipalities

LFGTE technology is believed to have real potential for energy generation, market, legislative and investment conditions are conducive to site specific development. However, regulations and policies regarding LFG utilization are still being developed in South Africa, and although these have the potential to be shaped in favour of developing such projects, and the future development of the international carbon market, there is also an opportunity to improve the return on investment in LFGTE projects in order to make them more attractive. Figure 6-4 illustrates a step by step standardised framework that will assist municipalities in dealing with project activities that involve WTE options.

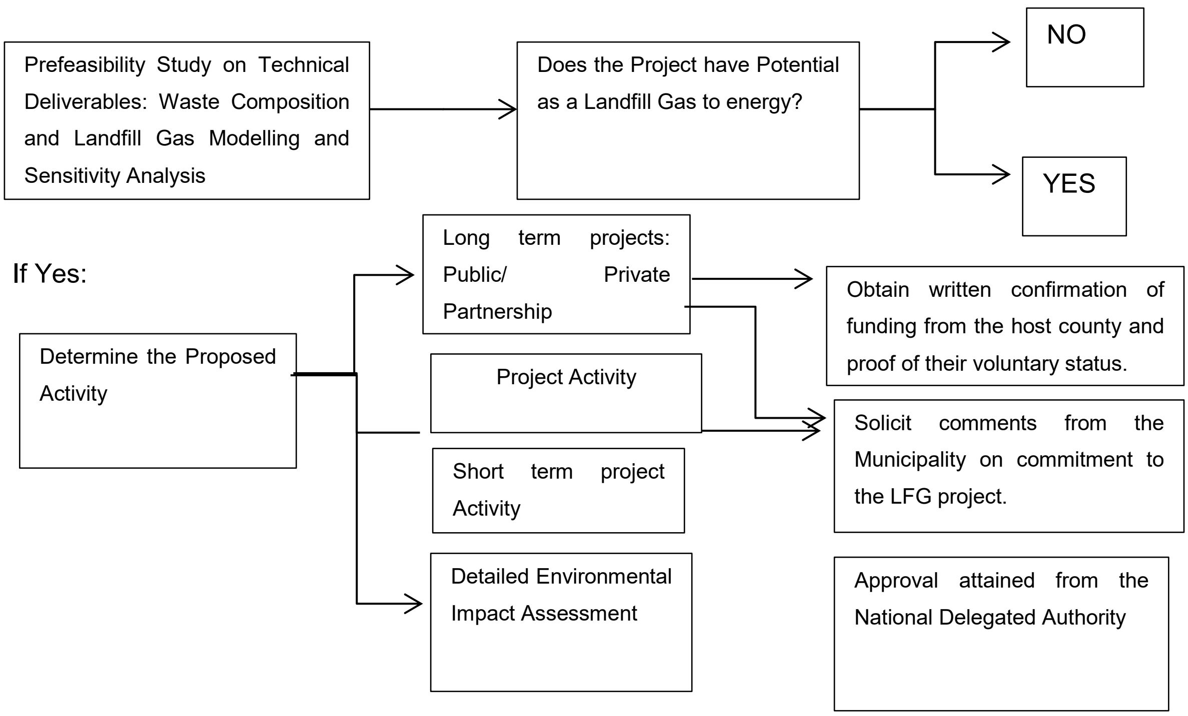

Figure 6- 11 Schematic diagram illustrating Pre-feasibility study to outline technical deliverables

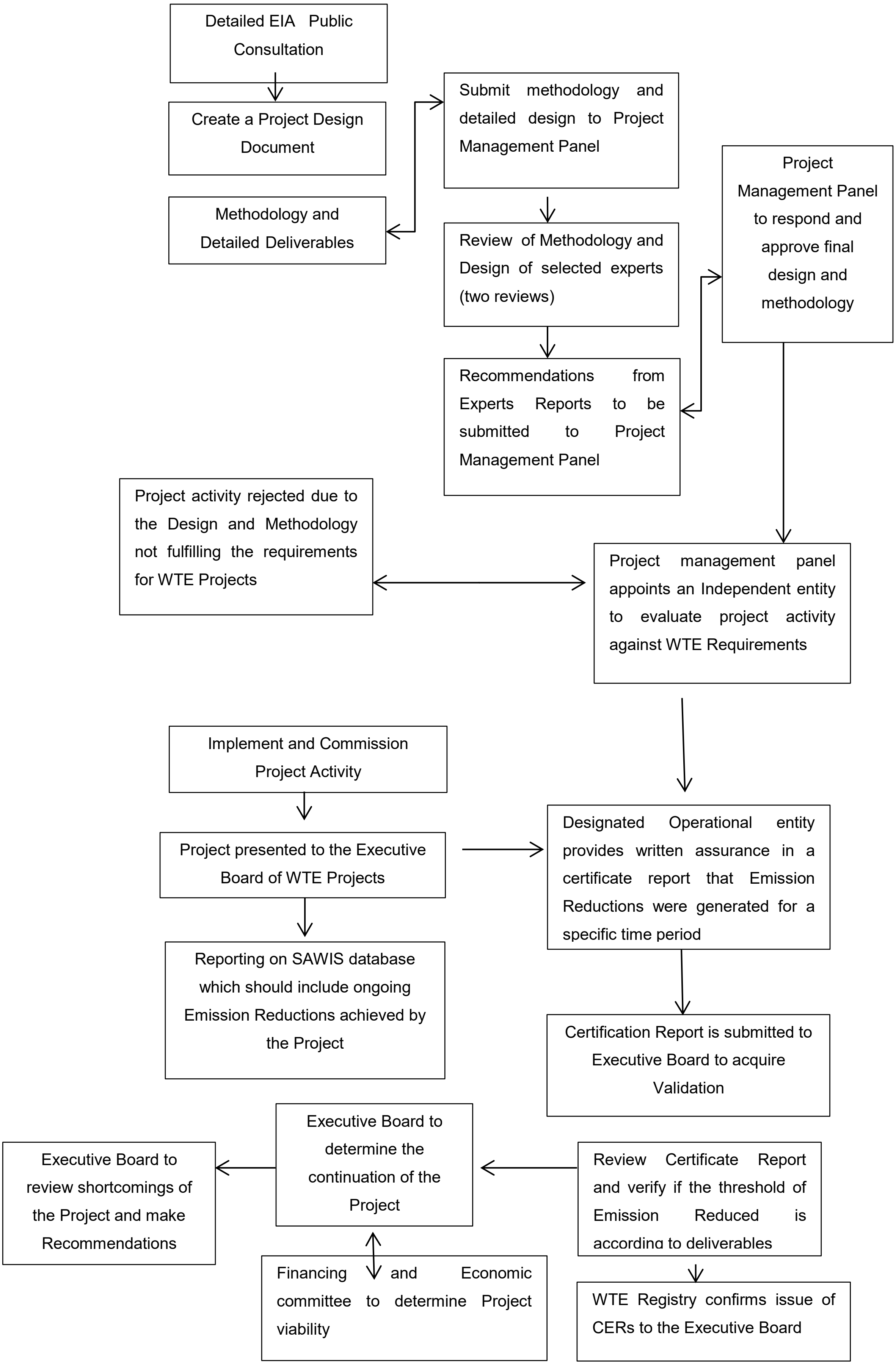

Figure 6- 12 Schematic diagram illustrating the EIA and Methodology for WTE Project Activities

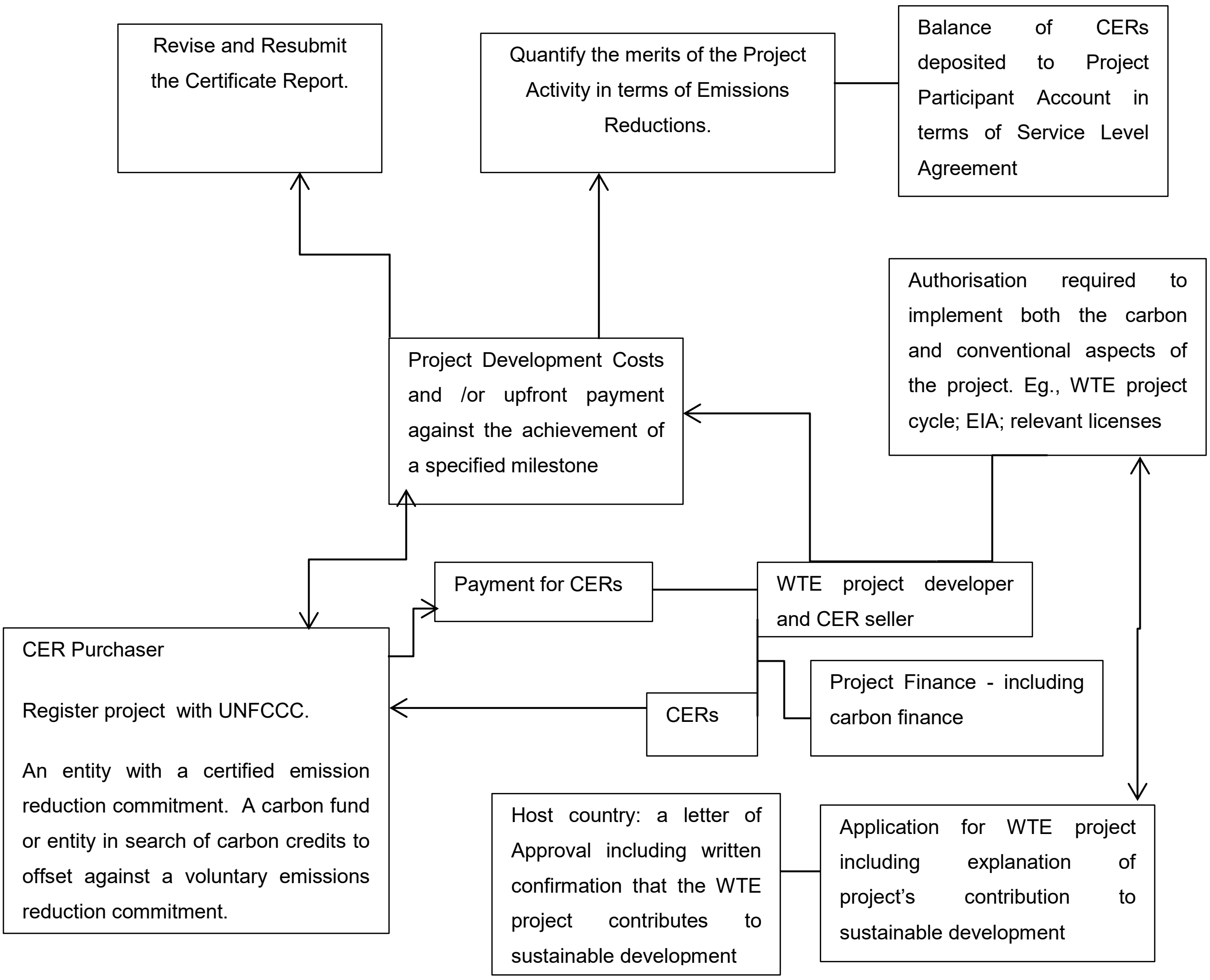

Figure 6- 13 Schematic layout of WTE project certification , costs and energy recovery pathway for Municipalities (Source: World Bank Handbook (2004)

6.7 Checklist for applicable energy policies, legislation and regulation and market for the Preparation of Landfill Gas to Energy Projects in Municipalities

Risks exist that will seriously impact the achievement of sustainable project management. This depends on landfill gas as a direct and indirect source of revenue. The following questions need to be answered by all spheres of government that deal with WTE projects before implementing any project activity. The answers to these questions become pertinent during project implementation when the project is handled at a higher level.

1. It is essential to identify the level of government and hierarchy of authority over electrical power generation.
2. Is the administration of the regulation under the same level of government authority (some jurisdictions may pass administration of a regulation to a different level of government or government controlled corporation or utility)?

3. Are there any legislative mechanisms that will create demand for alternative electricity generation?
4. Who will be responsible for building and maintaining the transmission lines from the landfill to the grid?
5. What is the current distribution market structure?
6. Does the regulation make provision for independent power producers to access the distribution grid and the markets?
7. Are independent power producers allowed in the specific country or region?
8. Who sets the price of power?
9. How does the price of power change over time?
10. Are there time limits on contracts that may compromise the pricing if there are project delays?
11. Is the use of transmission lines to carry the generated electricity permitted?
12. If yes, who regulates this?
13. Who sets the price of access to and wheeling through the transmission distribution grid?
14. Are any tariffs associated with private generation and access for sale of electricity?
15. Who is responsible for the design of the interconnect system?
16. In terms of permits and approvals: Who issues them? What timelines and costs are associated with this issue?
17. Emission reductions: Are carbon offsets regulated and therefore not able to be sold? Are there any policy statements regarding the existence of carbon offsets?
18. Do the guidelines place any restrictions on the ownership, transfer or validation of emission reductions?
19. Is the concept of renewable energy embodied in any energy policies and regulations?
20. Will documentation of energy as “green” allow increased pricing?
21. Does legislation automatically assign renewable energy credits to the generators or the utilities or direct consumers?
22. Do any standard power sales contracts exist that are applicable to the potential project?
23. Is there any specific testing embodied in any energy policies or regulations? This can be a relatively expensive line item and affects the financing phase of any project development.

6.7.1 Risks in Landfill Gas to Energy Projects

The tool and factors for LFG generation depend on the quantities and generation rate of the landfill gas. A major risk factor is the real quantity of waste available. There is uncertainty about the amount of waste already at the site or with regard to the future quantities of waste that the site could receive. The other risk in terms of quantities of waste is uncertainty about the percentage of the waste that is organic, both currently and in future waste streams as this will determine future LFG as a resource. Some of the risks can be eliminated by using pumping test data together with LFG modelling to validate current LFG quality and quantities and help improve the factors to input the model. Pumping test data should be analysed with the physical characteristics and site specifics.

6.7.2 Technological risks in Landfill Gas to Energy

The equipment utilized to collect and manage LFG is a source of risk based on the operations. Technologies to collect LFG are generally well-developed and reliable. However, equipment poses a risk in a site-specific condition that may eliminate the application of the proven technologies. All LFG cannot be collected from the waste generated. A well-designed and operated LFG collection system can collect up to 70% or more of the total quantity of LFG generated. The risks associated with LFG rates relate to operation and maintenance of LFG collection systems. Poor operation and maintenance usually hinders in the performance of the LFG collection system and reduces LFG quantity and quality. Operation and maintenance programs are risky as we have learnt from the literature review of the case studies, however we need to be proactive and are able to adapt and change with time. The common problem is over-pumping from LFG extraction wells can have serious safety implications and can negatively affect energy supply by diluting and reducing the available LFG quantity, thereby reducing its heating value. The reason for this is that there is immense pressure to meet target set which are unrealistic. Ideally the collected landfill gas is approximately 50% by volume of methane. This also varies based on the heterogeneity of the waste stream. The other common problem is that LFG is wet and potentially corrosive gas that may require some degree of pre-treatment prior to utilization. This is a financial issue which impacts on the lifecycle costing of the project which is often ignored and is not a technology risk as the technologies are well-developed and proven.

Contracts for LFG projects stipulate a desired output of landfill gas or gas collection rates and there is normally a penalty for non-compliance. This places undue pressure on the landfill owner and undue financial risk. Risks are often mitigated by providing an environmental assurance e.g., ISO 14000 at the landfill.

The risk relating to financial viability/ opportunity with regard to return on investment is a long term asset which is well in excess of 20 years.

6.7.3 Regulatory and Approval Risks

Most landfill gas management projects are delayed as a result of the regulations not being informedwith regard to the collection of landfill gas. The development of landfill gas projects is achieved voluntarily thereby attaining emission reduction credits.

The challenge lies with the acquisition of permits and approval for active waste disposal sites which remain critical for project viability. A section 78 of the Municipal System Act 32 of 2000 is legislation which details a process within a municipality is essential to determine the project viability especially with landfill gas management projects. The requirements and objectives of each project is specifica to its own dynamics and should be included as an integrated approach. The timeline for waste projects poses a risk. It is well known that LFG management is time-sensitive; a decline in LFG generation rates is normally followed by closure and rehabilitation of the site, particularly with the decline of degradation rate with the organic component of waste.

6.7.4 Market/Revenue Risk Factors

The source of revenue is with no uncertainity is what determines the viability and continuity of any landfill gas to energy project. The project effectiveness will largely depend on the market proce of the competing energy sources. Countries with higher energy cost which have landfill gas to energy projects will be more financially viable where the landfill gas to energy remains an open market.

At the onset the issues around ownership of CER's from LFG should be clarified as the resource and revenue will largely depend on the nature of waste disposal especially in South Africa. The potential risk factors should be identified, quantified and managed by undertaking a sensitivity analysis. This impact in the various revenue options it may have on the project. The sensitivity analysis provides for the simplest and most effective market risk for the sale of energy, it also makes provides for negotiation and execution of long term contracts for the sale of energy.

Ideally, the regulatory framework in South Africa should implement policies and regulations that help to ensure that the energy values of "green energy" projects are protected in some manner.

6.7.5 Pre-Investment Phase

The landfill gas resource should be assessed and the sensitivity analysis should be undertaken to determine the present and future quantities of gas generation from a specific site and conditions. Any uncertainties or risks may affect the quantity of gas recovered as well as identifying the risks which should include:

- The market in terms of energy products and sales. The benefits of emission reduction should be quantified with a clear understanding of ownership and control of potential CERs.
- The project team that is steering this project should have an in-depth understanding of their responsibility and accountability.
- The capital and operational budget should be determined from the conceptual design with satisfactory cost estimates to support negotiations for financing and the revenue streams.
- The knowledge and understanding of LFG management project will integrate the overall waste management system which highlights LFG as a resource as well as identifying the various regulations, approvals or policies that may affect the specific site for the project.

The assessment should include:

- Technical issues at a national, provincial and local municipal level;
- Economic conditions; and
- Financial, social, political and regulatory considerations.

The assessment provides an analysis for the best option for the sale of electricity to the host municipality which allows for the power generation for sale. Direct LFG to supply the near-by industries to supply the compressed methane to insustry pipeline for their domestic use; and purify landfill gas to used.

6.7.6 Technical Pre-Feasibility

To assess the viability of any project it is important to firstly understand the specific nature and characteristics of the energy resource which will determin the basis for the project. The organic fraction of waste into the landfill is the by-product for LFG project in the waste management system. The project activity should have with the waste management system that generates the resource. This also means that some pre-knowledge and understanding of the overall waste management system is a prerequisite for developing a successful LFG management facility at a specific site and managing the economic risks associated with the project. The landfill gas resource should be seen in its ability to supply to other parties. It should not be viewed as a utility service such as a natural gas fuel supply. It is also important to understand the associated risk as resource.

6.8 Market Access and Pricing of LFG as a CER

To access any market it will be required that the landfill collection cost as a fuel should be estimated. A preliminary economic analysis should be undertaken with a thorough understanding of the market-specific conditions especially with regard to the country that the site is located. In order the determine project viability it is essential that the technologies and energymarket/revenue should be assessed at a pre-investment review. It is also essential that all the legal and technical requirements are identified to a candidate site. Consideration should be taken that some technologies may not be supported due to market conditions. Policies, procedures and regulations should be considered with regard to direct sales related to energy products or LFG. Most LFGTE project costs are exhorbitant due to cost of extensive infrastructure to transport and deliver energy, except in cases where the distance is short and in most cases located at the landfill site. Most potential projects are dependent on the existing infrastructure. The socio-political environment and geographical area also plays a pivotal role where the candidate site is located. There will be specific rules and boundaries with regard to the sale. The revenue would take the form of the expected value of any CERs (Rands per tonne of eCO_2) generated by a candidate project and the fuel product revenue net of all connection charges, tariffs or other related charges.

6.9 Project Economics

Market data and costs records should be inputted into a spreadsheet model with all landfill gas projects. This will determine whether the project is viable and to identify any limitiations within which the project could be developed. An area of concern is that cost issues vary between developed and developing countries which will impact significantly on the revenue of sales of the LFG as a by-product. The dynamics of understading of site and geographic- specific issues with respect to designing and constructing, as well as operating and maintaining it during the service life. Skilled staff is required to operate and maintain any LFG collection system efficiently.

6.10 Role players in the Project Structure

LFG management projects may have a typical risk or expertise requirements that may not be available in all areas of South Africa. In the case of infrastructure and related projects, various contracting parties and strategies can be developed and applied to LFG management.

6.10.1 Project Development Plan

A sound understanding is required for financial goals and objectives, together with at least an appreciation of all of the technical elements of a successful project. It is important to identify a team that includes people with practical experience of the various aspects of WTE implementation.

6.10.2 LFG Resource Expertise

Economic projections and market access arrangements will rely heavily on the ability to assess and quantify the LFG that is available; obtain the LFG fuel that is available; and continuously provide the LFG fuel over the term of any agreement that is negotiated. The entire project team must have confidence in these projections and be willing to base project success on the expertise of this team member.

6.10.3 Financial and Market Access Expertise

The ability to assess and manage the financial aspects of the project and to understand the risk aspects of this type of project are critical in decision making with respect to approval to proceed with a project based on the market value negotiated for the energy products and CERs. The ability to secure long term contracts for the sale of energy is fundamental to the success and risk management of a project. LFG management calculates cost per tonnes equivalent carbon dioxide reductions. The global objective of GHG emissions reduction benefit is most simply achieved through encouraging and supporting the development of LFG management projects that can be managed viably now and in the future. There are many development approaches that could be successful.

6.11 Performance Measurement of Sustainable Waste to Energy Projects

Figure 6-5 highlights the steps that should be followed to ensure a sustainable waste to energy project. It includes proposed indicators and targets that municipalities should include in measuring a project's performance.

Figure 6-5 was not only measured in terms of proposed indicators and targets but was also measured against institutional, environmental, social , economic and technical levels of priority in respect of project sustainability at the local sphere of government. Each step was measured on a rating of 5, with 5 being a high level priority and 1 a low level of priority. Generally, waste-to-energy projects at municipal level have taken the back seat in terms of IDP priorities, although there legislation and national strategies provides guidance to local municipalities. If grant funding is not received for these projects, it is impossible for municipalities to fund them with internal funding and no municipality will opt to take loans due to the financial and economic risks discussed earlier.

Steps	Proposed Indicators	Target	Institutional Sustainability					Environmental Sustainability					Social Sustainability					Economic Sustainbility					Technical Sustainbility				
			5	4	3	2	1	5	4	3	2	1	5	4	3	2	1	5	4	3	2	1	5	4	3	2	1
Prefeasibility Study on Technical Deliverables	Waste Composition	Detailed waste stream analysis	✦							✦					✦					✦					✦		
	Landfill gas Modelling and Sensitivity Analysis	Landfill Gas assessment				✦			✦						✦					✦				✦			
Determine the Proposed Activity	Long term projects/ PPP	Obtain written confirmation of funding proof from the host country	✦								✦		✦							✦				✦			
	Short term projects	Solicit comments from the Municipality on the Proposed activity	✦					✦							✦					✦					✦		
Establishment of Project Management Panel	A team comprising of expertise as municipality's do not have skilled expertise	Experienced individuals selected with WTE background	✦						✦						✦				✦				✦				
Detailed Environmental Impact Assessment	An approved EIA with all the relevant studies conducted	Environmental Authorisation from DEA		✦				✦						✦						✦				✦			
Create a Project Design Document	Methodology and Detailed deisgn to Project Mangement Panel	An approved final design and methodology			✦				✦						✦				✦				✦				
Recommendations from Expert Reports	The appropriate technology that will be determined for the project activity	Appropriate technology and project viability study		✦				✦						✦					✦				✦				
Appointment of an independent entity to evaluate project activity	Criteria to determine the appointment of the independent entity	100% potential of the accepted technology	✦					✦							✦				✦				✦				
Project presented to an Executive Board of WTE projects	An approved appropriate technology for the Project Activity	Select the appropriate Technology for the Project	✦					✦							✦				✦				✦				
Implement and Commission the Project Activity	Project implementation	100% of the Activity is being implemented and monitored	✦					✦							✦				✦				✦				
Reporting on SAWIS on Emission Reduction	Data reporting and analysis on emission reduction	Certification Report on Emission Reduction	✦					✦						✦					✦				✦				
Certification to the Executive Board to acquire Validation	An approved criteria for an assessment of Project Validity		✦					✦						✦					✦				✦				
Executive Board to determine Project Continuity	An assesment report of Project Validity	Finances and Economic report to determine Project viability			✦			✦					✦					✦						✦			
WTE Registry confirms issue of CER's to the Executive Board	To register the project as a WTE and confirm registry of CER's	Certification Report on Emission Reduction	✦					✦							✦			✦					✦				
Executive Board to review shortcomings of the Project and make recommendations	Review project report	Revise the Project based on the recommendations	✦					✦					✦						✦						✦		
Revise and Resubmit the Certification Report	Revised Cerification Report	Implement the recommendations and resubmit the certification report		✦					✦				✦						✦					✦			
Quantify the merits of the Project Activity in terms of Emissions Reductions	Measure the Emission Reduction	20% emission reduction achieved		✦				✦					✦						✦				✦				
Balance of CER's deposited to the Project Participant Account in terms of a Service Level Agreement	Measure the Emission Reduction in terms of the benchmarks	100% of the agreed CER's deposited	✦					✦						✦				✦					✦				

	Level of Priority
5	High Priority
4	
3	
2	
1	Low priority

Figure 6- 14 Matrix assessment of the Project Activity steps on levels of priority and sustainability

6.11 Conclusion

This chapter detailed a legislative pathway for an Integrated Waste Management System for municipalities to adopt as a standardized framework. A scenario analysis was also presented on the most appropriate technologies for the specific case studies for India and South Africa. The chapter also presented a comprehensive framework to monitor and assess the institutional, environmental, social, economic and technical performance of WTE options that will be appropriate for municipalities.

The legislative framework considered the realities in South Africa in terms of energy sales/ wheeling agreements, and some bottlenecks in the legislation, especially with regard to off take agreements. Public-private partnerships and the practicalities of municipal WTE projects would require further integration. The technical aspects of grid and network complications in respect of ownership should be clearly defined at the onset of project in order to avoid litigation during the project which would compromise its success. Here again, the registration of servitudes, the cost thereof and EIAs and other regulatory and legislative requirements for gas pipelines need to be clearly completed.

Many projects are too expensive and the process takes too long for many municipalities to afford them. Although options are selected by many municipalities, the cost estimates are often not accurate and fluctuate according to market reviews. Market fluctuations have a huge impact on cost estimates. Large, metropolitan municipalities may have the time and resources to follow the methodology prescribed in terms of the legislation; however, the process is tedious. Hence the suggestion of a standardized framework such as the one set out in this chapter for technology assessment for municipalities.

7: CONCLUSIONS AND RECOMMENDATIONS

7.1 Introduction

The primary objective of this research study was to develop an institutional framework to assist municipalities in developing countries to adopt zero waste strategies and technologies that exclusively target specific fractions of the MSW stream of landfill sites in South Africa and India. The study therefore set out to:

- Conduct a comprehensive waste stream analysis for Deonar, a case study from India and a medium size site in Newcastle, South Africa.
- Determine the sources, characteristics and quantities of MSW generated and calculate the GHG savings that could be achieved in local municipalities' integrated waste management strategy.
- Assess various integrated waste management strategies in developed countries that seek to maximize GHG emissions reductions and conduct baseline research and case studies in order to develop an institutional framework for municipalities in developing countries.
- Assess the efficiency and appropriateness of various integrated waste management technologies and identify the different scenarios for municipalities to utilize depending on the waste stream in each case study.
- Critically assess these waste management strategies and provide recommendations based on the results with regard to environmental sustainability.

The results of the statistical analysis were critically reviewed and an institutional model was developed that could assist municipalities to determine the best strategy to maximize the reduction of GHG emissions. Best waste management practices as a mitigating tool in comparison with current/alternative methods were identified.

7.2 Challenges with Implementation

Society is continually searching for improved methods of waste management and ways to reduce the amount of waste that needs to be landfilled.

All new technologies come with challenges that only become clear after implementation. The key areas to be considered are costs, public perceptions and participation, the institutional framework, potential markets and the stability of the product yielded by landfill gas recovery, materials, and aerobic composting.

South Africans and Indians have not yet fully accepted an integrated waste management system that reduces the amount of waste at source, recycling, reusing, or composting as much of the waste as is economically reasonable, burning the waste that cannot be recycled to generate heat in WTE facilities that reduces the need for fossil fuels, and finally, landfilling the remaining waste in an environmentally acceptable manner.

In order to achieve a recycling and composting rate to meet this goal, new recycling technologies are required.

Solid waste management is not an easy process because it involves many disciplines. These include technologies associated with the control of generation, storage, collection, transfer and transportation, and disposal of solid waste. All these technologies have to be carried out within existing legal and social guidelines that protect the environment and are aesthetically and economically acceptable.

Changes in solid waste management have had a significant effect on public works operations and will continue to do so in the future.

Communities that wish to include recycling in their MSW management strategies have several options for separating recyclables from other waste. They can offer convenient sites where residents can receive payment for containers (buy-back centres), or provide drop off centres that accept a wide range of recyclable materials separated by residents.

7.3 Financial options and challenges

Waste management technologies become more complex as we move away from the traditional method of simply collecting the waste and disposing of it in the municipal landfill. The increased complexity of waste management technology results in increased complexity in the requirements for financing new programs. Not only is there a need for greater capital expenditure using borrowed funds, there is also a need to finance multiple facilities. The need for multiple facilities in such an integrated system often leads to system financing rather than individual facility financing. The best financing option is obviously not the same for all communities.

The increased complexity of integrated solid waste management has also resulted in a move towards the privatization of services. Municipalities do not wish to become involved as they lack experience and often contract with private firms that specialize in such services.

7.4 Institutional Framework

The challenge of MSW management is far from new. Today, local governments remain the institutions that are responsible for ensuring that the waste generated by households, business and industries is collected and properly managed.

Local government is well suited for this role to determine the types and amount of solid waste generated vary considerably from community to community. Local government is thus in the best position to determine the most appropriate technologies applicable in managing this waste. Daily waste management decisions depend heavily on other local factors such as available airspace, public attitudes and behaviour, the applicable legislation and financial constraints.

As waste management has become more complex in many countries, the roles and responsibilities of local solid waste officials have changed to keep pace. This has prompted many countries to look at more innovative ways to manage MSW. Some countries are taking steps to prevent the generation of waste.

7.5 Recommendations

The modelling of GHG emissions from waste management can be greatly improved by the development of emission factors and an appropriate model for developing countries like South Africa and India can be utilized to determine their calorific value.

There is a need for detailed research on LFG extraction and collection and flaring design and cost estimates for the MCGM.

There is also a need to identify interested parties for the development of LFG projects and to conduct a detailed evaluation of potential revenue from emission reductions from the sale of electricity and anticipated revenue from the MCGM and in South Africa.

The introduction of separation at source by household generators into two categories, wet and dry waste, would reduce the capital costs of the mechanical plant for pre-treatment of the material recovered.

A feasibility study should be conducted to investigate the potential of anaerobic digestion on the sewage treatment plant and biogenic waste on the MSW.

7.6 Conclusion

The study evaluated the environmental impacts of various waste management strategies that can be used to create an institutional framework for municipalities.

It focussed on NLM and the MCGM and their principal environmental impacts, and evaluated GHG impacts and the possible waste diversion strategies that can be adopted for similar municipalities.

The use of the MBT results in significant environmental benefits in terms of GHG reductions. The strategy should include facilities to recover recyclable waste, separating the residue waste and biogenic waste and thereby increasing the lifespan of the landfill site. The capital costs of procuring an MRF should be weighed against environmental costs and social benefits.

A sound instituitional framework for sustainable waste management on the local level needs a lot of organisations such as:

Service providers that range from government departments and municipalities, public corporations and private sector companies to community based organisations. Regulatory and enforcement bodies have a crucial role in establishing and ensuring the effective application of tools for a sustainable waste management. The private sector plays an important role in financing sustainable waste management projects. Commercial banks and other financial institutions can finance both public and private sector service providers. Local authorities can play an important role in overseeing the implementation of activities in waste management within their boundaries and within their local and regional jurisdiction. Non governmental and community based organisations can play an important role in developing and communicating waste management policies. Also, they can advocate on behalf of nature and environmental protection, develop and test new models and tools for waste management, increase awareness of the need for sustainable waste management and mobilise communities to get involved.

An institutional framework needs to be co operative, and have clear definitions of roles and responsibilities. Organisations need to work transparently and in dialogue with each other. It is possible and helpful to build partnerships on the basis of basic policies accepted by all parties.

THE WAY FORWARD

The integrated waste management system has examined way in which there should be a decentralised waste management system involving households, local communities, industries working in collaboration with the municipality in their effort to reduce the amount of waste going into the landfill site. The case study of Mumbai reflected that huge amount of waste can be diverted from landfills, such efforts are minimal. The effort needs to be scaled up in all communities. Local municipalities should consider best practices of separation at source investing in technologies of material recovery facilities to allow for reuse and recycling to be maximised. This would require concerted education and awareness campaigns with greater emphasis on waste reduction, reuse, recycling sustainability of the waste management system. Appropriate waste technologies and its viability to candidate sites should be encouraged and supported as best practices in efforts towards a green footprint.

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ANNEXURES:

Annexure A: Permission to enter Deonar Site in Mumbai

भारतीय प्रौद्योगिकी संस्थान मुंबई
पवई, मुंबई-४०० ०७६, भारत
Indian Institute of Technology Bombay
Powai, Mumbai-400 076, India

दूरभाष/Phone : (+91-22) 2572 2545
फैक्स/Fax : (+91-22) 2572 3480
वेबसाईट/Website : www.iitb.ac.in

21st March 2011

To,

The Chief Engineer (SWM)
Municipal Corporation of Greater Mumbai
Palton Road, MRA Marg
Mumbai

Dear Sir,

Ms. Thava Kelly is starting her PhD in School of Engineering, University of Kwa-Zulu Natal, South Africa under the supervision of Prof. Cristina Trois, Head of School, Civil Engineering Department. As a part of her Ph.D. study, she will also work on our collaborative research project with University of Kwa-Zulu Natal, South Africa (PI: Prof. Cristina Trois) funded under Indo-South African Science & Technology Cooperation scheme (Funding agency: DST, New Delhi). The collaborative project title is:
"Energy recovery options from municipal solid waste and control/treatment measures of carbon emissions from landfills"
Presently, Ms. Kelly is visiting Mumbai to collect information on the landfill operations. Therefore, I request for your kind approval for allowing Ms. Kelly to visit Deonar landfill site. She will like to collect the information on the management of landfill site.
The information will be used solely for academic purposes.
Thanking you in anticipation for your kind help and cooperation.

Best regards

Anurag Garg
Assistant Professor

60 बृहन्मुंबई महानगर पालिका
प्रमुख अभियंता (घकव्य) यांचे ChE
कार्यालय शिवाजी मार्केट (पलटन रोड)
21 MAR 2011
क्र.प्र.अ/ 26636

Dy.Ch.E (SWM) Project
O/C
No photography please
Ch.E (SWM)

Annexure B: Weighbridge Summary Report-MCGM

Authorised Signatory

Municipal Corporation of Greater Mumbai
Deonar Disposal Site Transaction Summary Report

Report Date : 27/07/2012

Date From : 27/07/2012 Date To : 27/07/2012

Shift wise report for Shift : Afternoon

Sorted by : slipsrno

Total No. of Vehicles	: 85	
Total Gross Weight	: 1321180 Kg	1321.2 Tons
Total Tare Weight	: 750240 Kg	750.2 Tons
Total Net Weight	: 570940 Kg	570.9 Tons

Municipal Corporation of Greater Mumbai
Deonar Disposal Site Transaction Summary Report

Report Date : 28/07/2012

Date From : 27/07/2012 Date To : 27/07/2012

Only Summary Report

Sorted by : slipsrno

Total No. of Vehicles	: 944	
Total Gross Weight	: 15343870 Kg	15343.9 Tons
Total Tare Weight	: 8513705 Kg	8513.7 Tons
Total Net Weight	: 6830165 Kg	6830.2 Tons

Annexure C: Questionnaire to Residents in MCGM

To whom it may concern,

The purpose of this Research Survey is to conduct a comprehensive waste stream analysis for Greater Corporation of Mumbai, with scrutiny to waste entering the Deonar Landfill Site. The Survey that is being undertaken is for academic purpose. The aim is to develop an integrated model that could assist Local Authorities in developing countries like South Africa and India to decide on the best waste management strategy to adopt in order to maximize Greenhouse Gas emissions reductions or energy production.

AREA:____________________

RESEARCH QUESTIONNAIRE:

1. Household Head?

MALE		FEMALE	

2. Highest standard of education of the Household Head?

PRIMARY		SECONDARY		TERTIARY	

3. How long have you been a resident in the area?

0-10yrs		11-20yrs		21-30yrs		>30yrs	

4. How many members are in your household?

2-4		5-7		8-10		>10	

5. What is the total income per household per month?

<Rs1000		Rs1001-Rs5000		Rs5001-Rs10000		Rs10001-Rs20000		>Rs20000	

6. Are you paying for a waste removal service?

Rs 200-500		Rs 500-Rs1000		Not Sure	

7. What types of waste does your household generate?

Paper		Plastic		Glass	
Metal		Kitchen		Other	

8. How much waste does your household generate per week?

5-10kg		11-15kg		16-30kg		>30kg	

9. How do you store your waste in your household?

Plastic in Bin		Drum or Bucket	
Plastic Bag		Other (Specify)	

10. How often is your waste collected from your household?

Once a week	Twice a week	Daily

11. How would you rate your waste collection? Please give a reason for your answer.

Excellent		
Good		
Poor		

12. How do you dispose off the following waste?

Type of Waste	Open Spaces	Contractor	Burn/Bury	Other means of disposal	Not Applicable
Construction waste					
Damaged Home appliances					
Garden Waste					
Plastic					
Glass					
Paper					

13. Do you have waste pickers picking up waste in your area at any time?

YES	
NO	

14. If YES, do you consider them to be problematic or beneficial?

15. Are you aware of any recycling programmes in your area?

YES	
NO	

16. If YES. What type of recycling programmes are you aware of ?

If No.Do you think recycling programmes should be encouraged? Why?

17. Which of the following waste methods do you currently practice?

COMPOSTING	RE-USE	RECYCLE	NONE

18. Are there any illegal dumping in your area?

19. If YES, what types of wastes are disposed off illegally?

CONSTRUCTION AND DEMOLITION MATERIAL	HOUSEHOLD WASTE	GARDEN REFUSE	OLD APPLIANCES/ FURNITURE	OTHER

20. How far from your home is there illegal dumping?

21. Who is responsible for the illegal disposal of such wastes?

RESIDENTS	OUTSIDERS	FACTORIES	OTHER

22. Which of the following impacts are prevalent in your area because of the illegal waste disposal?

ODOURS	UNAESTHETIC	RODENTS/INSECTS

23. Has your community approached authorities on the problem of illegal waste disposal?

YES	
NO	

24. If YES, how are the authorities reacting to the illegal waste disposal?

25. What suggestions do you propose to try and combat illegal waste disposal?

Annexure D: Recording of Data from Trucks in MCGM

		15	27	76	78	79
		29.01	23.01	24.01	30.01	30.01
		7220	5975	4325	5910	5890
		1802	1493.75	1081	1477	1472
		MH01L4451	MH02212	MH01LA9052	MH01LA4415	MH01LA4451
		MANKHURD	MANKHURD	MANKHURD	MANDKHURD	MANDKHURD
Paper and Cardboard						
Clean paper						
Common Mixed Waste	14.13		30	4.72	18.56	12.86
Newspaper						
Scrap Boxes and Cardboard						
Tetrapak						
Residual Paper						
Plastic						
LDPE						
HDPE	10.48			1.82	26.6	8.86
Polethethylene terephalate						
Polypropylene						
Polyvinyl Chlorine						
Polysterene						
Residual Plastic	34.92	36.42	20.27	8.58	29.4	6.88
Glass						
Green Glass						
Brown Glass						
Clear Glass	3.55		3.55			
Metals						
Organic Food waste	859	1264	1045.63	1838	886	1030.4
Garden refuse: Green waste					73.85	73.6
Cloth	63.95			54.05	73.85	

WASTE STREAM ANALYSIS

Date and Time:		Waste Collection Area	
Waste Truck and Registration		Area Classification	
Waste Material Classification		Weight in Kg	
	Sample 1	Sample 2	Sample 3
Paper and Cardboard			
Clean White Paper			
Common Mixed Waste			
Newspaper			
Scrap Boxes and Cardboard			
Tetrapak			
Residual Paper			
Plastic			
Low density Polyethylene			
High density Polyethylene			
Polyethylene terephthalate			
Polypropylene			
Polyvinyl Chlorine			
Polystrene			
Residual Plastic			
Glass			
Green glass bottles and containers			
Brown glass and containers			
Clear glass bottles and containers			
Metals			
Cans			
Beverage cans			
Other Metals			
Biogenic Wastes			
Organic Food Waste			

Garden Refuse: Green waste			
Garden: Wood Waste			
Residual Biogenic Waste			
Other Wastes			
Wood Waste			
Tyres			
Textiles, Cloth			
e-Waste			
Batteries			
Soil/Sand/Ash/Other			
Residual waste			
1. Foodstuff			
2. Paper and Cardboard			
3. Plastics			
4. Glass			
5. Green/Garden			
6. Soil/Sand/Ash/Other			
TOTAL WEIGHT:			

	TRUCK REG	GROSS WEIGHT	TARE WEIGHT	NET WEIGHT	WARD	VEHICLE DESCRIPTION	REMARKS
1	MH04DK1189	24310	1000	14310	G/N	TORUS PRIVATE	MIXED REFUSE
2	MH06AC7612	18250	9060	9190	M/E	COMPACTOR	MIXED REFUSE
3	MH01LA9075	17950	10140	7810	L	COMPACTOR	MIXED REFUSE
4	MH01L4473	15640	10140	5500	B	COMPACTOR	MIXED REFUSE
5	MH01LA9016	15590	10100	5490	L	COMPACTOR	MIXED REFUSE
6	MH03AH2461	14700	11500	3200	K/E	DUMPER	MIXED REFUSE
7	MH43E5069	10550	6200	4350	F/S	DUMPER	MIXED REFUSE
8	MH01LA9074	17470	10180	7290	L	COMPACTOR	MIXED REFUSE
9	MHAH2707	13360	10200	3160	K/E	COMPACTOR	MIXED REFUSE
10	MH03AH3454	17150	11200	5950	K/E	COMPACTOR	MIXED REFUSE
11	MH01L5606	12090	6400	5690	G/N	DUMPER	CONSTRUCTION WASTE
12	MH04FD2184	9970	6200	3770	F/N	DUMPER	MIXED REFUSE
13	MH04CU5898	17290	10000	7290	F/N	DUMPER	MIXED REFUSE
14	MH03AH2601	13540	10500	3040	K/E	COMPACTOR	MIXED REFUSE
15	MH04EL3484	23050	9300	13750	KTS	DUMPER	MIXED REFUSE
16	MH04DK2823	17660	10000	7660	N	DUMPER	MIXED REFUSE
17	MH01L4499	17030	10130	6900	L	COMPACTOR	MIXED REFUSE
18	MH03AH907	14260	10480	3780	F/S	COMPACTOR	MIXED REFUSE
19	MH01L5727	12880	6900	5980	E	DUMPER	MIXED REFUSE
20	MH03AH2458	13660	10300	3360	HY/E	COMPACTOR	MIXED REFUSE
21	MH01L4419	9930	6730	3200	PAID	DUMPER	MIXED REFUSE
22	MH01LOA9023	14320	10130	4190	E	COMPACTOR	MIXED REFUSE
23	MH03AH2602	14070	9910	4160	K/E	COMPACTOR	MIXED REFUSE
24	MH03AH2443	15070	10250	4820	H/E	COMPACTOR	MIXED REFUSE
25	MH01LA9008	16740	10200	6540	L	COMPACTOR	MIXED REFUSE
26	MH43E1004	9460	6300	3160	M/E	DUMPER	MIXED REFUSE
27	MH03AH1216	15690	9600	6090	F/S	COMPACTOR	MIXED REFUSE
28	MH43Y9662	10380	6500	3880	N	DUMPER	MIXED REFUSE
29	MH01L4448	11600	6530	5070	M/E	COMPACTOR	MIXED REFUSE
30	MH01L4470	14640	10180	4460	B	COMPACTOR	MIXED REFUSE
31	MH03AH2527	15120	10500	4620	H/E	COMPACTOR	MIXED REFUSE
32	MH01L4431	15980	10130	5850	E	COMPACTOR	MIXED REFUSE
33	MH01LA9002	17190	10140	7050	L	COMPACTOR	MIXED REFUSE
34	MH43E220	11510	6200	5310	M/E	DUMPER	MIXED REFUSE
35	MH01L4498	16880	10130	6750	L	COMPACTOR	MIXED REFUSE
36	MH10Z2212	11700	6500	5200	G/N	DUMPER	MIXED REFUSE
37	MH03AH968	15910	10480	5430	F/S	COMPACTOR	MIXED REFUSE
38	MH43E5893	8210	6260	1950	M/W	DUMPER	MIXED REFUSE
39	MH03AH2456	16670	10300	6370	H/E	COMPACTOR	MIXED REFUSE
40	MH03AH2445	14710	11700	3010	H/E	COMPACTOR	MIXED REFUSE
41	MH03AH2492	14220	11700	2520	D	COMPACTOR	MIXED REFUSE
42	MH06AQ1739	22400	10400	1200	KTS	DUMPER	MIXED REFUSE
43	MH04CU3795	13180	6170	7010	H/E	DUMPER	GARDEN REFUSE
44	MH02YA9251	14080	10500	3580	F/S	COMPACTOR	MIXED REFUSE
45	MH04DK2825	13950	10200	3750	G/N	DUMPER	MIXED REFUSE
46	MH04CA6062	6930	6800	130	PAID	DUMPER	MIXED REFUSE
47							
48							
49							
50							
51							
	TOTAL RECEIVED						
	930 VEHICLES	14922430	850935	6412595			
		14922.4 TONS	8509.8	6412.6			

	24-Jul-12					
	10:30					
		TRUCK REG	GROSS WEIGHT	TARE WEIGHT	NET WEIGHT	WARD
10:27	1	MH 01 L44333	10760	6420	4340	M EAST
	2	MH06 AC7612	16340	9060	7280	M/EAST
	3	MH 04CP5982	24270	8200	16070	PRIVATE
	4	MH 407712	23460	10000	13460	PRIVATE
	5	MH46H1285	21620	10000	11620	G NORTH
	6	MH03AH1481	17410	10800	6610	G NORTH
	7	MH04CP5506	17460	6200	11260	M/EAST
	8	MH04DD1031	8680	6200	2480	N
	9	MHMH01L4434	12420	6710	5710	M/EAST
	10	MH01L4449	16710	10130	6580	M/EAST
	11	MH04CP6094	9240	6460	2780	N
	12	MH 03AH1204	15370	10500	4870	G/N
	13	MH 04FJ8420	19290	10390	8900	PRIVATE
	14	MH01L4451	20810	10200	10610	M/EAST
	15	MH01L4465	12110	6500	5610	M/EAST
	16	MH01L4411	17350	10080	7270	M/EAST
	17	MH04EL5791	19600	10000	9600	KTS
	18	MH01L4464	10070	6200	3870	M/EAST
	19	MH 04EL4144	9310	6150	3160	G/N
	20	MH01L4298	9610	6200	3410	N
	21	MH01L4400	16540	10340	6200	E
	22	MH04EL5790	20380	9000	11380	KTS
	23	MH04DK2830	14250	10000	4250	M/W
	24	MH03AH981	16340	10200	6140	G/N
	25	MH04DD5733	20250	10000	10250	F/N
	26	MH01L5308	17140	10300	6840	M/EAST
	27	MH03AH2462	16810	10500	6310	K/E
	28	MH03AH2459	14010	10200	3810	K/E
	29	MH03AH2665	14540	11500	3040	K/E
	30	MH04DK5275	14350	10095	4255	G/N
	31	MH 01L4453	15990	10200	5790	M/EAST
	32	MH01L4390	15210	10170	5040	M/EAST
	33	MH04CU6654	16150	10500	5650	G/S
	34	MH43U1214	14650	8200	6450	H/E
	35	MH43Y804	11360	6160	5200	H/W
	36	MH04EY3064	16880	10500	6380	M/EAST
	37	MH43E299	17010	6210	10800	M/EAST
	38	MH04DD8623	21710	10490	11220	KTS
	39	MH04DD1907	15550	10000	5550	N
	40	MH04CE8021	8660	6250	2410	N
	41	MH04DD2964	16480	10030	6450	N
	42	MH03AH2463	15850	10510	5340	K/E
	43	MH03AH3454	15540	11200	4340	K/W
	44	MHO2CE8011	8620	6500	2120	N
	45	MH03AH2601	13660	10500	3160	K/E
	46	MH04DD9882	21650	11600	10050	GRTS
	47	MH01L4499	20430	10130	10300	L
	48	MH01LA9075	17920	10140	7780	L
	49	MH03AH2707	13270	10200	3070	K/E
	50	MH01LA9003	17810	10140	7670	L
11:30	51	MH04CP5983	23620	8200	15420	M/EAST
		SUMMARY	14521020	8136815	6384205	
		891 VEHICLES				
		TONS	14521	8136.8	6384.2	

26/07/2012							
1:00PM		TRUCK REG	GROSS WEIGHT	TARE WEIGHT	NET WEIGHT	WARD	VEHICLE DESCRIPTION
	1	MH 01L4433	7060	6420	640	M/E	COMPACTOR
	2	MH03AH2443	14120	10250	3870	H/E	COMPACTOR
	3	MH04CA8149	17630	10000	7630		DUMPER
	4	MH02YA9253	14850	10190	4660	G/N	COMPACTOR
	5	MH01L4322	15430	6200	10260	D	DUMPER
	6	MH46F1142	15980	10100	5880	F/S	DUMPER
	7	MH04CA6062	9060	6800	2260	PAID	DUMPER
	8	MH43E6996	13250	6200	7050	N	DUMPER
	9	MH02YA9243	19870	10800	9070	H/E	COMPACTOR
	10	MH01L4397	16600	10070	6530	M/W	COMPACTOR
	11	MH10Z212	12860	6500	6360	G/N	DUMPER
	12	MH43E8689	16060	10640	5420	G/SW	DUMPER
	13	MH01L4472	16170	10140	6030	E	COMPACTOR
	14	MH01LA9024	16220	10190	6030	A	COMPACTOR
	15	MH407712	22250	10000	12250	VLRT	DUMPER
	16	MH04CA8593	9470	6640	2830	PAID	DUMPER
	17	MH02YA9248	16890	10500	6390	H/E	COMPACTOR
	18	MH04DK6864	22430	10000	12430	VLRT	DUMPER
	19	MH43E9822	21810	8200	13610	H/E	DUMPER
	20	MH06AC7612	17830	9060	8770	M/E	DUMPER
	21	MH03AH2602	15140	9910	5230	K/E	COMPACTOR
	22	MH43Y804	13400	6160	7240	H/W	DUMPER
	23	MH032527	15830	10500	5330	H/E	COMPACTOR
	24	MH01L4430	16680	10190	6490	E	COMPACTOR
	25	MH43E5132	14960	6200	8760	N	DUMPER
	26	MH03AH3454	16910	11200	5710	K/W	COMPACTOR
	27	MH04EL973	24600	10600	14540	L	DUMPER
	28	MH43E8166	14680	6200	8480	H/W	DUMPER
	29	MH01L5727	11940	6900	5040	E	DUMPER
	30	MH03AH905	14640	11500	3140	N	COMPACTOR
	31	MH01LA9042	14290	9810	4480	D	COMPACTOR
	32	MH03AH2442	12010	10200	1810	H/E	COMPACTOR
	33	MH01LA9114	17410	9150	8260	GRTS	COMPACTOR
	34	MH43U1783	24160	10160	14000	L	DUMPER
	35	MH01LA9137	28290	10390	17900	VLRTS	DUMPER
	36	MH04CG7690	9980	6380	3600	G/S	DUMPER
	37	MH03AH1216	15690	9600	6090	F/S	COMPACTOR
	38	MH06AC1466	11560	6190	5370	F/N	DUMPER
	39	MH04E4140	10380	6120	4260	G/N	DUMPER
	40	MH01L5609	12800	6470	6330	F/N	DUMPER
	41	MH02YA9811	8900	6200	2700	L	DUMPER
	42	MH01L5606	12910	6400	6510	G/S	DUMPER
	43	MH06AC4592	16780	10000	6780	G/S	DUMPER
	44	MH01L4448	7810	6330	1280	M/E	COMPACTOR
	45	MH01L4441	9010	6600	2410	M/E	COMPACTOR
	46	MH04DK3966	14250	9740	4510	G/N	DUMPER
	47	MH02YA9785	16370	9600	6770	L	DUMPER
	48	MH01L5728	13370	9600	6470	H/E	DUMPER
	49	MH04DD8623	21580	10490	11090	KTSIT	DUMPER
	50	MH04DK4398	16310	9020	7290	F/S	DUMPER
	51	MH04DD2785	22000	9010	12990	F/N	DUMPER
	52	MH04CP5998	16200	8200	8000	H/E	DUMPER
	53	MH14AS9033	18640	10390	8250	F/N	DUMPER
	54	MH04FJ1035	27850	10000	17850	L	DUMPER
	55	MH02YA9245	17690	10080	7610	H/E	COMPACTOR
	56	MH01L4498	16670	10130	6540	M/W	COMPACTOR
	57	MH01L5613	13020	6230	6790	M/E	DUMPER
	58	MH01L5632	155890	6390	9190	M/E	DUMPER
	59	MH01L4457	16190	10140	6050	A	COMPACTOR
	60	MH01LA9055	19640	9560	10080	L	COMPACTOR
	61	MH03AH4663	14960	10000	4960	N	DUMPER
	62	MH03AH2725	13040	11500	1540	K/W	COMPACTOR
	63	MH01LA9041	15720	10020	5700	D	COMPACTOR
		NO OF VEHICLES	887				
	WEIGHT		14200160	8000830	6199330		
	TONS		14200.2	8000.8	6199.3		

27/07/2012		TRUCK REG	GROSS WEIGHT	TARE WEIGHT	NET WEIGHT	WARD	VEHICLE DESCRIPTION	REMARKS
02:30	1	MH43U8689	13750	10640	3110	GS	DUMPER	MIXED REFUSE
	2	MH04Y3430	16890	10700	6190	ME	DUMPER	MIXED REFUSE
	3	MH04FD2032	15800	9950	5850	N	DUMPER	MIXED REFUSE
	4	MH04DD2194	16700	10000	6700	N	DUMPER	MIXED REFUSE
	5	MH43U310	18540	10000	8540	ME	DUMPER	MIXED REFUSE
	6	MH04DD2599	15520	10000	5520	G/N	DUMPER	MIXED REFUSE
	7	MH03AH2468	15600	11500	4100	K/W	COMPACTOR	MIXED REFUSE
	8	MH04DD1907	15380	100000	5380	N	DUMPER	MIXED REFUSE
	9	MH06ACC7612	17280	9060	8220	ME	DUMPER	MIXED REFUSE
	10	MH04EL3484	23040	9300	13740	KTSIT	DUMPER	GARDEN
	11	MH06AC8512	17820	10000	7820	R/C	DUMPER	MIXED REFUSE
	12	MH43E5893	12280	6260	6020	M/W	DUMPER	MIXED REFUSE
	13	MH03AH2731	19740	11500	8240	KW	COMPACTOR	MIXED REFUSE
	14	MH43E5132	15300	6200	9100	N	DUMPER	MIXED REFUSE
	15	MH01L5723	10090	6200	3890	C	DUMPER	MIXED REFUSE
	16	MH04DD2785	20460	9010	11450		DUMPER	MIXED REFUSE
	17	MH03N7654	9340	7650	1690	MW	SKIP TRUCK	MIXED REFUSE
	18	MH02YA9245	15900	10080	5820	HW	COMPACTOR	MIXED REFUSE
	19	MH04DD2796	25690	8970	16720	G/N	DUMPER	MIXED REFUSE
	20	MH04DK4775	27390	8980	18410	F/N	DUMPER	MIXED REFUSE
	21	MH04DK3075	17940	10000	7940	ME	DUMPER	MIXED REFUSE
	22	MH01L5246	7820	6800	1020	MKT	ROLL TLB	MIXED REFUSE
	23	MH03AH2605	16910	11300	5610	KE	COMPACTOR	MIXED REFUSE
	24	MH01L4494	16980	10200	6780	GRTS	COMPACTOR	MIXED REFUSE
	25	MH02YA9604	8510	7400	1110	MW	COMPACTOR	MIXED REFUSE
	26	MH43E220	7640	6200	1740	ME	DUMPER	CONSTRUCTION
	27	MH04DD5733	28430	10000	18340	FN	DUMPER	CONSTRUCTION
	28	R 546	8380	6340	2040	PAID	DUMPER	MIXED REFUSE
	29	MH236645	16950	6200	10750	ME	DUMPER	MIXED REFUSE
	30	MH43U2427	20010	10000	10010	GRTS	DUMPER	MIXED REFUSE
	31	MH04EY3064	19150	10500	8650	ME	DUMPER	MIXED REFUSE
	32	MH43U1215	18190	9320	8870	ME	COMPACTOR	MIXED REFUSE
	33	MH01L4434	9310	6900	2410	ME	COMPACTOR	MIXED REFUSE
	34	MH01L4403	8220	6350	1870	MW	DUMPER	MIXED REFUSE
	35	MH43Y866	15840	6300	9540	N	DUMPER	MIXED REFUSE
	36	MH04CG99	8000	6880	1120	PAID	DUMPER	MIXED REFUSE
	37	MH01L4451	17940	10200	7740	ME	COMPACTOR	MIXED REFUSE
	38	MH01L4464	8260	6760	1500	ME	COMPACTOR	MIXED REFUSE
	39	MH04CU6654	14740	10500	4200	ME	DUMPER	MIXED REFUSE
	40	MH10Z212	14070	6500	7570	GN	DUMPER	MIXED REFUSE
	41	MH04DK6036	19550	8010	11540	F/S	DUMPER	MIXED REFUSE
	42	MH04DD8623	19970	10490	9480	KTSIT	DUMPER	MIXED REFUSE
	43	MH01L4390	17960	10170	7790	ME	COMPACTOR	MIXED REFUSE
	44	MH01L4449	17970	10130	7840	ME	COMPACTOR	MIXED REFUSE
	45	MH04EL973	19130	10060	9070	L	DUMPER	MIXED REFUSE
	46	MH01LA9114	17560	9150	8410	GRTS	COMPACTOR	MIXED REFUSE
	47							
	48							
	49							
	50							
	51							
	52							
	53							
	54							
	55							
	56							
	57							
	58							
	59							
	60							
	61							
	62							
	63							
		TOTAL VEHICLES 944						
		WEIGHT IN KG	15343870	8513705	6830165			
		TONS	15343.9	8513.7	6830.2			

		23.01	24.01	30.01
		4000	3955	3025
		1000	988	756.25
		MH01L4387	MH01L4413	MH01L4491
		GOVINDI	GOVINDI	GOVINDI
Paper and Cardboard				
Clean paper				
Common Mixed Waste	16.65		4.82	13.58
Newspaper				
Scrap Boxes and Cardboard				
Tetrapak				
Residual Paper				
Plastic				
LDPE				
HDPE	6.11		6.11	
Polethethylene terephalate	4		5.06	3
Polypropylene				
Polyvinyl Chlorine				
Polysterene				
Residual Plastic	33	14.48	45.37	38.36
Glass				
Green Glass				
Brown Glass				
Clear Glass				
Metals				
Organic Food waste	866	700	692.12	529.37
Garden refuse: Green waste				
Cloth				

		19	44	70	102
		29.01	28.01	24.01	30.01
		5040	6720	3440	4335
		1260	1680	860	1083.75
		MH01LA9177	MH03AH1398	MH03AH968	MH03AH1398
		KANJUR	KANJUR	KANJUR	KANJUR
Paper and Cardboard					
Clean paper					
Common Mixed Waste	15.4	10.7	51.36	10.03	13.48
Newspaper					
Scrap Boxes and Cardboard					
Tetrapak					
Residual Paper					
Plastic					
LDPE					
HDPE					
Polethethylene terephalate	15.6	2	55.8	3.5	2.48
Polypropylene					
Polyvinyl Chlorine					
Polysterene					
Residual Plastic	34.94	38.2	55.22	20.3	33.32
Glass					
Green Glass					
Brown Glass					
Clear Glass					
Metals					
Organic Food waste	847	882	840	602	758.63
Garden refuse: Green waste	43			43	
Cloth	504		504		

		14	20	98
		29.01	29.01	30.01
		6750	3515	6670
		1688	879	1667.5
		MH01L4400	MH03AH1398	MH01LA9177
		BYCULLA	BYCULLA	BYCULLA
Paper and Cardboard				
Clean paper				
Common Mixed Waste	15.43	4	2	25
Newspaper				
Scrap Boxes and Cardboard				
Tetrapak				
Residual Paper				
Plastic				
LDPE				
HDPE				
Polethethylene terephalate	16.23		10.1	24.4
Polypropylene				
Polyvinyl Chlorine				
Polysterene	5		5	
Residual Plastic	34.95	23	20.3	40.78
Glass				
Green Glass				
Brown Glass				
Clear Glass				
Metals				
Organic Food waste	853	1181	615	1167
Garden refuse: Green waste				
Cloth				

		32	42	62	66	77	97
		23.01	28.01	24.01	24.01	24.01	30.01
		6035	3160	3300	5010	4900	5600
		1508.75	790	825	1252.5	1225	1400
		MH04FD2184	MH03AH1481	MH03AH1206	MH236645	MH02CE8045	MH03AH981
		DHARAVI	DHARAVI	DHARAVI	DHARAVI	DHARAVI	DHARAVI
Paper and Cardboard							
Clean paper							
Common Mixed Waste	15.31	8.38		7.6	9	10.9	40
Newspaper							
Scrap Boxes and Cardboard	9.57	9.57					
Tetrapak							
Residual Paper							
Plastic							
LDPE							
HDPE	4.29				4.7	4.65	
Polethethylene terephalate	16.59		21.64	14.64	6.7		3.2
Polypropylene							
Polyvinyl Chlorine							
Polysterene							
Residual Plastic	34.76	12.7	56.78	34.4	12.8	26.26	83.92
Glass							
Green Glass							
Brown Glass							
Clear Glass	7.16	7.16					
Metals							
Organic Food waste	846.6	1056.12	632	57.75	876.75	857.5	980
Garden refuse: Green waste	46.04		39.5		62.62		
Cloth							

		57	59
		24.01	24.01
		5590	8640
		1397	2160
		MH43H7865	MH01LA9166
		NANACHOWK	NANACHOWK
Paper and Cardboard			
Clean paper			
Common Mixed Waste	8.16	12.5	7.3
Newspaper			
Scrap Boxes and Cardboard			
Tetrapak			
Residual Paper			
Plastic			
LDPE			
HDPE			
Polethethylene terephalate	13.77	10	15.87
Polypropylene			
Polyvinyl Chlorine			
Polysterene			
Residual Plastic	19.49	19.49	
Glass			
Green Glass			
Brown Glass			
Clear Glass			
Metals			
Metal			
Cans			
Beverage cans			
Other Metals			
Organic Food waste	978.25	978.25	
Garden refuse: Green waste			
Cloth			

Annexure F: NEWCASTLE WASTE COLLECTION DATA

	UPPER INCOME	MIDDLE INCOME	LOW INCOME	AVERAGE
CLEAN WHITE PAPER	10.71	11.43	0	7.38
COMMON MIXED WASTE	33.07	29.22	49.3	37.19
NEWSPAPER	7.18	13.06	5.1	8.44
SCRAP BOX AND CARDBOARD	11.01	12.18	7.26	10.15
TETRAPAK	5.48	7.21	3.51	5.4
RESIDUAL PAPER	14.87	12.34	9.05	12.08
LOW DENSITY POLYEHYLENE	7.6	13.04	2.75	7.79
HIGH DENSITY POLYETHELENE	7.7	12.33	4.11	8.46
POLYETHYLENE TEREPHALATE	5.63	6.84	5.67	6.04
POLYVINYL CHLORINE	3.47	4.95	2.46	3.62
POLYSTRENE	3.68	2.92	2.51	3.03
RESIDUAL PLASTIC	8.91	9	3.5	7.13
GREEN GLASS BOTTLES & CONTAINERS	12.29	11.89	10.75	11.64
BROWN GLASS & CONTAINERS	9.21	14.57	15.62	13.13
CLEAR GLASS BOTTLES & CONTAINERS	12.75	9.98	7.94	10.22
CANS	8.15	11.55	6.13	8.61
BEVERAGE CANS	8.78	11.06	6.91	8.91
ORGANIC FOOD WASTE	15.97	16.48	11.58	14.67
GARDEN: GREEN WASTE	14.2	13.43	12.91	13.51
GARDEN: WOOD WASTE	0	21	0	7
RESIDUAL BIOGENIC WASTE	21.04	22.6	9.5	17.71
TEXTILES AND CLOTH	8.17	3.6	4.18	5.31
SOIL/SAND/ASH/OTHER	17	21.12	17.33	18.48
				245.9

VEHICLE FLEET UTILISED

DATE	COLLECTION POINT	AREA CLASSFICATION	TRUCK TYPE	REGISTRATION
	MADADENI KHANANA	LOW INCOME	TRACTOR	NN52193
	MATHUKUZA	LOW INCOME	SKIP TRUCK	NN52193
	MADADENI SEC 7	LOW INCOME	SKIP TRUCK	NN39283
	MADADENI SEC 7	LOW INCOME	TRACTOR	NN40209
	FERNWOOD	LOW INCOME	COMPACTOR	NN12438
	MADADENI KHANANA	LOW INCOME	TRACTOR	NN52193
	MATHUKUZA	LOW INCOME	SKIP TRUCK	NN52193
	MADADENI SEC 7	LOW INCOME	SKIP TRUCK	NN39283
	MADADENI SEC 7	LOW INCOME	TRACTOR	NN40209
	FERNWOOD	LOW INCOME	COMPACTOR	NN12438

COLLECTION POINT	AREA CLASSFICATION	TRUCK TYPE	REGISTRATION
OSIZWENI SEC A	MIDDLE INCOME	TRACTOR	NN40207
OSIZWENI SEC D	MIDDLE INCOME	TRACTOR	NN48329
MADADENI SEC 5	MIDDLE INCOME	TRACTOR	NN40209
OSIZWENI SEC C	MIDDLE INCOME	SKIP TRUCK	NN52193
OSIZWENI SEC A	MIDDLE INCOME	TRACTOR	NN48329
MADADENI SEC 7	MIDDLE INCOME	TRACTOR	NN 40209
OSIZWENI SEC B	MIDDLE INCOME	TRACTOR	NN40207
CBD/FAIRLEIGH	MIDDLE INCOME	COMPACTOR	NN25881
MADADENI SEC 4	MIDDLE INCOME	TRACTOR	NN40209
OSIZWENI SEC F	MIDDLE INCOME	TRACTOR	NN40207
CBD/INDUSTRIAL	MIDDLE INCOME	COMPACTOR	NN48581
OSIZWENI SEC A	MIDDLE INCOME	TRACTOR	NN40207
ARBOR PARK	MIDDLE INCOME	COMPACTOR	NN55
OSIZWENI SEC A	MIDDLE INCOME	TRACTOR	NN40207
OSIZWENI SEC D	MIDDLE INCOME	TRACTOR	NN48329
MADADENI SEC 5	MIDDLE INCOME	TRACTOR	NN40209
OSIZWENI SEC C	MIDDLE INCOME	SKIP TRUCK	NN52193
OSIZWENI SEC A	MIDDLE INCOME	TRACTOR	NN48329
MADADENI SEC 7	MIDDLE INCOME	TRACTOR	NN 40209
OSIZWENI SEC B	MIDDLE INCOME	TRACTOR	NN40207
CBD/FAIRLEIGH	MIDDLE INCOME	COMPACTOR	NN25881
MADADENI SEC 4	MIDDLE INCOME	TRACTOR	NN40209
OSIZWENI SEC F	MIDDLE INCOME	TRACTOR	NN40207
CBD/INDUSTRIAL	MIDDLE INCOME	COMPACTOR	NN48581
OSIZWENI SEC A	MIDDLE INCOME	TRACTOR	NN40207
ARBOR PARK	MIDDLE INCOME	COMPACTOR	NN55

DATE	COLLECTION POINT	AREA CLASSFICATION	TRUCK TYPE	REGISTRATION
	CBD	UPPER INCOME	COMPACTOR	NN42328
	PARADISE	UPPER INCOME	COMPACTOR	NN48581
	NGAGANE	UPPER INCOME	SKIP TRUCK	NN52193
	NEWCASTLE CBD	UPPER INCOME	COMPACTOR	NN25881
	MADADENI CUSTOMERS	UPPER INCOME	COMPACTOR	NN40326
20/09/201	SUNNY RIDGE	UPPER INCOME	COMPACTOR	NN 55
	NEWCASTLE CBD	UPPER INCOME	COMPACTOR	NN 25881
	MADADENI CSTMERS	UPPER INCOME	COMPACTOR	NN 40326
	SIGNAL HILL	UPPER INCOME	COMPACTOR	NN42328
21/09/201	MADADENI CSTMERS	UPPER INCOME	COMPACTOR	NN40326
	NEWCASTLE CBD	UPPER INCOME	COMPACTOR	NN42328
24/09/201	INCANDU PARK	UPPER INCOME	COMPACTOR	NN48581
	NEWCASTLE CBD	UPPER INCOME	COMPACTOR	NN42328
	NGAGANE	UPPER INCOME	SKIP TRUCK	NN52193
	NEWCASTLE CBD	UPPER INCOME	COMPACTOR	NN12438
	LENNOXTON	UPPER INCOME	COMPACTOR	NN25881
	MADADENI CTMERS	UPPER INCOME	TRACTOR	NN40326
19/09/201	CBD	UPPER INCOME	COMPACTOR	NN42328
	PARADISE	UPPER INCOME	COMPACTOR	NN48581
	NGAGANE	UPPER INCOME	SKIP TRUCK	NN52193
	NEWCASTLE CBD	UPPER INCOME	COMPACTOR	NN25881
	MADADENI CUSTOMERS	UPPER INCOME	COMPACTOR	NN40326
20/09/201	SUNNY RIDGE	UPPER INCOME	COMPACTOR	NN 55
	NEWCASTLE CBD	UPPER INCOME	COMPACTOR	NN 25881
	MADADENI CSTMERS	UPPER INCOME	COMPACTOR	NN 40326
	SIGNAL HILL	UPPER INCOME	COMPACTOR	NN42328
21/09/201	MADADENI CSTMERS	UPPER INCOME	COMPACTOR	NN40326
	NEWCASTLE CBD	UPPER INCOME	COMPACTOR	NN42328
24/09/201	INCANDU PARK	UPPER INCOME	COMPACTOR	NN48581
	NEWCASTLE CBD	UPPER INCOME	COMPACTOR	NN42328
	NGAGANE	UPPER INCOME	SKIP TRUCK	NN52193
	NEWCASTLE CBD	UPPER INCOME	COMPACTOR	NN12438
	LENNOXTON	UPPER INCOME	COMPACTOR	NN25881
	MADADENI CTMERS	UPPER INCOME	TRACTOR	NN40326

DATE	COLLECTION POINT	PAPER	PLASTIC	GLASS	METAL	BIOGENIC	OTHER
		34.1	19.025	17.8	6.5	26.4	11.53611
	CBD						
19/09/2012	CBD						
		52.55	20.5		20	46.5	19.5
	CBD/FAIRLEIGH						
	CBD/FAIRLEIGH						
		88	12.85	21.85	19.6	16.3	12.44286
	CBD/INDUSTRIAL						
	CBD/INDUSTRIAL						
		62.1	37.55			31.05	32
	FERNWOOD						
	FERNWOOD						
		33.9	13.75	42.9	11	22.7	8.8
24/09/2012	INCANDU PARK						
24/09/2012	INCANDU PARK						
		67.4	19.05	25.8	6.65	16.1	15.42381
	LENNOXTON						
	LENNOXTON						
		74.4	26.95	8.5	5.15	19.6	16.715
	MADADENI CSTMERS						
21/09/2012	MADADENI CSTMERS						
	MADADENI CSTMERS						
21/09/2012	MADADENI CSTMERS						
	MADADENI CTMERS						
	MADADENI CTMERS						
	MADADENI CUSTOMERS						
	MADADENI CUSTOMERS						
		80.3375	45.02833	47.775	25.94	58.23	40.19257
	MADADENI KHANANA						
	MADADENI KHANANA						
		72.7	11.1	43.55	21.9	25.2	25.4
	MADADENI SEC 4						
	MADADENI SEC 4						
		18.8	20.3		22.95	60.5	18.85385
	MADADENI SEC 5						
	MADADENI SEC 5						
		18	43.5	15.5	16.5	23.5	26
	MADADENI SEC 7						
	MADADENI SEC 7						
	MADADENI SEC 7						
	MADADENI SEC 7						
	MADADENI SEC 7						
	MADADENI SEC 7						
		73.85833	29.55833	34.95833	16.25	45.175	27.38
	MATHUKUZA						
	MATHUKUZA						
		80.05	20.3	23.6	10.45	36.3	20.4
	NEWCASTLE CBD						
	NEWCASTLE CBD						

DATE	COLLECTION POINT	PAPER	PLASTIC	GLASS	METAL	BIOGENIC	OTHER
		34.1	19.025	17.8	6.5	26.4	11.53611
	CBD						
19/09/201	CBD						
		52.55	20.5		20	46.5	19.5
	CBD/FAIRLEIGH						
	CBD/FAIRLEIGH						
		88	12.85	21.85	19.6	16.3	12.44286
	CBD/INDUSTRIAL						
	CBD/INDUSTRIAL						
		62.1	37.55			31.05	32
	FERNWOOD						
	FERNWOOD						
		33.9	13.75	42.9	11	22.7	8.8
24/09/201	INCANDU PARK						
24/09/201	INCANDU PARK						
		67.4	19.05	25.8	6.65	16.1	15.42381
	LENNOXTON						
	LENNOXTON						
		74.4	26.95	8.5	5.15	19.6	16.715
	MADADENI CSTMERS						
21/09/201	MADADENI CSTMERS						
	MADADENI CSTMERS						
21/09/201	MADADENI CSTMERS						
	MADADENI CTMERS						
	MADADENI CTMERS						
	MADADENI CUSTOMERS						
	MADADENI CUSTOMERS						
		80.3375	45.02833	47.775	25.94	58.23	40.19257
	MADADENI KHANANA						
	MADADENI KHANANA						
		72.7	11.1	43.55	21.9	25.2	25.4
	MADADENI SEC 4						
	MADADENI SEC 4						
		18.8	20.3		22.95	60.5	18.85385
	MADADENI SEC 5						
	MADADENI SEC 5						
		18	43.5	15.5	16.5	23.5	26
	MADADENI SEC 7						
	MADADENI SEC 7						
	MADADENI SEC 7						
	MADADENI SEC 7						
	MADADENI SEC 7						
	MADADENI SEC 7						
		73.85833	29.55833	34.95833	16.25	45.175	27.38
	MATHUKUZA						
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	NEWCASTLE CBD						
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