

Towards a waste information-based platform for waste recycling and energy generation – North West province, South Africa

Mapereka Francis L. Chagunda

 **orcid.org 0000-0002-2715-5016**

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Promoter: Prof T.M. Ruhiiga

Co-promoter: Prof L.G. Palamuleni

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Student number: 28242270

DECLARATION

I declare that this thesis is original work generated from data collected by myself towards a PhD degree at North-West University. All sources of help have been acknowledged.

Part of the thesis have been presented at the following conferences:

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Candidate’s signature:.....Date:

Supervisor’s Signature:.....Date:

Co-Supervisor’s Signature:.....Date:

DEDICATION

I would like to dedicate this work to GOD. HE has shown me that anything is possible regardless of situation. Thank you, Almighty GOD!

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ABSTRACT

This study was conducted to assess the status of waste information on municipal solid waste management with particular interest in waste recycling and waste-to-energy (WtE) generation projects. The North West province of South Africa was selected as a study area because it is experiencing rapid development, population growth, lacks proper waste management strategies and lacks information on generated waste. On the other hand, existing waste management in North West province is rather poor, with no information on separation of waste, no known treatments of waste apart from the popular disposal of waste in controlled and uncontrolled open landfills where waste is burnt for volume reduction.

The study used a quantitative research design built around field observations and measurement of elements of the waste chain to generate primary data sets. The information was supplemented by the use of secondary data sets of documents, records on waste information and waste management and informal consultations with officials responsible for the individual waste directorates at local municipalities. Multiple correlation and linear regression techniques were used to analyse primary and secondary data sets.

The results showed that it is a challenge for North West province to have waste information that meets the requirements of the South African waste information system (SAWIS) on waste data collection and submission. The results revealed that information along the waste chain is not being collected. It also shows lack of information on other waste treatment strategies apart from landfilling in the province. There is no adequate information on WtE generation and recycling, but there is potential for stand-alone WtE generation and waste recycling in the province. Weaknesses are noted in the current waste information collection system. These include lack of proper tools for information collection, processing and dissemination, lack of compliance with the national waste information regulators by role players, lack of proper handling of waste information during collection and processing and lack of collection of data or information from point of waste generation through to treatment or disposal.

The results were then deployed in the design of an interactive waste information platform (WIP) that overrides current constraints. The contribution of the WIP is that it allows for the inclusion of measures originally not covered within existing municipal tools, representing a break-through, the first of its kind in South Africa. The WIP introduces a methodological innovation in data collection, allows for data optimization, has an impact on decision structures and is compatible with the existing SAWIS.

ACRONYMNS

C&DW:	Construction and Demolition Waste
C&IW:	Commercial and Industrial Waste
DEA:	Department of Environmental Affairs
DEAT:	Department of Environmental Affairs and Tourism
est:	Estimated
GHGs:	Greenhouse Gases
GPS:	Global Positioning System
IWMP:	Integrated Waste Management Plan
ms:	Measured
MSW:	Municipal Solid Waste
MSWM:	Municipal Solid Waste Management
NEMA:	National Environmental Waste Management Act
NEM- IWMB:	National Environmental Management: Integrated Waste Management Bill
NEMWA:	National Environmental Management: Waste Act
NWMS:	National Waste Management Strategy
NWP:	North West Province
NWU:	North West University
PIWMP:	Provincial Integrated Waste Management Plan
READ:	Rural Environment & Agricultural Development
SAWIC:	South African Waste Information Centre

SAWIS:	South African Waste Information System
SWM:	Solid Waste Management
USA:	United States of America
WIP:	Waste Information-Based Platform
WIS:	Waste Information System
WMS:	Waste Management Systems
WtE:	Waste-to-Energy

Table of Contents

DECLARATION	i
DEDICATION	ii
ACKNOWLEDGEMENTS	iii
ABSTRACT	v
ACRONYMNS	vi
LIST OF TABLES	xiv
LIST OF FIGURES	xvi
LIST OF PLATES	xviii
DEFINITION OF CONCEPTS	xix
CHAPTER 1	1
INTRODUCTION	1
1.1 Background.....	1
1.2 Problem Statement	4
1.3 Research Aim.....	5
1.4 Objectives	5
1.5 Hypothesis	5
1.6 Rationale.....	6
1.7 The Study Area	7
1.8 Ethics.....	12
1.9 Structure of the Thesis.....	12
CHAPTER 2	13
LITERATURE REVIEW	13
2.1 Introduction	13
2.2 Waste management	13
2.2.1 Policy and legislative initiatives in waste management.....	13
2.3 Waste treatment	16
2.3.1 Waste recycling.....	16

2.3.2	Waste-to-energy generation	17
2.4	Waste information.....	20
2.5	Information Platforms Theories	23
2.6	Key challenges	27
2.7	Knowledge gaps.....	29
CHAPTER 3		32
METHODOLOGY		32
3.1	Introduction	32
3.2	State of waste information in the NWP	32
3.2.1	Research design.....	32
3.2.2	Population and unit of analysis	32
3.2.3	Data sources	32
3.2.4	Specification of variables.....	33
3.2.5	Collection instruments	33
3.2.6	Sampling procedures	33
3.2.7	Data collection	34
3.2.8	Analytical techniques	34
3.3	Components of the waste chain facilities	34
3.3.1	Research design.....	34
3.3.2	Population and unit of analysis	35
3.3.3	Data sources	35
3.3.4	Specification of variables.....	35
3.3.5	Analytical techniques	36
3.4	State of waste treatment in NWP	36
3.4.1	Research design.....	36
3.4.2	Population and unit of analysis	36
3.4.3	Data sources	36
3.4.4	Specification of variables.....	37

3.4.5	Collection instruments	37
3.4.6	Data analysis	37
3.5	Potential for waste-to-energy generation and recycling	37
3.5.1	Research design.....	37
3.5.2	Population and unit of analysis	38
3.5.3	Data sources	38
3.5.4	Specification of variables.....	38
3.5.5	Sampling procedures	39
3.5.6	Estimating the quantities of each class of waste	39
3.5.7	Measuring moisture content.....	41
3.5.8	Calorific values of the waste.....	41
3.5.9	Analytical techniques	41
CHAPTER 4		42
STATE OF WASTE INFORMATION IN THE NWP		42
4.1	Introduction	42
4.2	Importance of waste information	42
4.3	Results and Discussion.....	44
4.3.1	Waste indicators	44
4.3.2	Compliance with SAWIS.....	46
4.3.3	Handling of waste information by municipalities	52
4.3.4	Type of information available.....	56
4.3.5	Stages of waste information.....	60
4.4	Challenges in implementation of SAWIS	63
4.5	Summary	65
CHAPTER 5		66
COMPONENTS OF THE WASTE CHAIN FACILITIES		66
5.1	Introduction	66
5.2	Waste chain profile	67

5.2.1	Transfer stations	67
5.2.2	Buy-back centres	68
5.2.3	Waste treatment facilities.....	68
5.3	Results and Discussion.....	70
5.3.1	Waste facilities	70
5.3.2	Distribution trends.....	71
5.4	Summary	80
CHAPTER 6		81
STATE OF WASTE TREATMENT IN NWP		81
6.1	Introduction	81
6.2	Recycling.....	82
6.3	Incineration.....	83
6.4	Waste-to-energy.....	83
6.5	Composting.....	84
6.6	Results and Discussion.....	85
6.6.1	Waste treatment.....	85
6.6.2	Waste treatment facilities.....	89
6.6.3	Distribution	91
6.7	Summary	94
CHAPTER 7		96
POTENTIAL FOR WASTE-TO-ENERGY GENERATION AND RECYCLING		96
7.1	Introduction	96
7.2	Waste-to-energy (WtE)	96
7.2.1	Process dynamics	96
7.2.2	Waste for WtE generation.....	97
7.2.3	Moisture content of MSW	98
7.2.4	Calorific value of MSW.....	98
7.2.5	WtE generation.....	99

7.2.6	Information on WtE generation.....	100
7.2.7	Current status of WtE generation	101
7.3	Waste recycling.....	102
7.3.1	Process dynamics	102
7.3.2	Waste streams for recyclables	103
7.3.3	Waste segregation at source	104
7.4	Results and Discussion.....	104
7.4.1	Waste generation in NWP.....	104
7.4.2	Moisture content of MSW	107
7.4.3	Calorific value of MSW.....	111
7.4.4	Potential of energy generation in NWP	113
7.4.6	Waste recycling	117
7.4.7	Potential of waste recycling projects	118
7.4.8	Options for the NWP	119
7.5	Summary	119
CHAPTER 8		120
DESIGN OF A WASTE INFORMATION-BASED PLATFORM		120
8.1	Introduction	120
8.2	Key findings	120
8.3	Rationale.....	123
8.4	South African Waste Information System (SAWIS)	123
8.4.1	SAWIS Framework	123
8.4.2	SAWIS design inputs.....	125
8.4.3	SAWIS design flow paths	125
8.4.4	Shortfalls in the SAWIS Operations.....	126
8.5	The Proposed Waste information-based Platform (WIP).....	127
8.5.1	Background	127
8.5.2	Assumptions.....	127

8.5.3	WIP design.....	128
8.5.4	WIP data collection template	130
8.5.5	WIP and SAWIS integration.....	131
8.5.6	WIP information generation.....	133
8.5.7	Applications potential of WIP.....	136
8.6	Summary	137
CHAPTER 9		138
CONTRIBUTION, CONCLUSION AND RECOMMENDATIONS		138
9.1	Introduction	138
9.2	Knowledge gaps.....	138
9.3	Key findings of the study	139
9.4	Knowledge gaps addressed by this study	141
9.5	Limitations of the study implementation of WIP	143
9.6	Contribution of the study.....	143
9.7	Conclusions	146
9.8	Areas of further study.....	147
9.9	Recommendations	148
REFERENCES		150
APPENDICES		166

LIST OF TABLES

Table 1:	Estimates of waste generation at each income level for municipalities for 2011, 2016 and 2020	2
Table 2:	Districts and Local Municipalities in NWP	7
Table 3:	Developmental Indicators for North West Province.....	10
Table 4:	North West province employment statistics by industry	11
Table 5:	Structure of thesis	12
Table 6:	Published waste generation data for Africa.....	22
Table 7:	Specification of variables	33
Table 8:	Specific variables.....	35
Table 9:	Specific variables.....	37
Table 10:	Specific variables.....	38
Table 11:	Indicators on SAWIS Template and Municipalities' Collection tools	47
Table 12:	Pearson's correlation analysis	48
Table 13:	Variables entered/removed, model summary and ANOVA.....	50
Table 14:	Coefficients.....	51
Table 15:	Status of information collection and reporting to SAWIS	52
Table 16:	Number of landfills that report waste information to SAWIS after trainings	53
Table 17:	Descriptive statistics on municipalities that report information to SAWIS	53
Table 18:	Correlations analysis on the relationship between number of municipalities and landfills trained and submitting waste information to SAWIS	54
Table 19:	Regression analysis.....	55
Table 20:	Standardised coefficients.....	56
Table 21:	Estimates of Quantities/Year of Municipal Waste for each District in NWP for 2011, 2016 and 2020.....	105
Table 22:	Averages of Moisture Contents of each class of Waste in NWP	109
Table 23:	Relationship between Moisture content and calorific value	110
Table 24:	Income Stages of a Country, Moisture Contents and Calorific Values of Waste	110
Table 25:	Calorific Values of Waste in Countries in the same Climatic Region as South Africa	112
Table 26:	Calorific Values of Waste Classes.....	112

Table 27: Summary of the Moisture Content, Calorific Values and Quantities/Year of Classes of Waste	113
Table 28: Quantities for the Classes of Waste after removing Waste for Recycling	114
Table 29: WtE technologies and energy generation.....	115
Table 30: Potential of energy generation in NWP	116
Table 31: Quantities of classes of waste before and after removing waste for recycling in SA	118
Table 32: Key findings	121
Table 33: Key findings carried forward.....	123
Table 34: Data collected by SAWIS	124
Table 35: WIP template	131
Table 36: Waste information generated by WIP	136

LIST OF FIGURES

Figure 1:	North West Province showing districts and municipalities	7
Figure 2:	Rail and road networks in NWP	8
Figure 3:	Major mines in the NWP	9
Figure 4:	Towns in the North Waste Province and their populations	10
Figure 5:	A typical incinerator	19
Figure 6:	Impact of moisture and organic content on calorific value of waste	21
Figure 7:	Linked streaming information platform	24
Figure 8:	Transport direct information platform	26
Figure 9:	Continuous healthcare service provision and connection	27
Figure 10:	Percentage of Information Collected	57
Figure 11:	Solid Waste Stream	67
Figure 12:	Distribution of waste facilities in municipalities	71
Figure 13:	Landfills in each municipality	72
Figure 14:	Transfer stations in each municipality	73
Figure 15:	Buy-back centres in each municipality	75
Figure 16:	Recycling facilities in each municipality	77
Figure 17:	Number and Type of Waste Treatment Facilities in Municipalities	90
Figure 18:	Distribution of waste treatment facilities	92
Figure 19:	Electricity Generation from MSW by Incineration	97
Figure 20:	Schematic of WtE generation plant	100
Figure 21:	Flow path for waste recycling	102
Figure 22:	Estimates of quantities of municipal waste for NWP	105
Figure 23:	Estimated Quantities of Waste Classes	106
Figure 24:	Average Moisture Contents of Waste in Different Rainfall Regions of the NWP	108
Figure 25:	South Africa Waste Information System (SAWIS)	124
Figure 26:	Authorisation process for the Central Registry	125
Figure 27:	Flow path of SAWIS	126
Figure 28:	Design of waste information-based platform	129
Figure 29:	Integration of WIP into SAWIS	132
Figure 30:	WIP	133
Figure 31:	Sample of WIP	134

Figure 32: Integrated SAWIS and Waste Information-Based Platform (WIP).....	135
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LIST OF PLATES

Plate 1:	Poor management of landfill. Delareyville landfill in Tswaing	72
Plate 2:	Transfer Station in Vryburg, Naledi Local Municipality	74
Plate 3:	Buy-Buck Centre in Sannieshoff, Tswaing Local Municipality	76
Plate 4:	Recycling Products Hartbeespoort, Madibeng Local Municipality	78
Plate 5:	Buy-Back Centres in Brits, Madibogo and Wolmaransstad	87
Plate 6:	Tyres at Schwaizer-Reneke landfill, plastics at Delareyville landfill and garden waste at Mafikeng dumpsite	107

DEFINITION OF CONCEPTS

Buy-back Centre: is a designated point where people deliver and sell recyclable materials (DEA 2011a).

Down-cycling is defined as the reprocessing of end of life waste into products of inferior quality, compared to the primary material, for example, concrete being crushed into aggregate (Haas et al., 2015).

Landfill: is waste disposal facility that adheres to waste treatment laws and processing regulations (DEA 2011a).

Municipal solid waste: is waste collected from the municipality by or on behalf of a local municipality and is defined as all domestic refuse and non-hazardous wastes such as commercial and institutional wastes, street sweepings and construction debris (Shekdar, 2009).

Platform: is used in this research to describe a particular type of framework based on multiple pathways each with a multiplier effect on downstream responses.

SAWIC: it is a national waste information tool developed to provide the public and government with access to waste information in South Africa (DEAT, 2005a).

SAWIS: the South African waste information system responsible for keeping waste databases from the various provinces for reference and control purposes

Recycling: is any recovery operation by which waste is reprocessed into products, materials, or substances that can serve the original or comparable purposes (Haas et al., 2015).

Solid waste management: is the collection, transportation, processing, recycling or disposal and monitoring of solid waste material from different sources (Wilson et al., 2015).

Transfer Station: is a facility where waste is temporarily stored, and ideally sorted, before it is transported more economically to either recycling centres or landfills (DEA 2011a)

Waste chain: is the path trace of waste from generation to the point of disposal that comprises of the following levels: generation, storage, collection, transfer and transport, processing and disposal of solid wastes (Sharholi et al., 2008).

Waste-to-energy generation: is incineration of waste where the combustible waste flux is converted to a gaseous phase (Antonopoulos et al., 2014).

Waste information: is the data on source, quantity, class, emissions, moisture content, calorific values and heavy metal levels in solid waste at each waste chain (DEAT, 2006).

Waste fraction: is the class of waste including plastics, food, garden, textile, leather, rubber, wood, and paper (Edjabou et al., 2015).

Waste treatment: is the process of minimizing the volume of waste to be landfilled whilst recovering as much resources out of it as possible (Arafat et al., 2015).

INTRODUCTION

1.1 Background

Waste information plays a critical role in municipal solid waste management (MSWM). Information on waste-source, quantity, composition, characteristics, seasonal variations and current generation trends are important planning inputs. This information is an important input for waste analysis and can be used to choose suitable treatment options. This is because different municipal waste streams often call for a differentiation in treatment methods (Ngoc and Schnitzer, 2009).

Globally there is a challenge of availability of proper waste information. The best available information consists of compilations of older, incomparable data that is often limited to national level (Karak et al., 2012). Key waste-related data comprise the calculated MSW generation per capita per year and the MSW composition, which both vary between cities (Wilson et al., 2015) and are important for resource recovery and/or technology selection. Lack of up-to-date and detailed waste data is often the norm in developing countries. This can either constitute a barrier to action or allow incorrect assumptions (Wilson et al., 2015); that is either an overestimation or underestimation of a particular waste treatment; thereby rendering it unsustainable. For instance, in recycling, there is recycling and down-cycling. In this context, data on recycling flows often do not allow distinction between re- and down-cycling; it is assumed that, in particular, the recycling flow of construction materials includes a considerable amount of down-cycling (Haas et al., 2015). Without proper information therefore, these two would be regarded as one thing and would result in misleading planning of recycling projects.

SWM has become an issue of increasing global concern as urban populations continue to rise and consumption patterns change leading to an increase in heterogeneity and complexity of the generated waste (Marshall and Farahbakhsh, 2013). It is estimated that the annual total solid waste generation worldwide is 17 billion tonnes and it is expected to reach 27 billion by 2050 (Karak et al., 2012). Of the 17 billion tonnes, about 1.3 billion tonnes are MSW generated by world cities, which are anticipated to generate up to 2.2 billion tonnes by 2025 primarily due to population growth, increasing urbanization and socio-economic development of low- and middle-income countries (Hoornweg and Bhada-Tata, 2012; Laurent et al., 2014; Kawai and

Tasaki, 2016). Estimates of waste generation volumes for South Africa and its provinces remain problematic due to issues related to the keeping of reliable data sets. Nevertheless, Table 1 shows Estimates for waste generation in North West province, districts, municipalities and at every income levels of the municipalities for 2011, 2016 and 2020.

Table 1: Estimates of waste generation at each income level for municipalities for 2011, 2016 and 2020

District	Municipality	Income levels	Waste Generation(tons/year)		
			2011	2016	2020
DRRM	Lekwa-Teemane	Low	3657.57	3696.89	3728.34
		Medium	7493.17		7638.16
		High	526.51	532.17	536.70
	Mamusa	Low	4723.80	4776.00	4817.76
		Medium	7368.45	7449.87	7515.01
		High	710.45	718.30	724.58
	Naledi	Low	4507.19	4545.73	4576.56
		Medium	9018.77	9095.88	9157.57
		High	1540.75	1553.92	1564.46
DKK	Tlokwe	Low	9962.15	10080.70	10175.54
		Medium	22816.29	23087.80	23305.01
		High	5517.83	5583.49	5636.02
NMM	Mahikeng	Low	21726.25	21852.27	21953.08
		Medium	35354.91	35559.97	35724.01
		High	7000.54	7041.14	7073.63
BOJANALA	Madibeng	Low	30362.03	30843.27	31228.26
		Medium	68983.23	70076.61	70951.32
		High	8990.99	9133.50	9247.51
	Rustenburg	Low	28620.88	29121.74	29522.43
		Medium	88321.92	89867.56	91104.06
		High	14749.74	15007.86	15214.36

The daunting increase in solid waste generation calls for solid waste management systems, which address environmental problems and ultimately contribute towards a more environmentally sustainable society (Laurent et al., 2014). Municipal solid waste management (MSWM) is the process of proper collection, processing, transportation, and monitoring of MSW products (Wilson et al., 2015). In most cities, the MSWM system comprises only of four activities, which are waste generation, collection, transportation, and disposal (Sharholy et al., 2008). The primary purposes of SWM strategies are to address the health, environmental, aesthetic, land-use, resource, and economic concerns associated with the improper disposal of waste (Henry et al., 2006; Nemerow, 2009; Senzige et al., 2014).

Solid waste management without waste prevention, education and awareness is known to be an important contributor to environmental problems, such as climate change, stratospheric ozone depletion, human health damages, ecosystem damages and resource depletion (Laurent et al., 2014). These issues are an on-going concern for nations, municipalities, corporations, and individuals around the world (Nemerow, 2009; Marshall and Farahbakhsh, 2013). It is, therefore, vital to build a common understanding of the importance of proper MSWM (Zhang et al., 2010). A proper MSWM system should be effective throughout the waste stream. Waste stream is the path of the waste from generation of waste, where if the waste is not reduced or reused, it is collected and transported to transfer stations where it is separated and taken to buy-back centres. From the buy-back centres it is either taken to treatment facilities (recycling, incineration, compositing) or landfills where it is either collected by waste reclaimers, buried or burnt. This will be discussed more in the coming chapters as the waste stream is crucial in building up of reliable waste information database.

While developed countries are better organised in implementing systems for handling waste, for many cities of the developing world remedial measures have been elusive; efforts are uncoordinated or ad hoc, and the resources invested in the sector are inadequate (Marshall and Farahbakhsh, 2013). In South Africa, legislation dealing with waste is fragmented and administered by a number of regulatory bodies across all tiers of government, resulting in duplication and overlapping of functions (Mudau et al., 2013; Mudau, 2015). Exacerbating the situation is the lack of proper flow of waste information (DEAT, 2005a).

Developed countries have waste information databases on quantity of waste generated, classification, and quantity of waste recycled, treated and taken to landfill. This information enhances the effectiveness and reliability of waste management systems thus ensuring that their

solutions are comprehensive, practical and encompass the wide variety of processes involved in each waste stream. Information on how the waste is increasing is important because it helps in planning for waste management. Challenges arise in how to generate and integrate the waste information flow system with the waste management systems to improve the waste management system. This thesis is driven by this challenge to develop a waste information-based platform for waste recycling and energy generation.

1.2 Problem Statement

Having waste information on quantity, separation, status of moisture content, calorific value, quantities, classification and nutrient content of the waste is important for it can be used in decisions about how to handle such waste (Cheng and Hu, 2010). The South African Waste Information System (SAWIS) was developed and implemented in 2005 (DEAT, 2005b; DEAT 2006). It makes it possible to standardise methodologies for waste data collection, packaging and transmission to a central data base. Two internet-based information systems support the collection of waste data; the Central Registry and the Waste Information System (WIS) (DEAT, 2005a). The former is where municipalities, businesses, institutions companies or individuals register their identified activities on waste, waste facilities and land use for waste. Although SAWIS has been developed, there is still a waste information gap. The problem is that most provinces do not collect information on waste characterisation, volumes generated as well as recycling and other waste treatment (DACE, 2008). Troschinetz and Mihelcic (2009) in a study on sustainable recycling of municipal solid waste in developing countries noted that there was no reliable waste information available for South Africa. National legislation and guidelines on waste and its management have been set up since 1995 but municipalities still face severe hardships. These arise as a result of the failure to develop a standardized methodology for collecting, reporting and disseminating waste information. For NWP, the need to establish the feasibility of waste recycling projects and waste to energy facilities becomes very important. This is because both are examples of industrial projects whose set up requires that certain policy and economic fundamentals be evaluated. These two require significant capital investment which are normally raised through private sector money markets. Capital has to be competed for both within the NWP domestic market and within the larger South African national money market.

Given that every investment faces underlying risks, it is necessary that a feasibility assessment be carried out to inform NWP government about opportunities, threats and potential benefits

that may accrue. Decision-making with regard to long term industrial investments cannot ignore the prevailing economic climate and key fundamentals. The extent to which the NWP government is willing to invest directly and or indirectly in supporting such projects will also be informed by the results of such feasibility analysis.

Against this background and in line with the findings of the READ (2017a) and READ (2017b), this study, therefore, aims to make a contribution towards establishing a waste information system to improve municipal waste management through the development of a waste information-based platform.

1.3 Research Aim

The aim of this study is to develop a waste information-based platform for waste recycling and energy generation in NWP.

1.4 Objectives

The following objectives were advanced to guide the study:

- 1- Review, assess and report the state of waste information in North West province (NWP).
- 2- Outline the waste chain facilities.
- 3- Examine adequacy of waste treatment and report state of waste treatment facilities in NWP.
- 4- Assess the potential for waste recycling and waste-to-energy generation in NWP.
- 5- Develop a waste information-based platform.

1.5 Hypothesis

The hypotheses stated here makes it possible to test the waste information system in terms of its usefulness in waste management and methods of waste information collection. H_0 : Null hypothesis and H_1 : Alternative hypothesis. For purposes of this study, two research hypotheses are specified that directly attempt to test the link between information collection, landfills and the status of training for municipal personnel.

Research Hypothesis 1: H_0

There is no relationship between the information available (y) for waste data capture and transmission to the SAWIC template and the indicators within the six collection tools ($X_1 \dots X_n$). The research hypothesis is of the form: $H_1: \beta \neq 0$ while the corresponding null hypothesis is of the form: $H_0: \beta = 0$. Hypothesis testing in this case attempts to find evidence or otherwise of the null hypothesis in light of the applicable statistical analyses.

Research Hypothesis 2: H_0

H2: There is no relationship between the extent of training and the regular reporting of waste statistics from landfills to SAWIS. The research hypothesis is of the form: $H_1: \beta \neq 0$ while the corresponding null hypothesis is of the form: $H_0: \beta = 0$. Hypothesis testing in this case attempts to find evidence or otherwise of the null hypothesis in light of the statistical analyses.

1.6 Rationale

There is contradicting waste information for developing countries, including South Africa. The information that is available on generation as well as treatment of MSW is neither consistent nor reliable. There is information that shows that in South Africa the amount of waste that is taken for landfilling is 90 % while 10 % is recycled but this information is based on estimates (DEA, 2012). However, the information on waste that is available for South Africa as a country is not disaggregated to indicate information per province. Some of the provinces in South Africa do not have any information on waste including North West province. Therefore, North West province was selected as a study area because of the rapid development, increase in population, lack of proper waste management and the need to address the lack of information on waste that is generated in the province (DACE, 2008). On the other hand, existing waste management in NWP is rather poor, with no information on separation of waste, no known treatments of waste apart from the popular disposal of waste in controlled and uncontrolled open landfills where waste is burnt for volume reduction. This creates a danger to the environment and population health. This study is the first of its kind that has observed and study the information system on waste throughout the waste chain and developed a waste information-based platform. This study is important because, apart from establishing the reliable waste information system, it will influence the waste management teams at different waste chain levels to integrate waste information collection within a well-functioning MSW management system so as to guarantee proper treatment and disposal of municipal solid waste in South Africa.

1.7 The Study Area

North West province of South Africa (Fig. 1, inset) lies in the northern part of South Africa on the Botswana border. The province has 4 districts and 19 local municipalities shown in Table 2 and in Fig. 1. Fig. 1 also shows 8 randomly sampled municipalities.

Table 2: Districts and Local Municipalities in NWP

Name of District	Local Municipality
Ngaka-Modiri Molema	Ratlou, Mahikeng, Tswaing, Ditsobotla and Ramotshere Moiloa
Dr. Kenneth Kaunda	Maquassi Hills, City of Matlosana, Ventersdorp and Tlokwe
Dr. Ruth Mompoti	Kagisano/Molopo, Naledi, Taung, Mamusa and Lekwa-Teemane
Bojanala	Kgetlengrivier, Madibeng, Moretele, Rustenburg and Moses Kotane

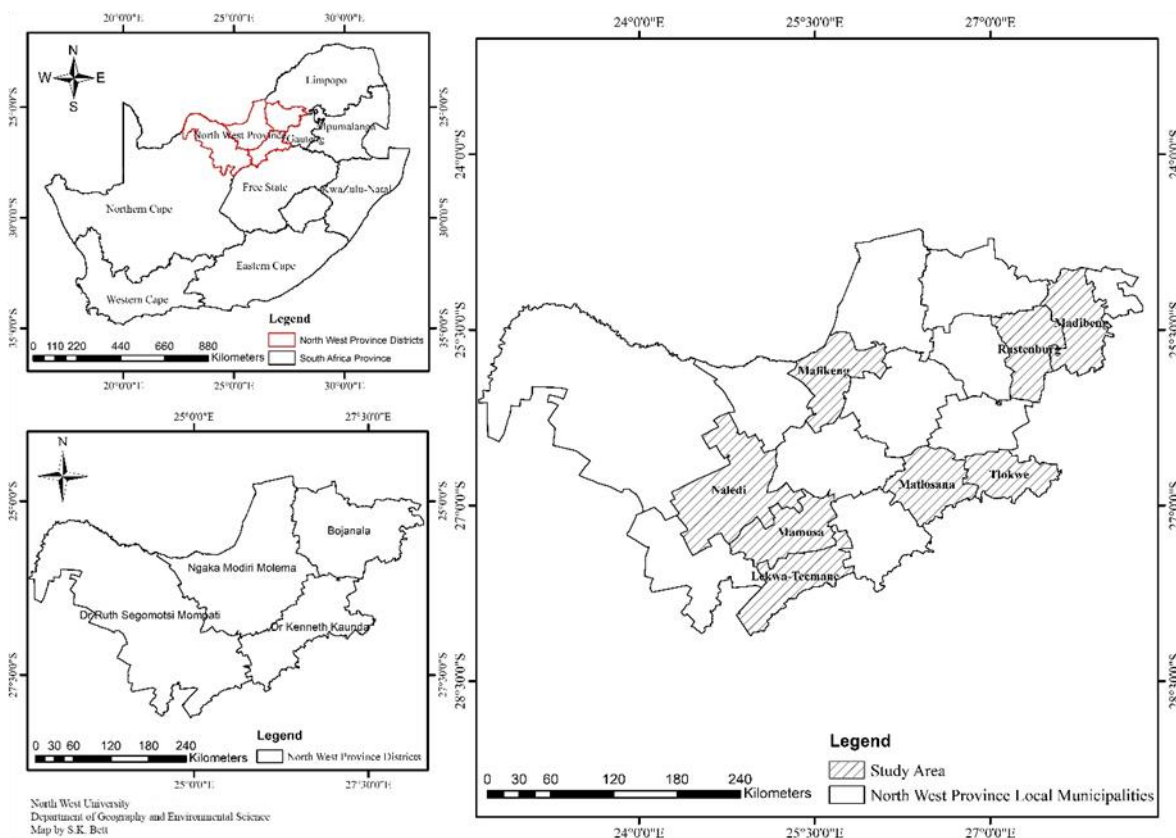


Figure 1: North West Province showing districts and municipalities

NWP is one of the nine provinces of South Africa covering a total land area of 105,076 km², which translates to 8.6 % of South Africa's total land area.

NWP is strategically located in that the main railway line that runs from Cape Town to Zimbabwe passes through the provincial capital, Mahikeng. The railway links the NWP to several southern African countries, including Angola, Zambia and Botswana. Fig. 2 shows the railway and road network in NWP.

The major commercial centres of the province are connected to the rest of the country through an extensive road network of 1,700 kilometres as of 2016. Harbour linkages are with Maputo in Mozambique, Richard's Bay and Durban in Kwa-Zulu natal, Port Elizabeth the East London in Eastern Cape and Cape Town in Western Cape.

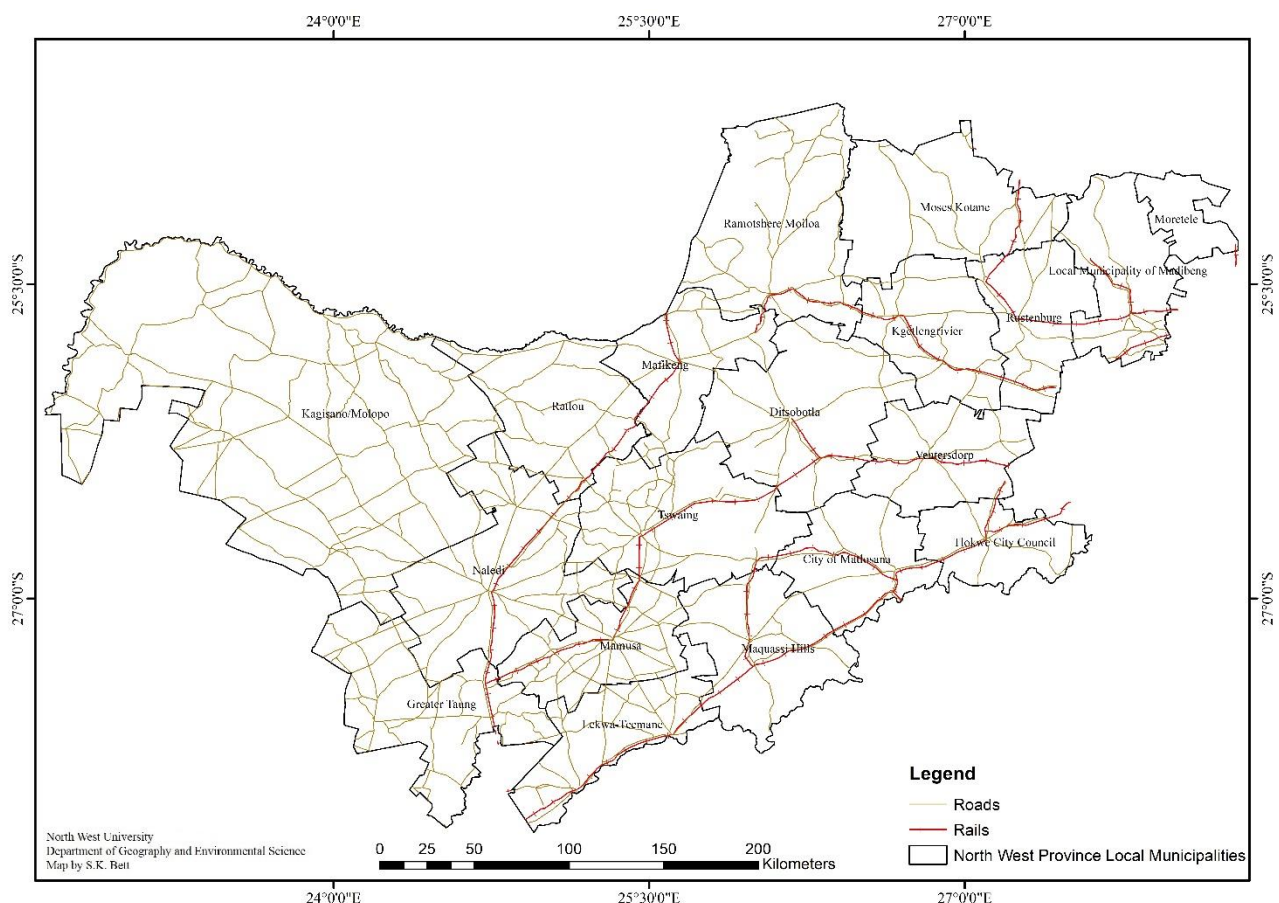


Figure 2: Rail and road networks in NWP

The business sector has developed in recent years due to improvements in inter-state transport highways along the Trans Kalahari Corridor linking NWP with both Botswana and Namibia. The province has wide climatic variations due to its sub-tropical location. Temperatures range

from 17°C to 31°C in summer and from 3°C to 21°C in winter. Annual rainfall totals about 360 mm, with almost all of it falling during the summer months, between October and April.

The main economic activities of North West province are mining and commercial agriculture. Together with the Free State province, the NWP is a major bread basket for South Africa (cereals, beef & dairy). Mining generates more than half of the province's gross domestic product and provides jobs for a quarter of its workforce. Fig. 3 shows the distribution of some of the mines in the NWP. The province contributes 6.8 % to the national gross domestic product.

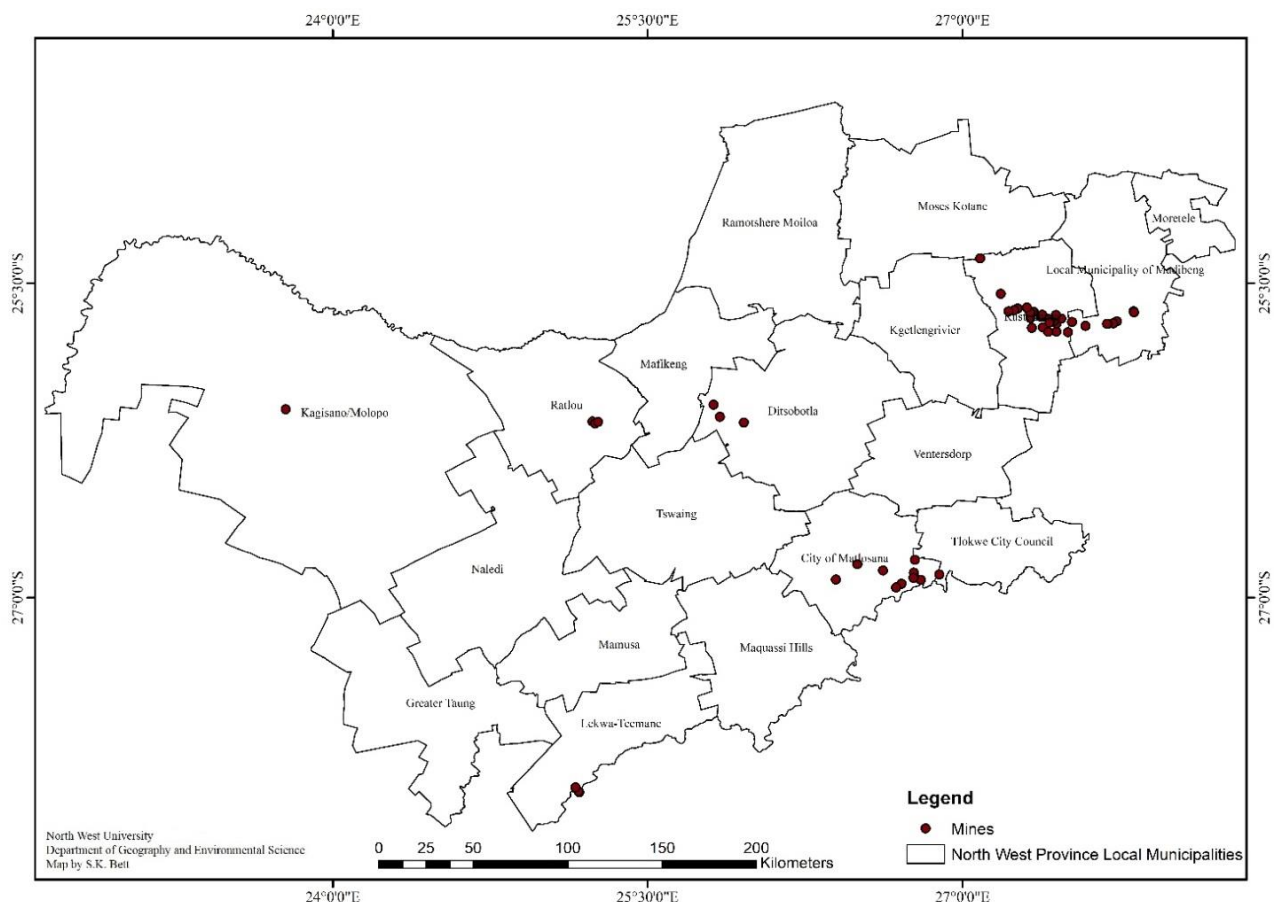


Figure 3: Major mines in the NWP

South Africa has a growing population characterized by both urbanization and the rapid development of the African middle class. Population of the North West province was 3,509,953 in 2011 (StatsSA, 2011) and StatsSA (2017) estimated the population to be 3, 856,200 in 2017. Fig. 4 shows the towns in NWP and their populations. The rapid development that is observed in South Africa as a country is also a characteristic of NWP. However, it is worth noting that development changes lifestyle and fashion, which directly impact on waste management.

Changing lifestyles and fashion over the years have led to increase in the amount of waste generated and has created problems for the government and local authorities in managing the collection, processing and disposal of waste (Kalyani and Pandey, 2014). Development in an area is shown by developmental indicators. StatsSA (2016) reports improvement in most of the applicable social indicators in NWP- Table 3.

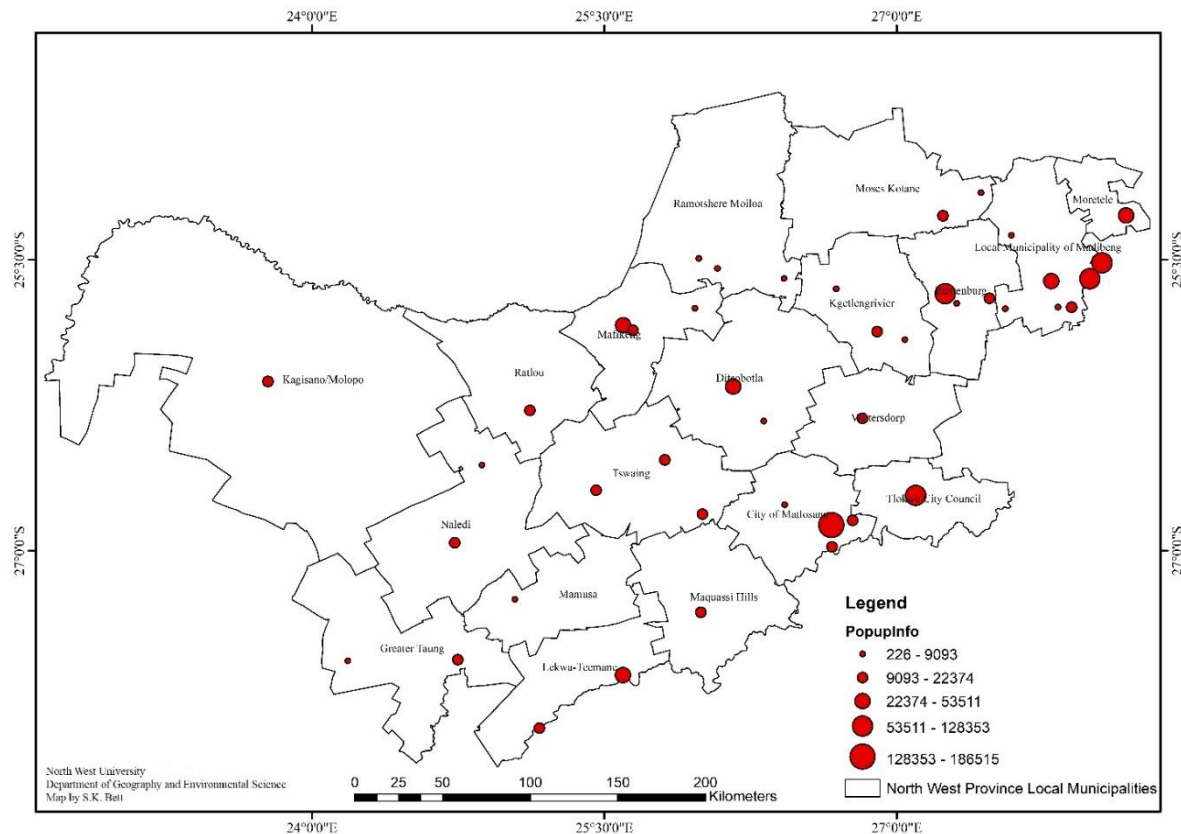


Figure 4: Towns in the North Waste Province and their populations

Table 3: Developmental Indicators for North West Province

Indicator	2009	2015
Human development index (HDI)	0.52	0.62
People living in poverty below the upper poverty line (%)	59.1	44.5
Index of Buying Power	0.0538	0.0549
Tress Index	0.5108	0.5012

Source: StatSA, 2016

Most notable of the indicators is the improvement in Human Development Index (HDI), which was 0.62 in 2015, up from 0.52 in 2009. Improvements were also observed in both the number

and percentage of people living below the upper poverty line at 44.5 % (2015) compared to the 59.1 % (2009). With regards to the economy, the Tress Index provides insight into the level of concentration (or diversification) within an economic region (Global Insight, 2016). A Tress index value of 0 means that all economic sectors in the region contribute equally to gross value added (GVA), whereas a Tress index of 1 means that only one economic sector makes up the whole GVA of the region (Global Insight, 2016). The Tress Index for NWP shows that the province's economy has become more diversified since 2009. This is an indication that the efforts to diversify the economy are paying off. The NWP is a large and significant local economy in the South African context, it contributes approximately 5.7 % to national production.

NWP has also experienced increase in employment in some key industries, decreasing the unemployment rate to slightly lower than that of the national average. Table 4 shows that manufacturing, construction, trade and transport have recorded a positive change between 2015 and 2016.

Table 4: North West province employment statistics by industry

Industry	April-June 2015 (Thousands)	April-June 2016 (Thousands)
Agriculture	54	37
Mining	154	140
Manufacturing	64	70
Utilities	5	4
Construction	62	77
Trade	171	193
Transport	25	33
Finance	110	83
Community and Social services	212	201
Private households	83	77

Source: StatsSA, 2016

The rapid urbanisation, population growth and industrialisation which include the increase in employment contribute towards large-scale increase and change in the characteristics and composition of solid waste generated (Tan et al., 2014). The increase in employment shows growth in the industries. The growth in industry is linked with generation of commercial and industrial waste (C&IW) and construction and demolition waste (C&DW) (Nasrullah et al., 2014). Increased construction leads to greater volumes of rubble. Trading activities are commonly associated with waste due to the related packaging industry. The waste generated

from trade can be in form of plastics, papers and cardboards, clothing and food, to mention a few. This means that increase in trade will increase the production of the mentioned waste classes. Manufacturing always comes with materials that cannot be used in production anymore known as by-products, leftovers or offcuts, which enter the waste stream if there is no proper plan for them. Increase in number of manufacturing industries means increases in the production and quantities of such materials.

1.8 Ethics

This research was carried out in compliance with ethical considerations of the North West University. Permission to collect data from the local municipalities was sought and obtained from authorities of the relevant institutions. Permission to take notes was obtained from the participants. The study followed principles of respect, the participants' right to anonymity, voluntary and right to refuse to participate was respected at individual, institutional and national levels; principles of protection of information, to ensure confidentiality, anonymity and privacy; numbers were used instead of names on the observation schedules so that participants would not be identified. The observation schedules were stored in a locked and secured place accessible to the researcher only; principle of prevention of harm when conducting research and the principles of transparency of information gathered from national government, local government, provincials, municipalities, landfill and waste treatment facilities were given to the waste management directorate.

1.9 Structure of the Thesis

The compilation of this thesis is organised in nine (9) chapters as shown in Table 5

Table 5: Structure of thesis

Chapter	Heading
1	Introduction
2	Literature review
3	Methodology
4	State of waste information in NWP
5	Components of the waste chain facilities
6	State of waste treatment in NWP
7	Potential for waste-to-energy generation and recycling in NWP
8	Design of waste information-based platform
9	Contribution, conclusion and recommendations

LITERATURE REVIEW**2.1 Introduction**

The brief survey of literature presented in this chapter addresses three linked issues. Firstly, it presents an overview of the state of knowledge on waste recycling and on waste-to-energy generation. Secondly, it provides the state of research on recent developments in waste management and alternative treatments other than the practice of traditional landfilling. Third, it situates the critical place of waste information in literally every form and stages of waste management.

2.2 Waste management

The waste management hierarchy remains a pillar of most waste minimization strategies. The aim of the hierarchy is to extract the maximum practical benefits from products and to generate the minimum amount of waste (Ngoc and Schnitzer, 2009). For the maintenance of environment health, there is need to develop effective ways of managing waste as an on-going project. Procedures for waste management include the setting up of legislative frameworks and applicable guidelines (DACE, 2008). Various tools, strategies and schemes need legislative policy for effective implementation (Zaman, 2014).

2.2.1 Policy and legislative initiatives in waste management

Good governance and policy instruments have always been considered as success factors in waste management systems. The integration of different waste management streams is critical as it involves the alignment of policies, initiatives, legislation and administrative systems. These initiatives are waste management laws that govern the generation, transport, storage, treatment and disposal of waste to protect human health and the environment. A democratic, public process of solid waste management (SWM) goal formulation is essential to determine the actual needs of the citizens, and therefore prioritize limited municipal resources appropriately (Marshall and Farahbakhsh, 2013). If adequate attention is not paid to these governance aspects, then any attempt to modernise SWM systems through technological improvements are likely to fail (Scheinberg et al., 2010).

The world, regional and national waste legislations endorse principles of waste management hierarchy. Policy weaknesses have failed SWM systems in many low-income countries due to inadequate formulation and implementation of realistic policies (Marshall and Farahbakhsh, 2013). Most developed nations have had legislative initiatives on waste management for ages and they put in place effective and functioning policy measures to address SWM needs. Some of the initiatives have been effective on improving the status of waste recycling and treatment while others have not impacted as expected.

In the United States, in 1795, Corporation of Georgetown and Washington DC, introduced legislation that prohibited waste disposal on the streets and required individuals to remove waste themselves or hire private contractors. This resulted in 50% of all major US cities providing a waste collection system in 1915, which rose to 100% by 1930. In 1989 Environmental Protection Agency (EPA) set its goal on national waste reduction and recycling. This goal was echoed in executive order 12780 that was issued in 1992, to stimulate waste reduction, recycling, and procurement of recycled goods in all federal agencies. This order was followed by two other executive orders between 1994 and 1998 where federal agencies were required to establish waste reduction and recycling programs and to buy and use recycled and environmentally preferable products and services (Kollikkathara, 2009).

Japan is a densely populated country with scarce land to accommodate disposal of increasing waste generation; this pressures Japan to come up with plans for effective waste management. There are a lot of researches being conducted and legislations enacted in Japan. The main framework of the present waste management, the 1970 Waste Disposal and Public Cleansing Law is constituted of two laws. The first law is Waste Disposal Law, which was enacted in 1900, to overcome sanitary problems in the cities and the second one is on Public Cleansing which was ratified in 1954 to secure a hygienically sound living environment (Tanaka, 2007). Adding to the two laws, Japanese government made efforts to implement Johannesburg Plan which was adopted at the World summit on Sustainable Development in September 2002. The Johannesburg plan called upon nations to encourage and promote the development of a 10-year framework of programs in support of regional and national initiatives to accelerate the shift toward sustainable consumption and production. Japanese government is implementing the Johannesburg plan by proposing the launch of an international joint research project to establish a common scheme to address the issues of material flow accounts and resource productivity in the Communiqué of the G8 Environment Ministers' Meeting held in April 2003 in Paris. In

keeping with this policy, Japan also proposed the 3R (reduce, reuse, and recycle) initiative at the G8 meeting held at Sea Island, Georgia, USA (Tanaka, 2007). These laws enhance several waste treatment methods to reduce the waste taken to landfills. However, Japan suggests the provision of adequate information to communities for it to achieve its goals on improved waste management (Tanaka, 2007).

In South Africa, waste management is covered by several acts of parliament at the national scale resulting into duplication and overlapping of functions (DACE, 2008). This negatively affects the collection, transportation and disposal of MSW (DACE, 2008). Two of these legislations are (i) The National Waste Management Strategy and (ii) Municipal bye-laws. The national Waste Management Strategy is a document that presents the Government's Waste Management Strategy. It identifies weaknesses in the system: lack of sufficient priority afforded to waste management; fragmented legislation; unacceptable health, environmental and safety impacts from current waste management practices (DACE, 2008). Municipal bye-laws operate at local level to ensure functioning of waste management systems. However, these laws do not address modern waste management; they require modernization to bring them in line with current best practices (DACE, 2008). This then leads to new enabling legislation, the National Environmental Management: Integrated Waste Management Bill (NEM: IWMB), 2008 which has been approved by Parliament and the National Council of Province (DACE, 2008). The legislation seeks to ensure integration of waste management from the point of generation to final disposal, focusing on the waste management hierarchy (DACE, 2008). However, all the 3 legislations that DACE (2008) reported, namely: National Waste Management Strategy, Municipal bye-laws and the NEM: IWMB including the modification that was recommended, there is no mention of waste information as part of the integrated waste management. This waste information gap calls for development of the information platform.

This study therefore aims at developing a waste information platform as part of integrated waste management to guide and help improve on waste recycling and treatment (waste to energy generation) activities. Developing the most appropriate mix of infrastructure and services to manage waste stream is an effective way of ensuring that waste management solutions are comprehensive, practical and encompass the wide variety of processes involved in each waste stream.

2.3 Waste treatment

Waste treatment refers to the activities required to ensure that waste has the least practicable impact on the environment. It includes recycling, waste to energy and compositing of waste. Waste recycling and waste to energy are components of integrated solid waste management. Haas, et al. (2015) defined waste recycling as any recovery operation by which end of life waste is reprocessed into products, materials, or substances that can serve the original or comparable purposes. Apart from recycling and making compost manure, energy production from waste could also be factored in. Waste to energy (WtE) process may be perceived as a potential management alternative as it not only provides renewable source of energy but also utilises recycling potential of degradable-organic portion of solid waste generated by numerous activities (Kothari et al., 2010). Waste recycling and incinerating to recover energy should reduce the burden on the landfill and also open opportunities for new technologies in treating municipal solid waste (MSW) (Boesch et al., 2014). In recent years, movement towards ‘zero waste’ has meant that alternative production technologies could, in theory, literally eliminate waste as is understood today.

2.3.1 Waste recycling

Waste recycling deals with turning materials into valuable resources arising out of financial, environmental and social returns (EPA, 2012). The rate at which recycling is developed varies from country to country (Haas et al., 2015). Recycling has been widely accepted as a sustainable solid waste management method because of its potential to reduce disposal costs, waste transport costs and to prolong the life span of landfill sites (Folz, 1991). It is also a means of protecting the environment as it returns waste into the production cycle thereby safeguarding environmental health. Similar trends can be seen in Europe, where some countries, such as Austria and the Netherlands, now recycle 60 % or more of their municipal waste (Chaliki et al., 2016).

Solid waste recycling can be formal or informal. The formal recycling typically utilises curb side recycling programs to collect and sort wastes for recycling process. The collection of recyclables is either included within the system of MSW management in communities and in municipal government or it is collected and transported by collection companies (Zhang et al., 2010). In informal waste recycling, the recyclable materials are often collected at the source by freelance individual waste pickers and reusable waste reclaimers patrolling the residential

areas. In some cases, waste reclaimers call door-to-door to buy recyclables or residents deliver recyclables to the service sites themselves. The buyers in turn sell the materials to nearby buy-back centres where the materials are sorted and sold to waste treatment facilities as raw or processed materials (Zhang et al., 2010). The informal waste sector is poorly reported but it makes a significant contribution to resource recovery and GHG savings in cities of developing nations (Couth and Trois, 2012).

Couth and Trois (2012) found that the majority of countries in Africa were adopting waste recycling (re-use) and composting projects but the benefits were not sufficiently quantified. In Yaoundé, Cameroon, a non-governmental organisation –CIPRE- is recycling rubber into useful products (Achankeng, 2003). In Egypt, the Zabbaleen, which is a religious minority group involved in an informal recycling, is reported to have collected and sorted nearly 50 % of the household waste produced across Cairo, Egypt, since the 1930's (Ezeah et al., 2013). In 2006 Zabbaleen achieved a recycling rate of 74.3 % compared to 10.6 % by the formal sector (Ezeah et al., 2013).

South Africa's informal sector recycling is a set-up of community-based organisations (CBOs), co-operatives and associations supported by NGOs (Ezeah et al., 2013) and free-lance individuals. A study by Larney and van Aardt (2010) of solid waste disposal and recycling practices of the apparel industry in South Africa showed that 34.8 % of the waste from apparel was recycled. In North West province (NWP), waste recycling and re-use initiatives are at an early stage of development. There was one known recycling project in the Maquassi Hill local municipality in 1999 but has since closed down due to general mismanagement (DACE, 2008). Most recycling projects are carried out by the private sector or within the informal sector. Most of the waste recovery is done at landfills where members of the public and employees of small private recycling firms recover particular waste classes. It is estimated that in the Bojanala Platinum district municipality, between 0.4 % and 1.3 % of waste disposed of in their landfills is recycled by scavengers. The degree of accuracy of these values cannot be guaranteed because of the difficulty in estimating the recycling contribution of the informal sector (DACE, 2008).

2.3.2 Waste-to-energy generation

Waste-to-energy is a process of converting wastes to useful energy forms like hydrogen (bio hydrogen), biogas and bio-alcohol (Kothari et al., 2010) through either direct combustion (for example incineration, pyrolysis, and gasification); anaerobic digestion or mechanical

biological treatment (Cheng and Hu, 2010). It can be in form of compositing, thermal and chemical treatments of the MSW in order to offset the need for fossil-based energy (Cucchiella et al., 2014). MSW is a viable energy source for electricity generation in a carbon-constrained world (Kaplan et al., 2009).

Incineration with energy recovery is a good performance process due to the high amount of energy generated (Antonopoulos et al., 2014). By recovering energy, it produces electricity and/or steam for heating and prevents hazardous organic wastes from entering the environment (Brunner and Rechberger, 2015). Three types of incineration are recognised: in the first example, incineration is for electricity recovery only, the second one is a combined one to generate heat and power. The third type of incineration is the mass-burn incineration commonly used for medical care waste. The third one is incineration to destroy waste without heat or energy generation (Tan et al., 2015). It was estimated that by 2003 about 130 million tons of MSW would be combusted annually in over 600 WtE facilities worldwide, producing electricity and steam for heating as well as recovering metals for recycling (Cheng and Hu, 2010). As a reliable environmentally sound technology, WtE has been used extensively in Europe and developed countries in Asia such as Japan and Singapore (Cheng and Hu, 2010).

Fig. 5 shows a heat-producing incinerator, which uses hot combustion gas to produce steam in the boiler, in a super heater-boiler-economizer arrangement. The remaining heat of the flue gas, after steam production, is used to preheat the water in an economizer. The produced steam can have various internal or external thermal applications or can be used to generate electricity (Van Caneghem et al., 2012).

Incineration of MSW has numerous advantages such as volume reduction, which is estimated at 90 %; mass reduction, estimated at approximately 70 %; complete disinfection and energy recovery (Zhang et al., 2010). Incinerators have a considerable potential as an analytical tool to support waste management. They are of great value for decision makers because they provide reliable and proven information on composition, trends in composition, and biogenic fraction in MSW and other wastes at hand (Brunner and Rechberger, 2015).

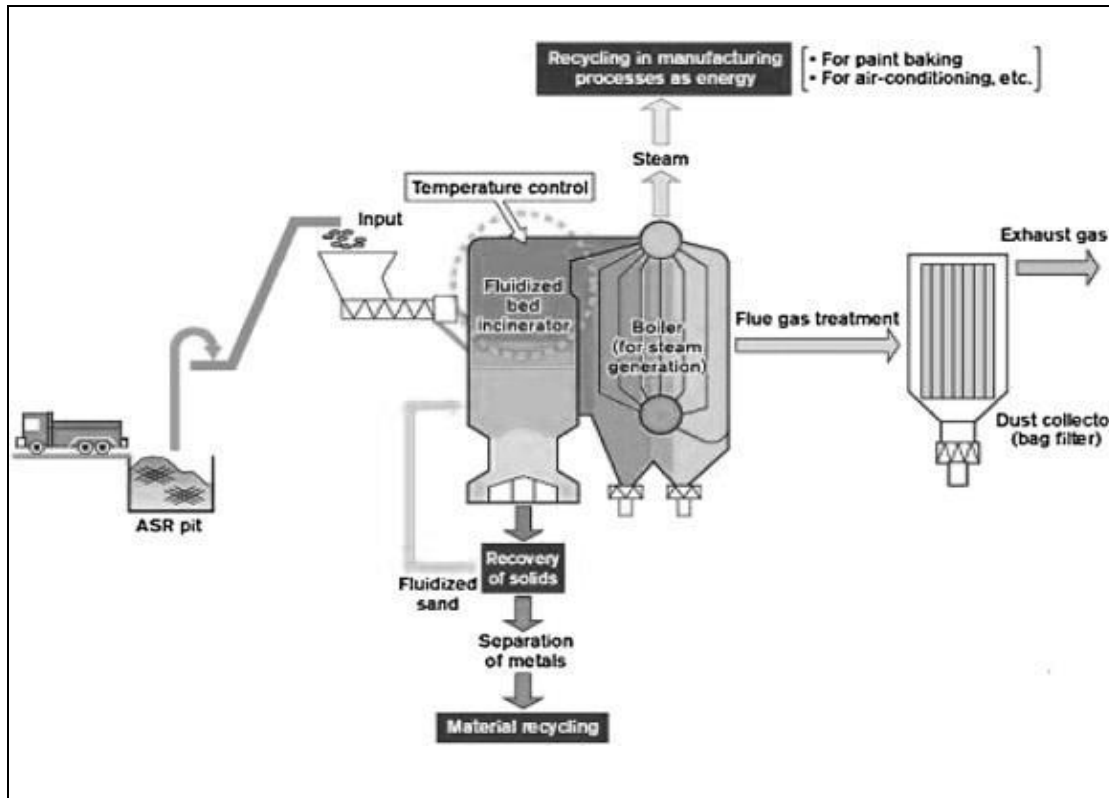


Figure 5: A typical incinerator

Source: Van Caneghem et al., 2012

The first generation of incinerators, before improvements were made to the designs, contributed to environmental degradation (Zhang et al., 2010). The process releases emissions of toxic air pollutants and volumes of solid residues for example bottom ash, grate sifting and fly ash which are generated at different points during MSW incineration into the environment (Zhang et al., 2010). However, currently the highly developed combustion and air pollution technology, state of the art waste incineration has reached the first goal of environmental protection, and the second goal of waste management which is resource conservation and material recovery (Brunner and Rechberger, 2015). The capacity to harness energy from the MSW has socio-economic benefits through electricity sale of. The South African government passed into law the Renewable Energy Feed-In Tariff (REFIT) mechanism in March 2009 to promote the deployment of renewable energy (Pegels, 2010). In Denmark, about 40 % of electricity generated is from biomass co-generation plants using wood waste, straw and animal wastes for biogas, and in Finland it is 10 % using sawdust, forest residues and pulp liquors (Sims et al., 2003).

Although incineration is beneficial through energy generation and environmental protection, maintenance costs are relatively high (Zhang et al., 2010) Thus their costs are very capital-demanding compared to other treatment alternatives because of the high capital costs and the higher variable costs needed with regard to maintenance, material costs and personnel costs (Merrild et al., 2012). The viability of incinerators to generate electricity or heat from MSW is dependent on the organic matter, moisture content and calorific values of the waste. Energy content of the wastes can be predicted by their initial organic matter and moisture content (Komilis et al., 2014). Controlled incineration as a method for waste disposal for municipal waste is not wide-spread in the developing world due to low stages of waste sorting at source (Friedrich and Trois, 2011). For effective implementation of waste recycling and treatment projects, the status of moisture content, calorific value, quantities, classification and nutrient content of the waste is essential. Therefore, there is need to generate and regularly update information on these variables.

2.4 Waste information

A study by Singh et al. (2014) highlights the fact that statistics on waste often under-represent the real severity of the waste problems. Haas et al. (2015) concludes that estimates of the different material flows entails considerable uncertainties. Hence, there is an urgent need to develop an interactive waste information-based platform to overcome these challenges and speed up the progress towards the global waste management system. Knowing the composition of the waste will inform on the choice of a proper treatment option for a particular waste stream. Information on calorific value and moisture content of MSW gives guidance on type of treatment to be adopted. Waste with low calorific value and high moisture content is not suitable for energy generation and heat utilisation (Zhao et al., 2014). It has been suggested that for incineration, the minimal heating value must on average be 7000 kJ/kg, and must never fall below 6000 kJ/kg (Zhang et al., 2010). The relationships between moisture content and organic matter of waste to energy generation is shown in Fig. 6; the lower the moisture content the higher the heating value (Komilis et al., 2014).

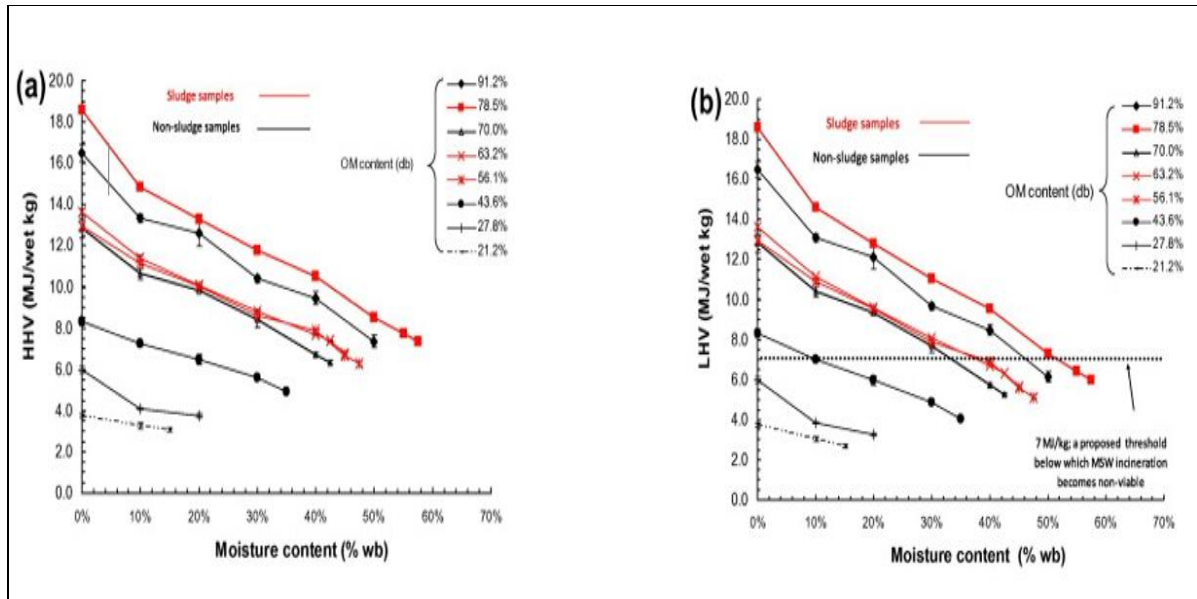


Figure 6: Impact of moisture and organic content on calorific value of waste

Source: Komilis et al., 2014

While the developed countries have available waste information, developing countries struggle to develop waste information systems that can generate reliable waste information. Usually the information on quantities is estimated and not on classes of waste as separation of waste from source is still a nightmare. Literature shows that there, is to-date, no reliable waste information in developing countries. Seng et al. (2010) indicates that there is limited information which is not complete. This makes it extremely difficult to gain an insight into the complex problem of municipal solid waste management. Wilson et al. (2015) reported lack of up-to-date and detailed waste information in developing countries as it does not form part of solid waste management. Nonetheless Table 6 shows some published information on waste generation and composition as extracted from various sources.

Most developing countries have poor waste management data. To overcome lack of historical data, IPCC guidelines (IPCC, 2006) are used to estimate and calculate such data (Friedrich and Trois, 2011). However, these estimates introduce high uncertainties in the final results. Most African countries are in this situation and all reported rates from literature on some African case studies (Table 6), are lower than the generation rate proposed by the IPCC (2006) methodology (Friedrich and Trois, 2011). The inaccurate information on waste generation rates can negatively affect estimation of factors that are a threat not only to the global environment but also at national and municipal stage (Couth and Trois, 2010), for example GHGs emissions.

Table 6: Published waste generation data for Africa

		Biodegradable	
	Amount Generated	organic fraction	
City/Country	(kg/capita/day)	(%)	References
AFRICA			
Makurdi-Nigeria	0.54	36-57	Sha’ Ato et al. (2007)
Abuja- Nigeria	0.55-0.58	52-65.3	Imam et al. (2008)
			Ayininuola and Muibi
Ibadan- Nigeria	0.2-0.33	0	(2008)
Freetown- Sierra Leone			Sood (2004) in Gogra et
	0.45	84	al. (2010)
Accra- Ghana	0.4	60	Fobil et al. (2008)
Dar es Salaam- Tanzania			Kaseva and Mbulingwe
	0.4	0	(2005)
Botswana	0.33	68	Bolaane and Ali (2004)
South Africa- developed areas	0.8	0	
South Africa -less developed areas			Karani and
	0.3	0	Jewasikiewitz (2007)
IPCC rate for Africa (based on a study from Sudan)	0.79	0	IPCC (2006)
Average African countries	0.44	59.8	

Source: Friedrich and Trois, 2011

Poor management of waste in landfills and in some waste treatment facilities are a source of GHGs emissions. There is need to generate accurate information on waste so that waste management practices emphasise on resource conservation and recovery that reduce emissions of GHGs. For example, landfill gas collection efficiency, recycling rate potential, WtE as well as composting.

A review of the waste information for South Africa shows gaps in the waste information. Troschinetz and Mihelcic (2009) reported insufficient waste data on waste characterisation for

South Africa. Information on characterisation is important for waste treatment options such as recycling projects. Because of limited waste characterisation data, South Africa was among 5 other developing countries that were left out as case studies in a study on sustainable recycling of municipal solid waste in developing countries conducted in 2009 (Troschinetz and Mihelcic, 2009). DEA (2009a) reports the ineffectiveness of data collection systems and lack of compliance as one of the challenges for limited data on waste information.

However, since 2004, South Africa has made efforts to develop the waste information flow system called South Africa Waste Information System (SAWIS) (DEAT, 2005a; DEAT, 2006). DEA (2012) reported the absence of a fully operating SAWIS which results into a lack of accurate waste information. Alberts (2014) noted lack of waste information due to lack of reporting of waste information to SAWIS and suggested that the reporting be mandatory for persons conducting certain waste management activities. In practice, there are three government spheres (namely the National, Provincial and Local government) and the waste industry, households, businesses and institutions that play an important role in collecting, compiling and reporting waste information to SAWIS. These have specific roles and responsibilities to play and uphold in implementing SAWIS.

Collection of information by the role players in waste handling is the most critical step in the entire process surrounding the SAWIS. However, the role players are faced with some challenges in the collection of accurate data; this step is considered the potential *weak link* in the process (DEAT, 2006). For example, some key players use estimation system to determine the quantity of waste generated, which is not accurate since waste are heterogeneous and have different densities (DEAT, 2006). These assumptions affect the accuracy of calculations and make validation of results a very challenging process (Friedrich and Trois, 2011). Moreover, there is no separation of waste at the collection sites although the waste generated is heterogeneous. These call for proper data capture systems to be designed to collect data both through an estimation system and weighbridge (DEAT, 2006) and development of information platform to improve the system.

2.5 Information Platforms Theories

In general, an information platform should incorporate characteristics that are ideal for solving challenges that are encountered due to lack of the information. Wetz et al (2014) stated that the characteristics of information platform includes the suitability, accuracy, usability, scalability,

and modularity of the system. The only difference between information platforms is the mode of data presentation, some information platforms present static data system while the other platforms are a real-time streaming systems. Fig. 7 shows example of an information platform.

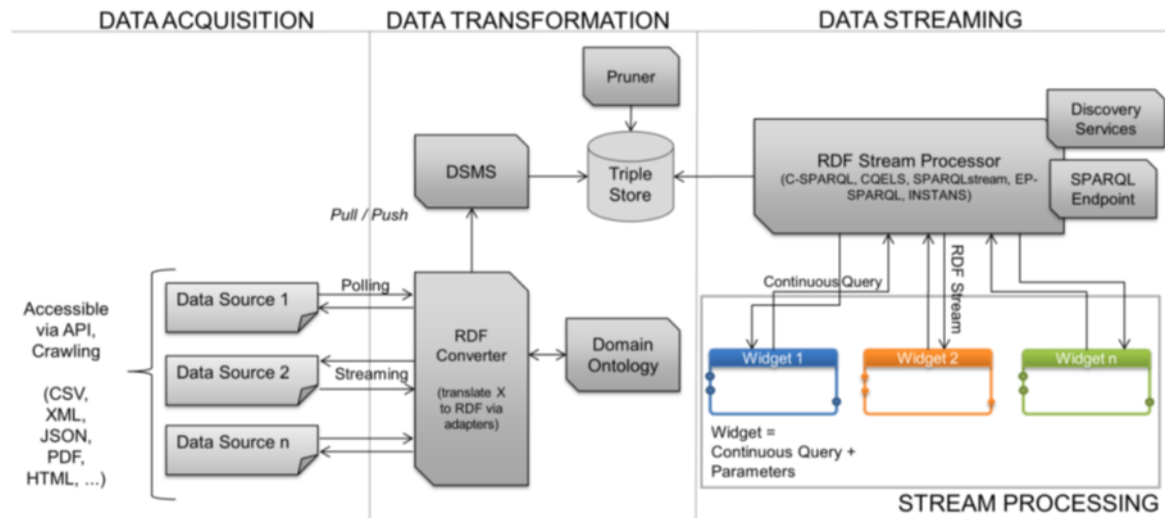


Figure 7: Linked streaming information platform

Source: Wetz et al., 2014

Other than SAWIS, there are other information platforms developed for different systems to promote open information interface and sharing environment to assist with information exchange services, integrating service resources and providing diversified remote innovative services (Li et al., 2012). Some of these information platforms have performed very well and they have brought improvements on services and performance. Examples of such systems are environmental systems, transport systems and health systems. The three information platforms discussed in this section have been successful in solving the problems in their respective fields.

Environmental systems information platforms

Wetz et al (2014) developed, an environmental information platform to solve environmental challenges. Organisations use the environmental systems information platform for sustainability of the environment. The information that is collected and generated is key to addressing negative environmental challenges that affect air and water quality, waste dispels problems, noise pollution and the climate (Melville, 2010). Computer science methods and technologies have been used in developing information platforms to improve the understanding of the environment and contribute towards solving environmental challenges. Fig. 8 is a system that was developed by Wetz et al (2014) to help with addressing environmental challenges.

In this system, information collected on variables that affect environment is collected and captured into the information platform where it is processed and then it is streamed in real time to organisations informing them about the environmental conditions at that particular time and predicting conditions for the rest of the day or week. However, Wetz et al (2014) noticed a challenge with the real time streaming, in that it requires large storage system to handle the continuity of large size data (Wetz et al., 2014). The environmental systems information platform, shows that information can be collected and transformed into accurate and reliable information through a platform. This is important reference towards development of a waste information platform that aims to address the current waste information gaps.

Transport systems information platform

The transport systems information platform provides information to travellers. The existing traveller information systems provide information to a certain extent, but are limited by the data available and the scope of their implementation (Doshi, 2010). This prompted development of transport information platforms for traveller information that support the development of traveller information system for rural and urban areas in United States of America. The architecture incorporates a central processing and storage module, which acts as an information clearing-house and supports receiving, managing and sending data to and from multiple sources and interfaces. This results in a more efficient transportation network, leading to savings in time, cost and environmental and social benefits (Doshi, 2010). Fig. 8 shows the transport information platform that was developed by Doshi, (2010) to indicate real time information on expected arrival and departure times of buses or trains.

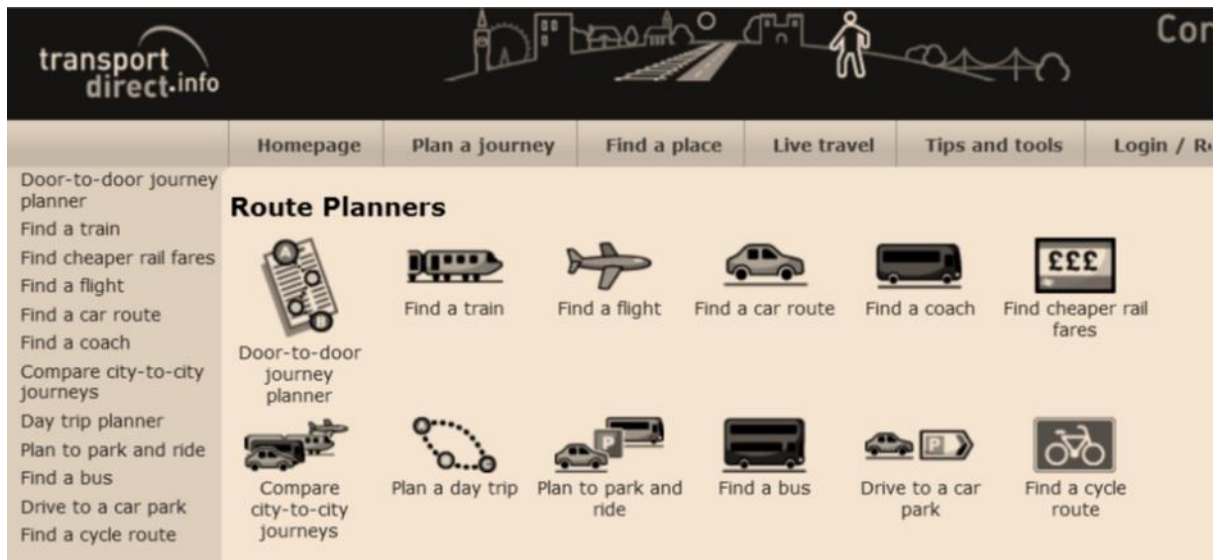


Figure 8: Transport direct information platform

Source: Dosh, 2010

This setup allows sharing of data for analysis or application development, but with access control where required. The information is available online using computers, cell phone and displayed screens in convenient places for example at the stations/stages or in the mode of transport for planning travel.

Health systems information platform

There are problems of healthcare services with elderly people as younger population is moving further away from home, living the elderly alone at home than before. To deal with this, the application of information and communication technologies to medical and healthcare services is one of the most important means in the development of needed medical treatment and healthcare. This has led to the development of health information platform to solve the mentioned problem. The health systems information platform is a source of information and communication of needed medical treatment and healthcare. It is called telecare information platform. The telecare information platform was designed by Li et al (2012) in Taiwan, Fig. 9, to capture and processes information on sicknesses of patients and treatment. The telecare information platform was designed based on the concept of a service-oriented architecture (SOA). It uses the Microsoft.Net™ platform to design, develop, and complete establishment, linkage, and integration of a telecare service model system (Li et al., 2012).

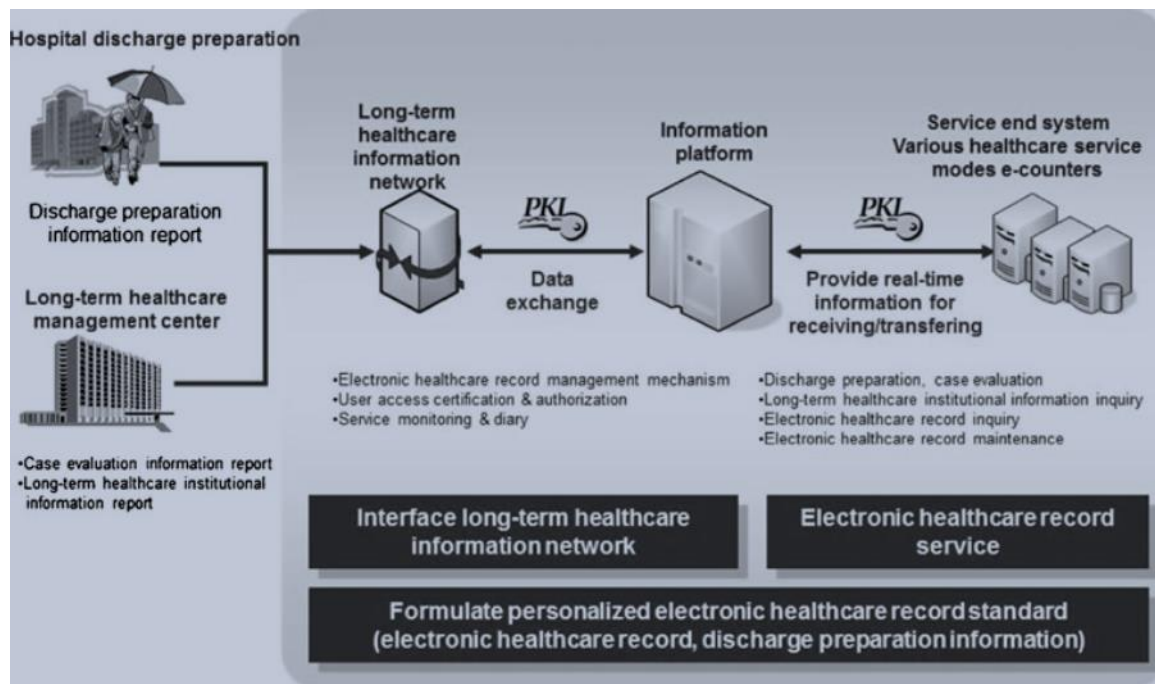


Figure 9: Continuous healthcare service provision and connection

Source: Li et al., 2012

The telecare information platform was developed to promote an open telecare information interface to assist in developing healthcare information exchange services, integrating service resources among various different healthcare service modes, accessing externally complex community affairs information, supporting remote physiological information transmissions, and providing diversified remote innovative services (Li et al., 2012).

The telecare receives information from different patients into its information processing system. The system generates information that shows the ailment of the patient, location of the patient and treatment the patient is receiving. The system can also show the number of patients in an area. The telecare information processing system with the capability of generating such type of information would be considered for applications in waste information system for the waste information platform to generate the required information on classes, quantities, moisture content, calorific values, location of waste facilities and waste treatments across the waste chain.

2.6 Key challenges

The chapter has focused on waste treatment, information and information flow in the waste chain. The importance of waste information on recycling and energy generation is emphasised.

There are challenges that have been identified on waste information in relation to global, developed countries, developing countries, Africa and South Africa.

Globally

- ❖ There is lack of waste information on moisture content, calorific values, waste quantities and waste characteristics that is packaged in a manner that can aid decision making for waste management.
- ❖ Waste activities contribute to global warming due to greenhouse gas emissions, which is becoming an important environmental issue.

Developing countries

- ❖ The extent to which developing countries have improved the status of waste information systems remains unreported in most countries.
- ❖ There is improper collection of waste information, leading to generation of incomplete and unreliable information on generated waste in developing countries.

Africa

- ❖ The status of waste information is not consistent in African countries.
- ❖ There is little comprehensive and reliable data on waste management in Africa.
- ❖ There is lack of information on classification, volume, emissions, moisture content and calorific values of waste. This negatively affects the planning, handling and management of waste.
- ❖ There is lack of standardised data to allow comparison on waste generated per capita, proportion of waste being managed by different methods.
- ❖ Incineration of waste remains a low option practice for Africa.

South Africa

- ❖ There is difficulty in estimating the recycling contribution of the informal sector.
- ❖ There is lack of sufficient priority afforded to waste management.

- ❖ The MSWM system is fragmented resulting in unacceptable health, environmental and safety impacts.
- ❖ The information that is collected on waste generation and treatment activities is not standard, resulting in differences in information that is generated.
- ❖ The current waste management system in the province lacks adequate information on waste generated and the type of treatments the waste is subjected to.
- ❖ There is fragmented waste legislation administered by a number of regulatory bodies across all tiers of government, resulting in duplication and overlapping of functions.
- ❖ There is insufficient information on waste in South Africa.
- ❖ There is no mandatory reporting on waste activities for persons conducting certain waste management activities.
- ❖ Due to the complications on the waste information collection template, it is a challenge for some role players in waste to collect and report waste data to SAWIS.
- ❖ Not all measurements on quantities of waste are recorded at weighbridges.

This chapter has provided a review of the state of knowledge in the context of the research problem of the study. Authors have been cited to highlight series of knowledge gaps in the existing literature.

2.7 Knowledge gaps

From the key challenges identified in this chapter, areas of concern can be isolated as knowledge gaps. The specification of knowledge gaps is informed by the focus of this study, which is ‘waste information in the context of the waste recycling and energy-to-waste generation’. These two represent areas of concern deserving research attention. The inherent knowledge gaps may be classified under two sub-headings: (i) data collection methodology and (ii) governance.

Data Collection Methodology:

First, the collection of waste information data is not consistent across countries to allow for developing comparisons across time (Waste information data).

Second, there are glaring loopholes in collection methods that simply target waste delivered to landfill sites (Landfill data).

Third, significant elements of waste information are not adequately reported leading to incomplete and often unreliable statistics (Data Reliability).

Fourth, for most developing countries, the lack of a standardised instrument for waste information collection, processing and transmission across the different administrative areas poses a serious handicap (Instrument).

It will be noted that the *methodological gap* centres on the related issues dealing with waste collection, waste characterisation, waste classification, instruments, data reliability and landfills. Underlying this is that the state of waste information across countries suffers from particular methodological constraints, which in turn have a negative effect on the potential use of such waste data. *Therefore, the need to develop better methodologies and in the process diminish (reduce) these inherent constraints becomes essential in order to address this outstanding knowledge gap.*

Governance:

First, the use of estimates, especially with regard to waste types and volumes of waste generated per administrative unit across countries undermines the possibility of factoring such data into: (i) policy (ii) planning (iii) programmes (iv) waste recycling projects (v) waste-to-energy generation (WtE) and, (vi) budgeting for waste management at different levels of local government.

Second, there is lack of waste information that is concise, well documented and packaged in a manner that can aid decision making for waste management (Decision Making in WMS in relation to waste Information). In short, two constraints stand out here: the use of waste estimates and the packaging of waste information. These two enter into governance structures at the municipal, city, metropolitan, provincial and national levels of government. The problem with waste estimates is that they are fundamentally flawed given the diversity of input parameters used in their calculation. Second, estimates are often based on assumptions about changes in population, standards of living, consumption patterns and projections of change thereof. The deviation between estimated values and actual values generated from ground measurement should not in principle be ignored. The success of government structures and the

private sector with reference to planning for service delivery, waste recycling and WtE depends on reliable data. The packaging of waste information, too, should be such as to allow for input into decision making with regard to WMS. *It should immediately be noted that improving the documentation and packaging of waste information at all levels will remain a major challenge as long as the methodological knowledge gap is not addressed. The second knowledge gap on 'governance' is, therefore, intertwined with methodological issues.*

The current study intends to address these knowledge gaps in the waste information system to improve waste management. The next chapter, chapter 3 describes the methodology employed to achieve each objective.

METHODOLOGY

3.1 Introduction

The methods reported here have been broken down into the corresponding chapters 4, 5, 6 and 7. The subheadings, therefore, indicate the particular chapter that the methods reported apply. Subheading 3.2 indicates methodology for chapter 4, 3.3 applies to chapter 5, 3.4 applies to chapter 6, and 3.5 applies to chapter 7.

3.2 State of waste information in the NWP

3.2.1 Research design

Describing the state of waste information requires a quantitative research design built around field observations and measurement of elements of the waste chain to generate primary data sets. The information was supplemented by the use of secondary data sets of documents from SAWIS, the provincial department of Rural Environment & Agricultural Development (READ), district records on environmental issues and annual reports of local municipalities within NWP. At the third stage, informal consultations were conducted with officials responsible for the individual waste directorates at local municipalities.

3.2.2 Population and unit of analysis

This study was conducted in North West province of South Africa. In terms of scale, the population of interest in the study were local municipalities together with their individual waste directorate. In this study, unit of analysis is the status of waste information, looking at the handling of waste information, type of information available and stages at which the information is collected.

3.2.3 Data sources

Data was collected through secondary information from municipal, provincial and national waste management directorate. These include (i) SAWIS (ii) The State of the Environment Report, 2008 & the latest one (2014/15) (iii) District Annual report on the Environment (iv) Local Municipality Annual reports (v) SALGA Reports on the Province 2000-2015 (vi)

National Department of the Environment annual report (vii) National Treasury Reports on NWP. This was done to identify the type of waste information collected by the municipalities, information collected at the various stages of the waste chain, and the availability of information to the public including waste treatment facilities.

3.2.4 Specification of variables

The variables of interest in all collection instruments were captured on the ratio scale to allow for the use of conventional statistical techniques (Table 7).

Table 7: Specification of variables

Focal area	Variable	Description	Scale
Status of Waste Information	Availability of Information	Number of municipalities that collect and send waste information to SAWIS	Ratio
	Type of Information	General classification	Ratio
	Information	proper classification	Ratio
	available	waste composition	Ratio
	State of waste information	Type of information available or missing	Ratio

3.2.5 Collection instruments

An observation schedule, Appendix A, was developed to be used for collection of data through visual observations and inquiry from officials. The data collected included records for every municipality in terms of its name, location with GPS coordinates, workforce and infrastructure, status of waste information, waste treatment and facilities available in the municipality, management of waste through the waste chain and management of landfills.

3.2.6 Sampling procedures

Municipalities were required as study cases. A cross section sampling method was used to stratify municipalities on the basis of high, medium and low waste generation. From each category, a random sample of municipalities was done. Local municipalities were used as study cases. A simple random sampling using a table of random digits was used to randomly select the samples that are in Table 2 in section 1.7. This was done by arranging the Local Municipalities in alphabetical order and then each was coded by a 3-digit number. A table of

random digits with 5 digits in each cell was used to randomly select the sample of 8 local municipalities by using the last three digits. This was done by following row by row of the 5 digits in the table, starting from the first cell of set of the 5 digits on the right through to the left end cell of the row, then drop to the cell of 5 digits under it in the other row in the same column and search for 3 digit coding through that row from left to right, where the 3 digits of the code on the name of local municipality appeared in the set of 5 digits, the municipality was selected as a sample. And this was repeated going down the rows until 8 local municipalities were selected.

3.2.7 Data collection

Preparation of data collection involved designing of observation schedule (Appendix A) and then visits to local municipalities. Each of the local municipalities sampled as per item 3.2.6 was visited two times. The first visit was for introduction and application for official permission to conduct the research project in October, 2016. This visit was also used to identify and liaise with particular officials of the waste directorate who were asked to facilitate access to required secondary data sets. Thereafter, the waste directorates at each of the study area were notified via formal letters of the date and time and the duration of stay at each site. The second visit was then the collection of data and information that was requested during the first visit. It took six months to collect data needed for the study from the municipalities.

3.2.8 Analytical techniques

The collected primary data was tabulated and subjected to frequency computations using descriptive statistics. This was done to report and conduct preliminary analysis of field observation results. The outputs were presented in the form of applicable graphics to describe the state of affairs on data and information management for waste. The data was also categorised into key concepts then subjected to multiple correlation and linear regression techniques to evaluate the status of waste information.

3.3 Components of the waste chain facilities

3.3.1 Research design

To map the components of the waste chain facilities requires a quantitative research design built around field observations and measurement of elements of the waste chain to generate primary data sets. The information was supplemented by the use of secondary data sets of

documents from SAWIS, the provincial department of Rural Environment & Agricultural Development (READ), district records on environmental issues and annual reports of local municipalities within NWP. At a third stage, informal consultations were conducted with officials responsible for the individual waste directorates at local municipalities.

3.3.2 Population and unit of analysis

The unit of analysis is the waste chain, broken down into six clear stages: (i) generation points, (ii) collection points, (iii) transport, (iv) storage facilities (v) processing/treatment facility, and (iv) disposal.

3.3.3 Data sources

Sources specified in objective 1 were used to identify facilities in the waste chain in the study area. The data was verified through field visits, observations and measurements. Global Positioning System (GPS) was used to record coordinates of the facility and; characteristics and activities of each facility formed part of the attribute information for production of maps in the GIS environment. Observation schedule (Appendix A) was used to collect information at different stages of the waste chain. The information helped in identifying the waste facilities, location and activities from the waste generators to disposal facilities in the province.

3.3.4 Specification of variables

Table 8: Specific variables

Focal area	Variable	Description	Scale
Type of facilities	Transfer stations	Number of transfer stations	Ratio
	Buy-back centres	Number of buy-back centres	Ratio
	Recycling centres	Number of recycling centres	Ratio
	Energy generation facilities	Number of energy generation facilities	Ratio
	Composite facilities	Number of compositing facilities	Ratio

Observation schedules appearing as Appendix A was used. The variables of interest in all collection instruments were captured on the ratio scale to allow for the use of conventional statistical techniques (Table 8).

3.3.5 Analytical techniques

GPS coordinates were imported into Arc Map 10.3.1 software program where maps of the waste chain facilities were generated to illustrate the spatial distribution of available facilities across the waste chain for example transfer stations, buy-back centres, waste treatment facilities (recycling, WtE and composting) and landfills in the study area.

3.4 State of waste treatment in NWP

3.4.1 Research design

To assess the state of waste treatment in NWP a quantitative research design was used, built around field observations and measurement of elements of the waste chain to generate primary data sets. The information was supplemented by the use of secondary data sets of documents from SAWIS, the provincial department of Rural Environment & Agricultural Development (READ), district records on environmental issues and annual reports of local municipalities within NWP. At a third stage, informal consultations were conducted with officials responsible for the individual waste directorates at local municipalities.

3.4.2 Population and unit of analysis

In this study, unit of analysis is the waste treatment processes, looking at the waste treatment activities in the study area apart from landfilling. Details of the population and map of the study area are given in section 3.2.2.

3.4.3 Data sources

Objective 2 will provide the base information on relevant facilities and information on the state of waste treatment will be collected from secondary information from reports, waste recyclers and waste treatment facilities, field visits and informal consultation with managers. An observation schedule (Appendix A) will be used to collect information on type of treatment, type of waste used and quantity of waste used on daily or weekly basis. The captured information will provide information on status of waste treatment in the province and products of the processes.

3.4.4 Specification of variables

Observation schedules appearing as Appendix A was used. The variables of interest in all collection instruments were captured on the ratio scale to allow for the use of conventional statistical techniques (Table 9).

Table 9: Specific variables

Focal area	Variable	Description	Scale
Type of treatment plant	Landfill	Number of landfills	Ratio
	Recycling facilities	Number of recycling centres	Ratio
	WtE generation facilities	Number of WtE generation facilities	Ratio
	Compositing facilities	Number of composting facilities	Ratio

3.4.5 Collection instruments

An observation schedule, Appendix A, was developed to be used for collection of data through visual observations and inquiry from officials. The data on it included records for every municipality in terms of its name, location with GPS coordinates, workforce and facilities, status of waste information, waste treatment and facilities available in the municipality, management of waste through the waste chain and management of landfills.

3.4.6 Data analysis

The collected primary data was tabulated and subjected to frequency computations using descriptive statistics. This was done to report and conduct preliminary analysis of field observation results. The outputs were presented in the form of applicable graphics to evaluate the significance of each information variable to waste recycling and energy generation.

3.5 Potential for waste-to-energy generation and recycling

3.5.1 Research design

Addressing the objective on potential of energy generation from waste requires a quantitative research design built around field observations and measurement of elements of the waste chain to generate primary data sets. The information was supplemented by the use of secondary data sets of documents from SAWIS, the provincial department of Rural Environment & Agricultural Development (READ), districts records on environmental issues and annual

reports of local municipalities within NWP. At a third stage, informal consultations were conducted with officials responsible for the individual waste directorates at local municipalities.

3.5.2 Population and unit of analysis

The unit of analysis is the MSW looking at their quantities, moisture content, calorific values and technologies. Details of the population and map of the study area are given in section 3.2.2.

3.5.3 Data sources

Data was collected through secondary information from municipal, provincial and national waste management directorate and primary data was collected from field visits, informal consultation with managers, waste treatment facilities and objectives 1, 2, 3 and 4. The data indicate the composition of waste, quantity/volume of waste suitable for energy generation, moisture content of waste, calorific values of waste, sufficiency of wastes to sustain implementation of the energy projects and information on the waste quantities.

3.5.4 Specification of variables

The variables of interest in all collection instruments were captured on the ratio scale to allow for the use of conventional statistical techniques (Table 10).

Table 10: Specific variables

Focal area	Variable	Description	Scale
Potential of energy generation and waste recycling in NWP	Waste quantity	The amount of waste that is generated per day, month or year	Ratio
	Moisture content	How much water is in the waste	Ratio
	Calorific values	How much energy the waste can generate	Ratio
	Capacity of WtE technology	How much waste is used in the technology per day or year	Ratio
	Quantity to be recycled	How much waste will be recycled	Ratio

3.5.5 Sampling procedures

Local municipalities are used as study cases and waste from different dumpsites is unit of analysis. A cross section sampling method was used to stratify municipalities on the basis of high, medium and low waste generation. From each category, a random sample of municipalities was done. A simple random sampling using a table of random digits was used to randomly select the municipalities and the dumpsites that are in Mafikeng that are on map in section 3.2.2. To select both municipalities and the dumpsites in Mafikeng, for each, this was done by arranging the Local Municipalities as well as the identified dumpsites in alphabetical order and then each was coded by a 3-digit number. Table of Random digits with 5 digits in each cell was used to randomly select the sample of 8 local municipalities and 50 dumpsites. This was done by following row by row of the 5 digits in the table, starting from the first cell of set of the 5 digits on the right through to the left end cell of the row, then drop to the cell of 5 digits under it in the other row in the same column and search for 3 digit coding through that row from left to right, where the 3 digits of the code on the name of local municipality appeared in the set of 5 digits, the municipality. And this was repeated going down the rows until 8 local municipalities were selected translating to a sample fraction of 42 % for municipalities. The procedure was repeated to identify the 50 dumpsites translating to a sample fraction of 71.4 % for the dumpsites. To identify additional samples, rainfall distribution was used, that is areas with low, medium and high rainfall were identified.

3.5.6 Estimating the quantities of each class of waste

Estimation of quantities of waste was done using the generation rates for South Africa's waste classes and general waste from DEA (2012) with the population of 2011 from population census of 2011. The rates from DEA are used because DEA is government department and the mother body that takes care of all the information on waste in South Africa through SAWIC and SAWIS.

Calculation of generation rates

Estimating the quantities of each class of waste

To estimate the quantities of the classes of waste, populations for 2016 and 2020 were estimated and projected respectively, then the populations were categorized into income categories and lastly the waste generation volumes were calculated using the percentages of population and

the waste generation rates at each income category. A major difficulty revolves around the use of constants for generation rates. This implies an assumption of no change in consumption patterns across time. In reality, standards of living in South Africa have stagnated since the 2009 recession and the economy has in essence been shrinking since the early 2000. Population projections indicate minus net migrations in some of the provinces. It is then logical that we should expect waste generation values to decline, stagnate or increase across time. This should be the natural behaviour in the relationship between population and waste generation (READ, 2016).

Population estimates

Population estimates for the municipalities, districts and province of the North West have been carried out based on 2011 population census as base population. 2011 population, growth rates and annual household income classes for each municipality for the North West Province were extracted from the municipal profiles from Statistics South Africa.

Categorising the population into annual income stages

The information on annual household income and the percentages representation of the population of the municipality at each stage was used. Each municipality was profiled into low, medium and high-income categories as per classification by Census 2011 which were into four income categories: no income: R0, low income: R1–R19 200, middle income: R19 201–R307 200 and upper income: R307 201 and above (StatsSA, 2011).

Calculating waste generation volumes

Using the percentages of population represented in each income stage, population in each category was calculated for each municipality.

Using the population growth rates for each municipality, population for municipalities, at each income category was estimated for 2016 and 2020. The study calculated the waste generation rates at each income stage as follows:

- Low income 0.41 kg/person/day = 149.65 kg/person/year (READ, 2018b).
- Middle income 0.74 kg/person/day = 270.1 kg/person/year (READ, 2018b).
- High income 1.29 kg/person/day = 470.85 kg/person/year (READ, 2018b).

From the population and the generation rates at each income stage, waste generation for each class was estimated for each municipality at each income stage which was then estimated for the municipality, district and province for 2011, 2016 and projection for 2020.

3.5.7 Measuring moisture content

Moisture content was measured by using a Fristaden TK-100G, VER. 15G30A Multifunctional Moisture equipment. This moisture meter measures the moisture content of waste using the electrical resistance probe technique. It is a high-tech testing instrument with extensive probes that suit many materials moisture content testing. This type of moisture meter with this type of measurement technique is recommended and it was a selected technology out of four types of moisture content measurement techniques for a study by Gawande et al. (2003). The testing followed the following sequence: Waste was collected from the landfills and separated into different classes of waste like: plastics (bottles, papers), food, garden, textile, leather, wood, rubber and papers (cardboard, papers). Each class of waste was put in a 5-litre plastic container one at a time. The moisture meter was switched on and set to zero then the probes were pressed into the sampled class of waste in the 5-litre container and readings were recorded for every class of waste. The procedure was repeated 3 times for the same class of waste. The readings were then put in excel and average moisture contents were calculated for every class of waste based on the 3 recordings.

3.5.8 Calorific values of the waste

Determination of calorific value of each waste class was done using existing literature (Abu-Qudais and Abu-Qudais (2000); Visvanathan and Trankler (2003); Sumathi et al. (2008); Kumar et al. (2009); Unnikrishnan and Singh (2010)) and from existing and operational waste-to-energy plants to establish the optimum calorific values of each class of waste.

3.5.9 Analytical techniques

The collected primary data was tabulated and subjected to frequency computations using descriptive statistics to report and conduct preliminary analysis of field observation results. The outputs were presented in the form of applicable graphics to describe the state of affairs as it exists at present. Data was categorised into key concepts then subjected to multiple correlation and linear regression techniques to evaluate the significance of each information variable to potential of energy generation.

STATE OF WASTE INFORMATION IN THE NWP**4.1 Introduction**

This chapter describes the status of waste information in NWP. It describes the type of information required, type of information collected, available waste information, missing waste information, waste chain coverage and ends with a summary of the chapter. Waste information is a daily report on source, quantity, class and composition of municipal solid waste (MSW) along the waste chain. The relevant methods for this chapter were presented in chapter III, section 3.2.

Quantities on source of waste are the amount/volumes of waste recorded depending on where the waste is generated; which can also include classes of the waste. The information on source of waste can be waste from commercial, industrial, residential and municipal solid waste (Nkosi, 2015; EPA, 2017). The information collected on moisture content can inform on the percentage of water in the MSW while calorific values of the waste indicate the amount of energy available in the waste. Accurate and reliable information on waste composition is crucial both for planning and environmental assessment of waste management approaches as well as for improvement of resource recovery in society (Edjabou et al., 2015).

In South Africa, there is a standard of information collection of MSW that was set by DEAT for municipalities to use. The information is on vehicle number; vehicle type; volume of the vehicle; number of load; type of waste (denoted as G for General waste, GR for Garden refuse, B for Builders rubble, MB for Mixed builders' rubble, I for Industrial waste, F for Food waste and A for Animal carcass) density kg/m³; tonnage; date and name of landfill (DEAT, 2006). Municipal waste information is kept and maintained for informed future decision making purposes and to comply with the government's Waste Information System requirements.

4.2 Importance of waste information

For municipalities, it is important to produce reliable data and create proper information channels within and between municipalities. Decision makers responsible for planning and policy need to be well informed about the waste situation of the cities in order to make positive changes and develop integrated waste management strategies adapted to the needs of the

citizens (Guerrero et al., 2013). Municipalities can use it for planning of activities in the waste management unit. The waste information can help municipalities to plan for different activities within the waste management department such as training of personnel, waste collection and equipment updates for improved waste management. Waste information could assist waste directorates with proactive planning and budgeting for waste management; identification of potentially bankable projects from presented scenarios, develop business and implementation plans for alternative waste treatment besides landfilling. The information can also help municipalities to select sites for landfills.

Landfill selection is an important municipal planning process, which affects different regions (Gorsevski et al., 2012). Landfill selection is driven by many considerations about availability of land, multiple regional and state regulations, increasing amounts of waste production that complicate the process as well as the lack of information given to the public for siting new landfills (Kahvand et al., 2015). For the national government, two distinct categories of waste are recognised: hazardous and non-hazardous. They require different treatment methods. The hazardous waste needs to be treated with caution when handling, transporting, treating and final disposal. Therefore, information on type of waste and their quantities would help the government in setting out regulations on handling of the waste that is differentiating handling of hazardous and non-hazardous waste. Besides, informed decisions on waste facility licencing or permitting could be derived where authorities have the necessary information about type and composition of waste a facility plans to or handles.

Private facilities that handle and use waste for generating income or as an input for their activities require waste information on quantities and types of waste that are available to plan for their businesses or activities. The public can benefit from waste information by understanding the impact of waste on the environment or the health of people in general. In addition, sharing of such information and creating awareness about waste recycling and treatment will enable all participants to gain a better understanding of the relationship between pollution, waste management and the quality of life (DEAT, 2006). Guerrero et al. (2013) argues that when citizens receive information about the benefits of recycling, waste segregation and design of waste programs; they are more likely to participate in recycling campaigns. Moreover, citizens as end users increasingly demand such information to be localised for any area of interest and readily available at any time (Itodo et al., 2010). All in all, waste information on quantity, separation and composition can be used to analyse the state of waste,

location of waste facilities and could affect the way waste is handled (DEAT, 2006; Cheng and Hu, 2010).

4.3 Results and Discussion

4.3.1 Waste indicators

In most developing countries, waste information is recorded on quantities of classes of waste generated at different stages of the waste chain. In South Africa, municipalities and all the waste facilities that collect information on waste are supposed to follow the regulations that were set by DEAT on the type of information to collect and report to SAWIS. DEAT developed a tool for waste information collection, called SAWIS template. The SAWIS template has ten indicators reflecting the information that is supposed to be collected and shared with the public in the province. The indicators are on:

- Vehicle registration number
- Vehicle type
- Volume of the vehicle
- Number of loaded trips
- Type of waste
- Density of waste (kg/m³)
- Tonnage
- Total waste/day
- Date of information collection
- Name of landfill

Observations during the study showed that apart from the regulated waste information template from SAWIS, municipalities use six other waste information collecting tools, herein referred to as *six collection tools* to collect waste information. These collection tools are daily waste report, volume report, waste collection schedule, municipal trucks for general waste, waste from public to landfill, and monthly waste report. Collectively, all the six tools have 16 different indicators compared to the ten indicators on the SAWIS template. The indicators on the *six collection tools* are:

- Document number
- Date
- Page number

- Vehicle number
- Company name
- Tonnage
- Waste categories
- Name of persons
- Time in/out
- Number of loaded trips
- Number of bags
- Source of waste
- Type of waste
- Loads of waste
- Number of households
- Class of waste

Appendix B shows a comparison of information collected using the SAWIS template and the six information collection tools to determine the percentage of information collected as required by DEAT. It was observed that collecting information using the six tools, represented different percentages of information collected per indicator as compared to using SAWIS template. The result in Appendix B shows that 60 % of the indicators that are on SAWIS template are found on the collective six collection tools. These indicators are: vehicle number, number of loads, type of waste, tonnage, date and name of landfill. The results also show that on SAWIS template there are 4 indicators that are not on any of the six collection tools and these are vehicle type, cubic metres of vehicle, density of waste and total waste per day. The observation that could be made is that there is an obvious difference among municipalities in the type of waste collection tools despite SAWIS giving each municipality a template to be used. Waste information that is collected against these six collection tools is not representative of each other. Information collected is not standard; indicators that are on some tools are not present on other tools. For example, waste collection schedule tool collects information on only the number of waste bags that are collected from different sources. The challenge here is that there is no information on type, source and quantities of the waste.

4.3.2 Compliance with SAWIS

The National Waste Information Regulations require all the role players in waste to be registered with the South Africa Waste Information Centre (SAWIC) and to report waste information on a quarterly basis. The national waste information regulations set out requirements that are supposed to be adhered to for generation of reliable waste information. DEAT developed guidelines to provide the role players with information on how to collect, capture, report, verify and disseminate waste data and information. The guidelines that were developed are the User's Manual for Central Registry and SAWIS (DEAT, 2005a) and the Guidelines on implementing the South African Waste Information System (DEAT, 2006).

This study assessed the compliance to the National Waste Information regulations of the information that is collected and generated by the municipalities. This was done by comparing the similarities of information that is collected when using SAWIS template against (i) information collected by each of the six tools and (ii) information collected by all the six tools collectively. Table 11 presents the findings of the assessment. The last column of Table 11 represents the performance of the tools against the SAWIS indicator appearing in column 1. At the bottom, the values represent the relative performance of each tool against SAWIS template.

Similarity between SAWIS information collection template and each of the 6 tools:

The values at the bottom of Table 11, show that only two of the six tools have half of the indicators that are on the SAWIS template and one of the six tools has no any waste indicators that are on SAWIS. This shows that not all the important information is collected by the municipalities when they use either of the six tools rather than the SAWIS template. The results point towards non-compliance of the waste information collection tools to SAWIS. There is deficit of waste information in the NWP.

Similarity between SAWIS information collection template and all the 6 tools

The results in the last column (at the right) of Table 11 show that the vital indicator, tonnage of waste, is on only 16.7 % of the six tools. By using the six tools collectively, one waste indicator (type of waste) is collected on 66.7 % of the six tools. The results also show that 40 % of the indicators that are on SAWIS template are not found on all the six tools. These indicators are on vehicle type, volume of vehicle, total waste per day and density of waste (kg/m^3). The

results show that using the six tools collectively some information can be collected adequately but they are not the important information required for effective waste management.

Table 11: Indicators on SAWIS Template and Municipalities' Collection tools

Waste indicators on SAWIS template	Waste information collection tools in municipalities						% similarity of individual waste indicators
	Daily Waste Report	Volume Report	Waste Collection Schedule	General Waste: Municipal Trucks	Waste from Public to Landfill	Monthly Waste Report.	
Vehicle Number	1	1	0	0	0	0	33.3
Vehicle Type	0	0	0	0	0	0	0
Cubic meters of vehicle	0	0	0	0	0	0	0
Number of load	0	1	0	1	0	0	33.3
Type of waste	1	1	0	1	1	0	66.7
Density kg/m ³	0	0	0	0	0	0	0
Tonnage	1	0	0	0	0	0	16.7
Total waste/day	0	0	0	0	0	0	0
Date	1	1	1	0	0	0	50
Name of landfill	1	1	0	0	0	0	33.3
% similarity for each tool	50	50	10	20	10	0	

1= tool also has it 0= Tool does not have it

There are some indicators that are on SAWIS template but are not present on the six tools. In essence reliable waste information is supposed to be static in terms of units and type across the waste chain. Conclusively, waste information collection using the six tools is non-compliant with the SAWIS regulations. Pearson's correlation analysis was conducted to evaluate compliance of the waste indicators on the six tools and the SAWIS template.

Correlations Analysis

From the output of correlation analysis in Table 12, only the 'volume report' tool scores a high significant value of 0.885 at 0.01 level. This result shows that only 'volume report' tool is close to SAWIS template in terms of the similarity between SAWIS information collection template and each of the 6 tools. At 0.05 significance level, two tools are reported; the 'daily waste report' (0.737) and 'waste from public to landfill' (0.639). This shows that in the absence of

SAWIS template, ‘daily waste report’ and ‘waste from public landfill’ tools can be used to collect waste information.

Table 12: Pearson's correlation analysis

Correlations								
		Daily waste report (X1)	Volume report (X2)	Waste collection schedule (X3)	General waste municipal trucks(X4)	Waste from public to landfill (X5)	Monthly waste report (X6)	SAWIS template(Y)
Daily waste report	Pearson	1	0.600	0.333	0.000	0.333	. ^a	0.737*
	Correlation							
	Sig. (2-tailed)		0.067	0.347	1.000	0.347	.	0.015
Volume report	N	10	10	10	10	10	10	10
	Pearson	0.600	1	0.333	0.500	0.333	. ^a	0.885**
	Correlation							
Waste collection schedule	Sig. (2-tailed)	0.067		0.347	0.141	0.347	.	0.001
	N	10	10	10	10	10	10	10
	Pearson	0.333	0.333	1	-0.167	-0.111	. ^a	0.393
General waste municipal trucks	Correlation							
	Sig. (2-tailed)	0.347	0.347		0.645	0.760	.	0.261
	N	10	10	10	10	10	10	10
Waste from public to landfill	Pearson	0.000	0.500	-0.167	1	0.667*	. ^a	0.590
	Correlation							
	Sig. (2-tailed)	1.000	0.141	0.645		0.035	.	0.073
Monthly waste report	N	10	10	10	10	10	10	10
	Pearson	0.333	0.333	-0.111	0.667*	1	. ^a	0.639*
	Correlation							
SAWIS template	Sig. (2-tailed)	0.347	0.347	0.760	0.035		.	0.047
	N	10	10	10	10	10	10	10
	Pearson	. ^a	. ^a	. ^a	. ^a	. ^a	. ^a	. ^a
	Correlation							
	Sig. (2-tailed)	.	.	.	.	.	.	.
	N	10	10	10	10	10	10	10
	Pearson	0.737*	0.885**	0.393	0.590	0.639*	. ^a	1
	Correlation							
	Sig. (2-tailed)	0.015	0.001	0.261	0.073	0.047	.	
	N	10	10	10	10	10	10	10

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

a. Is not computed because at least one of the variables is constant.

Noticeable are the significant internal correlations between some of the X-variables, i.e. general waste municipal truck (X4) and waste from public to municipal landfills (X5) tools. These two tools collect information on indicators that are common on each other. Waste collection schedule (X3) registered negative coefficients against X4 and X5 pointing to the existence of no association between X3 and X4 and X5. This in turn may point to differences in terms of the indicators that are on the individual tools or internal constraints within the municipal systems for waste delivery. Overall, the correlation analysis results indicate that these tools cumulatively play an important role in explaining the status of the availability of information at the local municipality level. However, the coefficients revealed that there are some gaps in the information collected as far as the use of the 6 tools for waste information collection is concerned. As such, this study recommends that municipalities should adopt the SAWIS template to ensure compliance.

Regression analysis of the linear multiple form was carried out on the data in order to test the relative impact of the various explanatory variables with regard to waste information. Table 13 presents the model output of the SPSS programme. The ‘monthly waste report’ was taken out of the analysis (refer to Table 13) after it was established that it either had missing values or was in fact a constant.

Regression analysis

The model summary indicates an R value of 1.000 and a similar Adjusted R-value. This would appear to indicate that after removing ‘monthly waste report’ (X6), the remaining explanatory variables combined are able to account for all the changes in the ‘available information’.

Carrying forward results from R-squared, the ANOVA output indicates a 0.000 score for residual showing that as earlier shown, the regression model accounts for all the variations in the y-dependent variable. A value greater than 0.000 for residual would have indicated a certain percentage of ‘unexplained’ variation in y. It would then be concluded that some of the variations in y can only be explained by variables which are outside of the current model.

Table 13: Variables entered/removed, model summary and ANOVA

Variables Entered/Removed ^a						
Model	Variables Entered		Variables Removed	Method		
1	Waste from public to landfill, Waste collection schedule, Volume report, Daily waste report, General waste municipal trucks ^b		.	Enter		
a. Dependent Variable: <i>Information available</i>						
b. All requested variables entered.						
Model Summary						
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate		
1	1.000 ^a	1.000	1.000	0.000		
a. Predictors: (Constant), Waste from public to landfill, Waste collection schedule, Volume report, Daily waste report, General waste municipal trucks						
b. Predictors: (Constant), Waste from public to landfill, Waste collection schedule, Volume report, Daily waste report, General waste municipal trucks						
ANOVA ^a						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	18.400	5	3.680	.	. ^b
	Residual	0.000	4	0.000		
	Total	18.400	9			
a. Dependent Variable: Information available						

From Table 13, regression accounts for a value of 18.400, residual score 0.000 generating a total equivalent to the regression value. This would appear to indicate that $y = \text{'available information'}$ can be fully explained by the combined effect of predictors- X_1 , X_2 , X_3 , X_4 and X_5 earlier reported in Table 12. From the results, the p-value of 0.000 is less than alpha meaning that the association between the response variables (4 in total) is statistically significant. The P-value for hypothesis test $H_0: \beta_1=0$ is used to assess the null hypothesis. The null hypothesis (H_0-1) specified in section 1.5 of chapter 1 is that the association between predictor variables and the response- y variable is equal to zero. The corresponding alternative

hypothesis is that $H_1: \beta_1 \neq 0$ meaning that the set of predictor variables do indeed control variations in the y-response variable. The results indicate that the null hypothesis in this case can be rejected. The information available depends on the set of tools deployed within the SAWIS template for waste data capture and transmission.

Standardise coefficients were then computed for the data. The print out appears in Table 14.

Table 14: Coefficients

		Unstandardized		Standardized		95.0%		
		Coefficients		Coefficients		Confidence		
						Interval for B		
		Std.				Lower	Upper	
Model		B	Error	Beta	t	Sig.	Bound	Bound
1	(Constant)	4.256E-16	0.000		.	.	0.000	0.000
	Daily waste report	1.000	0.000	0.369	.	.	1.000	1.000
	Volume report	1.000	0.000	0.369	.	.	1.000	1.000
	Waste collection schedule	1.000	0.000	0.221	.	.	1.000	1.000
	General waste municipal trucks	1.000	0.000	0.295	.	.	1.000	1.000
	Waste from public to landfill	1.000	0.000	0.221	.	.	1.000	1.000

a. Dependent Variable: Information available

A standardized beta coefficient allows for a comparison between the strength of the impact of each predictor variable on the variation in the y-dependent variable. The beta coefficient provides the degree of variation in the outcome or output for every unit shift in the independent variable. From the results, the beta values in rank order indicate that X_1 and X_2 are the highest while X_5 and X_3 are at a lower level of effect. The regression equation is y (information available) = $4.256(\text{constant}) + .369(\text{DWR}) + .369(\text{VR}) + .221(\text{WCS}) + .295(\text{GMT}) + .221(\text{WPL})$. Where $\text{DWR} = X_1$, $\text{VR} = X_2$, $\text{WCS} = X_3$, $\text{GMT} = X_4$ and $\text{WPL} = X_5$. The intercept, $b_0 = 4.256$,

provides an estimate of the mean information available on each of the tools (y) when the number of tools ($X_1, \dots, X_n$) is held at zero. For every unit increase in the X's, there will be a corresponding increase in the y as shown by the individual coefficients.

Overall, the results do show that some of the indicators on the SAWIS template do not appear in the tools used by local municipalities to record and report waste information. The modification of SAWIS template by the municipalities creates limitations in the quality of the data that municipalities in general collect and transmit, compromising waste management. There is need to comply with these regulations in order to generate reliable waste information that can contribute to sustainability of waste management systems (Zaman, 2014). At a second level, the absence of complete records on waste from individual local municipalities has a negative effect on waste planning and the implementation of all waste related projects and programmes.

4.3.3 Handling of waste information by municipalities

During observations at the municipalities and from interviews with the waste management personnel it was observed that in terms of information collection, there are three categories of municipalities. These are categories that collect and report information to SAWIS, those that collect waste information but do not report to SAWIS and those that do not collect waste information at all. Table 15 shows the number of municipalities that are in each of the categories.

Table 15: Status of information collection and reporting to SAWIS

Municipality	Status Of Waste Information Collection in Study Area		
	Collect & Report	Collect no Report	No collection
Madibeng	1	0	0
Rustenburg	0	0	1
City of Matlosana	0	1	0
Tlokwe	0	1	0
Lekwa-Teemane	0	0	1
Mamusa	1	0	0
Naledi	0	1	0
Mafikeng	0	0	1
Total	2	3	3

1=Yes

0=No

The results in Table 15 show that out of 8 municipalities, only 2 do in fact collect and report waste information regularly to SAWIS. The results show essentially poor performance in this regard.

SAWIS has in recent years provided training to municipal personnel on its waste information collection and reporting system. Despite being trained on how to collect and report the waste information, there are some municipalities that do not collect and report information while others do. Table 16 shows the number of landfills that report information to SAWIS from municipalities where personnel was trained on how to collect and report information to SAWIS.

Table 16: Number of landfills that report waste information to SAWIS after trainings

District	Municipalities trained by SAWIS (X1)	No. of landfills in the trained municipality (X2)	No. of landfills reporting to SAWIS (Y)
NMMD	1	1	1
DRMD	2	6	1
DKKD	2	3	0
BOJANALA	2	2	0
Total	7	12	2

Source: SAWIS, 2016

The results in Table 16 shows that out of the 12 landfills whose personnel were trained by SAWIS, only 2 collect and report waste information to SAWIS. This result supports the finding in Table 17, which shows that only 2 of municipalities report information to SAWIS.

Table 17: Descriptive statistics on municipalities that report information to SAWIS

	Mean	Std. Deviation	N
X1-Municipalities trained	1.75	.500	4
X2-No of landfills in trained municipality	3.00	2.160	4
Y1-No. of landfills submitting to SAWIS	.50	.577	4

The results also show that in 2 districts whose municipalities were trained by SAWIS, none of the landfills report waste information to SAWIS. This can be explained by the fact that

reporting to SAWIS is still voluntary (Oelofse and Nahman, 2013) so there is no pressure to collect and report information.

Pearson's correlation analysis was run using SPSS™ to establish the nature of the relationship between the y-dependent variable and the two independent X-variables. In Table 18, the number of municipalities trained (X1) and the y-dependent variable generate a negative coefficient of -0.577 while for X2, the coefficient is a strong 0.617.

Table 18: Correlations analysis on the relationship between number of municipalities and landfills trained and submitting waste information to SAWIS

		Municipalities trained	No of landfills in trained municipality	No. of landfills submitting to SAWIS
X1-Municipalities trained	Pearson Correlation	1	.617	-.577
	Sig. (2-tailed)		.383	.423
	N	4	4	4
X2-No of landfills in trained municipality	Pearson Correlation	.617	1	.267
	Sig. (2-tailed)	.383		.733
	N	4	4	4
y-No. of landfills submitting to SAWIS	Pearson Correlation	-.577	.267	1
	Sig. (2-tailed)	.423	.733	
	N	4	4	4

It is noted that against y, X1 is negative while X2, the coefficient is a strong positive. The implication is that the training of personnel at local municipalities does not appear to link directly with the ability of landfills to submit regular statistics to SAWIS. Yet, for X2, the number of landfills submitting information to SAWIS on a regular basis is strongly correlated with the y-dependent variable. While correlation does not necessarily point to causation, the contradiction in the two outputs point to the fact that some of landfills where personnel have been trained collect data but do not submit such to SAWIS. The issue here therefore may be the problems of enforcing compliance rather than the technical skills required for data collection and transmission.

Regression analysis was run and the output shows a high coefficient of $R=0.981$ indicating the impact of the explanatory x-variables, Table 19. The score for the Adjusted R-square stands at 0.885 which translates to 88.5% of the variation in the shifts in y can be explained by the combined impact of the two x-variables. Note that in the ANOVA output, the strength of the two x-variables comes to 0.962 leaving a small residual value of 0.038. The null hypothesis

advances the position that each of the independent variables, X_1 and X_2 has no effect on the y-response variable. This would mean that they each have a coefficient of 0. But at a 95 % confidence interval, the impact of the predictors on the y-response variable generates a coefficient of 0.981 which is very strong. The null hypothesis, which advanced a claim of no effect on y- is, therefore, rejected.

Table 19: Regression analysis

Variables Entered/Removed ^a						
Model	Variables Entered	Variables Removed	Method			
1	No of landfills in trained municipality, Municipalities trained ^b	.	Enter			
a. Dependent Variable: No. of landfills submitting to SAWIS						
b. All requested variables entered.						
Model Summary						
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate		
1	0.981 ^a	0.962	0.885	0.196		
a. Predictors: (Constant), No of landfills in trained municipality, Municipalities trained						
ANOVA ^a						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	0.962	2	0.481	12.500	0.196 ^b
	Residual	0.038	1	0.038		
	Total	1.000	3			
a. Dependent Variable: No. of landfills submitting to SAWIS						
b. Predictors: (Constant), No of landfills in trained municipality, Municipalities trained						

Standardised coefficients were then derived from the data producing an output that reinforces earlier conclusions, Table 20.

Table 20: Standardised coefficients

		Coefficients ^a						
		Unstandardized Coefficients		Standardized Coefficients	95.0% Confidence Interval for B			
		Std.		Beta				
		B	Error		t	Sig.	Lower Bound	Upper Bound
1	(Constant)	2.115	0.423		5.000	0.126	-3.260	7.491
	Municipalities	-1.385	0.288	-1.199	-4.811	0.130	-5.042	2.272
	trained							
	No of landfills in	0.269	0.067	1.007	4.041	0.154	-0.577	1.116
	trained							
	municipality							

a. Dependent Variable: No. of landfills reporting to SAWIS

The beta coefficient compares the strength (impact) of each predictor variable on the y-variable. In this case, predictor variable X_1 has a stronger effect – though negative at -1.199 than predictor variable X_2 at 1.007. The regression equation is:

The number of landfills reporting to SAWIS (y) = 2.115 - 1.385(Municipalities) + 0.269 (Landfills).

4.3.4 Type of information available

Observing completed tools from municipalities, there were gaps in some of the completed six collection tools. Results of the analysis of the collection tools showing the percentages of the completed indicators and missing indicators on the tools are shown in Appendix C. The results show that 25 % of the indicators on the six tools were not completed by the responsible officers. These indicators include document number, date of information collection, tonnage of waste and class of waste.

However, further analysis was conducted on the 75 % of the indicators that were completed to determine the type and percentage of information they contribute to waste information. Fig. 10 shows the information that is collected and percentage of information each indicator contributes to SAWIS when using the six collection tools.

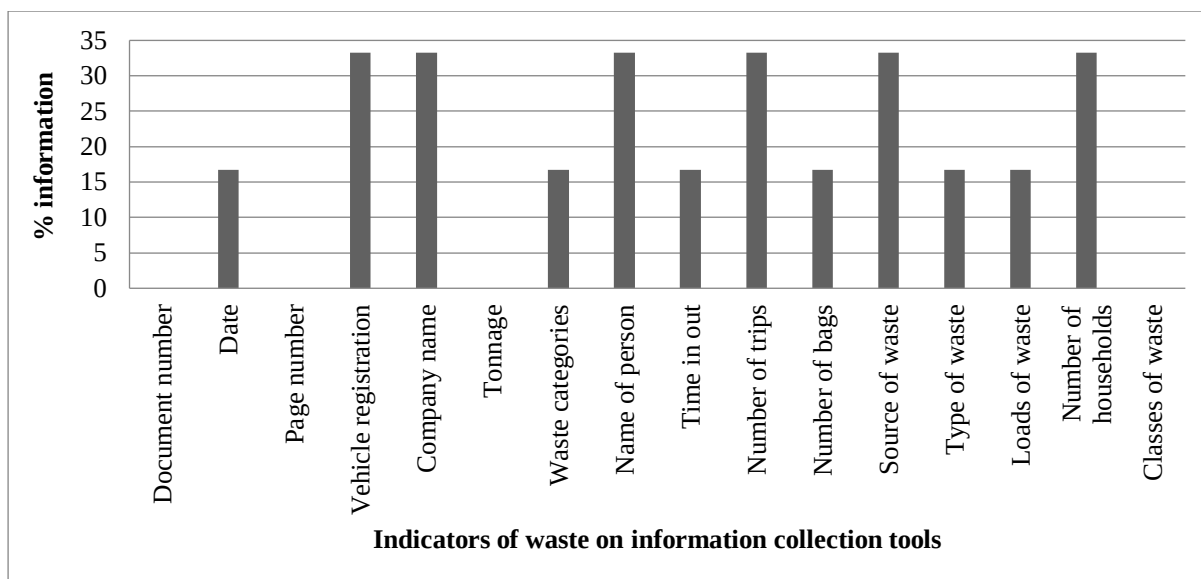


Figure 10: Percentage of Information Collected

The results in Fig. 10 show that information is collected on 12 of the 16 waste indicators and no information is collected on the remaining four. Two indicators from the four whose information is not collected are the key indicators in information collection. The indicators are quantity and classes of waste. It is worth noting that there are some important waste indicators that are on the six collection tools. These indicators are on tonnage or quantity of waste, type of waste, waste categories and classes of waste. These four indicators are key in planning for proper handling and treatment of waste. This indicates that there is little or no quantification and characterisation of MSW in the province. Lack of quantification and characterization of MSW is common in developing countries where the information on MSW generation have a short history and usually insufficient for the nation or province. This result agrees with Troschinetz and Mihelcic (2009) who reported that South Africa does not have available waste data representative of the national population or a large urban or peri-urban population centre. In spite of impressive national legislation since 1995 on waste guidelines and management and the setting up of provincial structures tasked with waste management, municipalities across the country still face severe hardships in collecting waste information.

It is important that waste information should be available to the public to enable planning of waste treatments like recycling, waste-to-energy generation, composting and landfilling. The information availability starts with information collection and submission to SAWIS. For waste information to be easily accessible by the public, the collected information is supposed to be processed and reported to SAWIS to be stored in SAWIC. SAWIC makes information available for use by government, the waste sector and the general public. Until recently, waste

information has been collected differently by different role players through the waste chain, which makes the compilation of data on waste quite challenging (DEA, 2012). The role players and locations to collect waste information are landfills, recycling centres, transfer stations, buyback centres, composite stations, WtE and households. SAWIC uploads the information on their database so that any interested party can access it through the internet or by obtaining hard copies.

In developed countries, reliable information on MSW generation and management are updated periodically and are available in the literature. This information is normally collected on a daily basis, which provides a rational basis for planning and executing waste management operations (Karak et al., 2012). Hence, a robust waste type analysis for each municipality is required in order to make informed decisions on new waste management strategies and facility development (DEA, 2011b). The quantity of waste that is produced per capita (kg/person/day) can be used to estimate volumes of waste generated for a country per day, per week, per month or per year. Different countries or areas have different per capita waste generation rates because of their socio-economic and cultural differences. Scarlat et al. (2015) report that in many Sub-Saharan African cities, MSW generation per capita/day ranges between 0.3 and 0.8 kg/capita/day. This is by far below the values in developed countries where the score is up to 1.39 kg/capita/day. In three Danish municipalities, the waste generation rates were expressed in kg/person/week and estimated at 3.4 ± 0.2 kg/capita/week, 3.5 ± 0.2 kg/capita/week, and 3.5 ± 1.4 kg/capita/week for Aabenraa, Haderslev and Sønderborg, respectively (Edjabou et al., 2015).

In South Africa, waste generation rates are estimated based on the origin of waste. For example, the estimated volume of waste in rural settlements is pegged at 0.3 kg/person/day while from the urban population it is – 0.8 kg/person/day. These estimates are similar in most Sub-Saharan African cities (DEA, 2012). The current practice in all the municipalities in the study area is the use of non-containerized collection system; hence information on the quantities of waste generated per class is rarely available. This was evident during the study where no municipality has information about tonnage, class and only 16.7 % (Fig. 10) collect information on loads of waste. Although segregation of waste is done at some disposal sites by waste reclaimers, it was observed that there is inconsistency in the reporting of estimates of waste for each class. This could be attributed to different sizes of collection bags as well as unit of measurement where some report in kilograms and others in tonnes. In this case, only recyclable materials are therefore accounted for.

The analysis of composition of waste material typically consists of three phases: first sampling of the waste itself, then sorting the waste into the desired number of material classes (for example paper, plastic, organics, combustibles), and finally handling, interpretation and application of the obtained data (Edjabou et al., 2015). One of the aims of a national waste classification system is to standardize the reporting of waste data (DEA, 2012). Waste characterisation should be undertaken to understand the composition of the domestic stream. There is currently no comprehensive information available on the types of waste which constitute the general domestic waste stream in the study area. Source separation of waste especially organic wastes not only brings economic benefit, but also makes the recycling of other components more efficient (Al-Maaded et al., 2014). Waste information that is collected by municipalities is not on waste characterisation although some companies separate waste before taking it to landfill. This is because the companies do not understand the reason for separating the waste at source consequently, they take the separated waste to landfill and dump them, mixing them with unsorted waste. This still leaves the municipalities without information on waste characterisation.

Similarly, Sibernagl (2011) reported that in South Africa few waste characterization studies have been undertaken, which further complicates the issue of reporting waste streams at the required stage of detail. Where waste characterization studies have been undertaken, these studies have used different methods and waste categories, which make direct comparison difficult (Wise et al., 2011). In the present study for example, observations from the systems at different landfills showed that the incoming waste weighed at the weighbridge is a composition of mixed waste. However, categories such as general waste and or garden waste are used without absolute classification to quantify the classes of waste. This information does not talk much about quantities and classes of the waste. It is therefore difficult to share such information with the public or other researchers. The absence of international standards for solid waste characterisation has led to a variety of sampling and sorting approaches, making a comparison of results between studies challenging (Edjabou et al., 2015). Hence, a standardised approach for waste characterisation ought to be developed by the Department of Environmental Affairs to ensure comparable results from the different waste information sources.

The information collected on moisture content can inform the percentage of water in the waste while calorific values provide an indication of how much energy is available in the MSW. These variables for the same sample differ depending on location of collection. A study in China showed that moisture in MSW of Shanghai in 1998 was 58.87 %, while that of Beijing

was 39.31 % in the same year. Moisture a considerable extent influences the heating value (HV) of MSW (Zhou et al., 2014). Hence, the need to have an aggressive approach that requires mandatory acquisition of information on moisture content and calorific values for specific classes of waste.

4.3.5 Stages of waste information

Collecting waste information through the waste chain traces waste from point of generation through to treatment or disposal (DEA, 2012). This is waste information on generated waste at source, at transfer station, during transportation, at treatment facilities (recycling, energy generation and compositing) and finally waste taken to landfill. Collecting waste information through this chain prevents waste information losses through leakages that occur because some waste recyclers collect waste from generation points before it reaches treatment or disposal sites. To prevent the waste at any stage from polluting the environment, effective waste management need to be put in place. Proper management of waste is dependent on knowledge of quantities from source to treatment/disposal. This then requires records of information throughout the waste chain. Results on the stages at which information is collected through the waste chain in the study area are tabulated in Appendix D. The results in Appendix D show 4 of the 7 types of waste facilities collect waste information in the municipalities within the study area, but only one of these, the information at landfills, is reported the information to SAWIC. This result agrees with the report by Godfrey et al. (2012) that the number of landfills reporting information to SAWIC in 2011 represented an estimated 12- 13 % of operating landfills. The challenge is that since the information is often collected at landfills, only waste disposed of at municipal landfills is accounted for. Where accurate information is available from industrial waste generators, the information is often considered to be sensitive or confidential (DEA, 2012). The results also show that there is no waste data collected at WtE and households. At household stage, it is difficult to collect information because the system of separation at source has not yet been introduced. Besides, there is no data collected from WtE because there are no projects in the NWP that are generating energy from waste. This means that SAWIC cannot as yet provide a complete overview of waste information in the NWP. Besides, not much information is available for the public to use. It is important to collect and have all the required waste information at all stages in the waste chain.

Generation points

Solid waste is generated from different points which are categorized as commercial centres, public sites, construction sites, households, industrial zones, institutions, imported, and others which can be prescribed from time to time. The information required is on quantity of waste that is generated per day or week, type, source and composition. This information can be used to provide necessary advice on how to identify techniques that can reduce waste and increase recycling and other treatments in order to minimize volumes of waste destined for landfills (Bagchi, 2004). Information on quantities of the recyclable municipal waste such as glass, plastic, paper and moisture content will make recovery of waste for recycling and landfilling easier. High moisture content of MSW is regarded as one of the greatest concerns as it poses difficulties for the recovery of recyclable materials, increases the amount of leachate in landfills and reduces the net caloric value for incineration (Zhang et al., 2010). In addition, the information on quantity could assist municipalities in prioritising and allocating resources for collection of waste from generation points (Bagchi, 2004). For instance, local authorities tend to collect waste daily from the central business districts (CBDs) where waste quantities are higher than from households where the generation of waste is slightly lower and waste collection can be done once or twice a week (Henry et al., 2006). Information on quantities of separated waste is also vital for the municipalities in planning of time for collection of waste. Additionally, the appropriate fleet or vehicle deployed to collect waste often depends on the type, source and composition of waste. In smaller (rural) towns, bullock carts, tractor-trailers, tricycles are mainly used for the transportation of MSW while light motor vehicles and trucks are generally used in big towns or cities to transport MSW (Sharholy et al., 2008). In NWP, there is a wide range of vehicles, from light motor vehicles to trucks that transport MSW to the dumping sites.

Transfer Stations

The information that is required here include the following:

- mean distance from collection points to the nearest landfill
- mean distance from collection points to waste sorting centre
- mean number of daily trips per waste collection vehicle
- mean volume of waste delivered per vehicle per trip to landfill site
- mean daily/weekly/monthly volume of waste generated
- the number of collection vehicles available to the waste directorate

- the existence of route scheduling within the waste directorate

This information is important as input into the process of planning for the setting up of waste transfer stations. Beyond the metropolitan municipalities and large cities, the small size of the NWP means that the need for waste transfer stations is not yet a priority.

Waste collection and Transportation

At this stage, waste is collected and transported to the next stage of the waste chain. Basically, this is an issue of the availability of fleet of vehicles, routes to be used during waste collection from different source points, condition of the roads and location of waste facilities. This information can be helpful to management on the type of vehicle that should be used for transportation of the waste. Vehicles used for collecting solid waste door to door should be chosen based on local limits on roads due to bridges and culverts and design load of the roads (Douglas, 2016). The full weight of the vehicles should be checked against the road limits before choosing one. The available design and capacity of the collection vehicles vary widely. This is important in implementing the heuristic approach in routing of vehicles which leads to substantial cost savings. Thus, much data is required before a routing can be done. The time spent on each pickup, travel time between pickup points, street layout, topography of the area and capacity of the vehicle greatly influences the efficiency of waste collection (Bagchi, 2004).

Treatment

At this stage there are a number of treatments that waste is subjected to: recycling, incineration (for energy or just burning), composting of waste and many more. Facilities that are involved in collecting waste information at this stage tend to record and keep accurate information on the quantities, type, sources and composition of waste received for treatment (DEAT, 2006). This information is important for determining the use of the waste. For example, waste with high nutrient and low stages of heavy metals could be used for composting (Singh et al., 2011). Information on calorific value and moisture content of MSW gives guidance on type of treatment. The lower the moisture content, the higher the heating value (Komilis et al., 2014). Waste with low calorific value and high moisture content is poorly suited for energy generation and heat utilisation (Zhao et al., 2014). Data on incineration can be used to compare the impact of incineration to landfilling in terms of waste volume reduction, mass reduction and the amount of carbon released into the atmosphere (Zhang et al., 2010). Incineration can reduce up

to 1.3 tons of carbon equivalent per ton of MSW through avoiding the release of methane from landfills and offsetting emissions from fossil fuel power plants (Cheng and Hub, 2010).

Landfills

Though there is a decrease in use of landfills in developed countries, landfilling still remains the dominant option for waste disposal in developing countries (Laner et al., 2012). As such, there is need to collect information at the landfills to safeguard the land and environment. Although the annual total tonnage of waste disposed at the landfill site is not required for SAWIS purposes, it may be useful information to the facility in terms of planning for personnel, equipment, handling of waste and managing the landfill not to damage the environment. The information on the type and composition of waste that is being disposed of at the landfill will be useful during the time the landfill is in use or after landfill closure.

Closed MSW landfills will continue to require aftercare and post-closure care until protection of human health and the environment is not compromised. Aftercare management of closed landfills typically includes monitoring of emissions (for example leachate and gas) and receiving systems (for example groundwater, surface water, soil, and air) and maintenance of the cover and leachate and gas collection systems (Laner et al., 2012). This depends on site-specific data. For example, the European Landfill Directive (EC, 1999) specifies a period of at least 30 years of aftercare.

The information on waste composition is useful to identify the most significant sources of cellulose and hemicellulose. Such information also represents a starting point for estimates of what is buried in a landfill to generate estimates of greenhouse gas emissions and carbon sequestration associated with paper and wood products in landfills. Unfortunately, the available information does not completely address the composition of materials in or buried in a landfill (Barlaz, 2006). The study noted that waste information is collected at landfill gate using either weighbridge or vehicle estimates. This shows that of all the stages through the waste chain, waste information that is reported to SAWIS is collected at the disposal point only, the landfill.

4.4 Challenges in implementation of SAWIS

Despite the fact that 94.7% of the municipalities in the province were trained by SAWIS on how to collect and submit waste information to SAWIS the results still show that the municipal authorities are unable to implement SAWIS fully, only 25% in NWP and 25% of the

municipalities in the study area collect and submit the information. Interviewing the management in the waste directorate, on why it is difficult to implement SAWIS fully, they attributed the problem to structure of the waste management department in terms of personnel.

The top management hierarchy in waste management department is different from one municipality to another. The first one is that in some municipalities there are waste management units, the second one is that in other municipalities the waste management unit is a small unit within another department. In the third trend, there is no waste management unit in the municipalities, the municipality has to outsource all the services that are required for waste management.

Though some municipalities have waste management units, there are no personnel, the municipalities hire untrained personnel in waste management positions for a short time to help with the load of the work. With the changing of staff, there are a lot of vacant professional posts with a lot of general workers and drivers that deal with collection of waste. Due to the scarce skills in waste management in the country and particularly at municipal level, it will often be found that inappropriate persons take charge of the waste department or leading the waste program. The poor background in waste management know-how further impacts on the operations (Mannie and Bowers, 2015). Henry et al., (2006) reports that in Nairobi and Kisumu, local authorities are overstaffed with poorly trained workers. The untrained personnel collect improper waste information for submission. For example, some waste managers do not correctly identify source generator of waste and others report waste quantities in kilograms mistaken for tonnes.

Lack of expertise to administer solid waste management programmes in municipalities creates challenges in waste information collection as the outsourced services are not trained in waste information collection, processing and submission to SAWIS. This could result into ineffective and inefficient MSW services. It can also lead to collection of scanty information from the public domain (Chung and Lo, 2008) leading to incomplete, unreliable information on generated waste (Seng et al., 2010).

Nonetheless, according to interviews with people in directorate, vacant posts in each of the top levels affect the implementation of SAWIS. In most municipalities there is shortage of waste management staff stationed in the offices of waste departments and landfill sites resulting in several vacant posts in various management positions in the department. This brings immense

pressure on the current workers because they have to now stretch themselves across all the tasks and responsibilities in order to keep the municipality functional.

4.5 Summary

The results in this chapter show that there are regulations that were set by DEAT on waste information collection for the waste information collectors. Accurate waste information has different significance for different organisations depending on how they use or treat the waste. On the basis of the results, the objective on the state of waste information in NWP has been successfully addressed. Listed below are the key findings:

- ❖ Apart from the regulated waste information from SAWIS, municipalities use other waste information collecting tools to collect waste information.
- ❖ Information collected is not standard, indicators that are on some tools are not present on other tools.
- ❖ There is no information on type, source and quantities of the waste.
- ❖ Some of the waste indicators on the collection tools are left uncompleted by officers.
- ❖ There is no information on characterisation of waste.
- ❖ There is no information on quantities recorded for each class of waste.
- ❖ There is absence of information on moisture content and calorific values of waste.
- ❖ Only 33.3% of information collected on the indicators complies with the SAWIS template.
- ❖ There is no clear indication that waste information is collected from all the stages of the waste chain.

The non-adherence to the SAWIS information collection tool means that information collected by municipalities is not standardised and does not meet the requirements of SAWIC. Reliable information on MSW generation, classes, composition and management provide a rational basis for planning and executing waste management operations (logistics, disposal and treatment). For proper representation of this information, the information must be collected from every level of the waste chain.

COMPONENTS OF THE WASTE CHAIN FACILITIES

5.1 Introduction

This chapter identifies and maps the location of the elements of waste chain that are in the study area across the waste chain. It determines the population of each of the waste facility in each municipality. Waste chain is a very important source of collection of reliable waste information which is collected as the waste passes through different stages in the waste chain. Waste chain is the path trace of waste from generation to the point of disposal. This chapter aims to map the waste chain facilities in terms of information on type, numbers and location. Currently there is no reliable information on numbers of waste handling facilities which include recycling, landfill, compositing and WtE facilities. It should be noted that information on the waste facilities will contribute to plans to introduce or site waste facilities in the municipalities. Therefore, an assessment of available waste facilities across the waste chain should be carried out. The relevant methods used for the results presented here have been presented in chapter III, section 3.3.

Characterization of waste across the waste chain can help to identify the suitable strategy for waste management and treatment. That is, it is important for making decisions on whether to take waste for recycling, composting, WtE generation or landfilling (Jha et al., 2011). In simple terms, waste chain comprises of the following stages: generation, storage, collection, transfer and transport, processing and disposal of solid wastes (Sharholy et al., 2008). However, in actual life the waste chain is complex and not easy to outline because it is not a straight stream but a back and forth movement of waste through the chain. Fig. 11 shows the complex schematic diagram of the solid waste chain and waste information collection through the different stages.

At each stage of the waste chain, there is supposed to be facilities to manage the waste before the waste moves to next stage. MSWM requires appropriate facilities and equipment to provide effective and sustainable waste services in line with international best practice and economies of scale (Sharholy et al., 2008; DEA, 2011b). Each facility at any stage of the waste chain contributes to reduction of waste volumes cascaded to the next stage and later to landfills. In the past, the facilities primarily included only waste collection, landfills and incineration facilities. However, due to increases in population, urbanization and waste quantities, these

facilities became insufficient to deal with the huge volumes of the generated waste (Bagchi, 2004; Barlaz, 2006; Mannie and Bowers, 2014). This resulted in the birth of ideas to introduce other waste handling facilities (Barlaz, 2006). In general, waste facilities that are found in the waste chain stages are transfer stations, buy-back centres, landfills and treatment facilities (recycling, compositing and WtE).

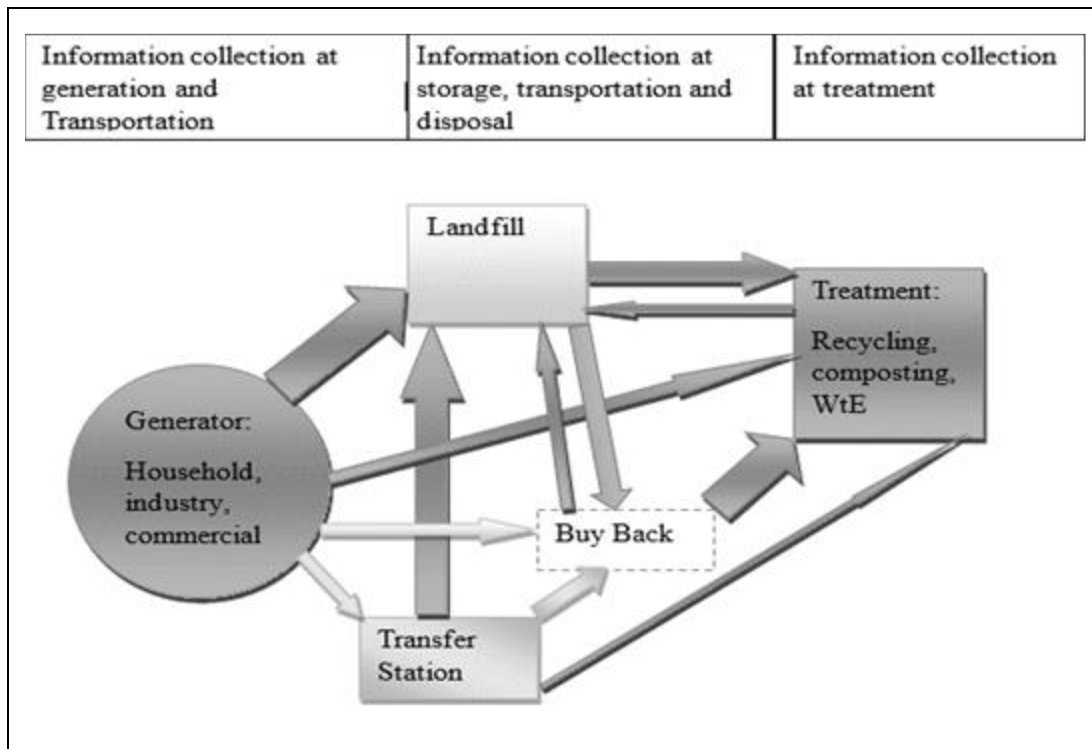


Figure 11: Solid Waste Stream

Source: Author, 2017

5.2 Waste chain profile

5.2.1 Transfer stations

These are facilities where waste is taken to after it is collected from the generation points. They are a very important part of preparation of the MSW for handling and transportation system. Transfer stations allow for the transfer of waste from smaller collection equipment to bulk haulage vehicles for transport to the disposal or treatment facilities (Hazra and Goel, 2009; DEA, 2011b). Secondly, waste could be compressed and separated to ensure efficient transporting and recycling rate (Zhen-shan et al., 2009) and thirdly, transfer stations give opportunities to waste collectors to sort and separate the waste before the waste is taken to

landfills for disposal. The waste that is separated from these facilities is taken to either buy-back centres, waste treatment facilities or landfills.

5.2.2 Buy-back centres

These are privately owned retail outlets that buy sorted materials from waste reclaimers with the intention of treating or reselling it to waste treatment facilities. At this stage, the waste is sorted further, treated and compacted in readiness to be transported. Buy-back centres are important because they shorten the distance the waste pickers cover to sell the reclaimed materials for income (DEA, 2011b). The whole process contributes to reducing waste that is taken to the landfill as well as increasing the chances of recycling and waste treatment initiatives.

5.2.3 Waste treatment facilities

Waste management options are now being applied in most countries with resource recycling, recovery and energy generation facilities from solid waste. Waste treatment is important because it removes waste from the waste chain thereby reducing the volume of waste being landfilled. For the purpose of this study, the treatment facilities include recycling, composting and WtE.

Recycling Centres

At these facilities waste is cleaned, treated or changed for other uses. Recycling is the concept of turning materials that would otherwise become waste into valuable resources of financial, environmental and social returns (EPA, 2012). Recycling process adds value to waste, that make it economically useful. It has been widely accepted as a sustainable solid waste management method because of its potential to reduce disposal and waste transport costs, and also to prolong the life-span of landfill sites (Moh and Manaf, 2014).

WtE facilities

These are plants where waste is burnt to get rid of the waste or to generate energy in terms of heat or electricity at the same time minimising mass and volume of waste (Kirkeby et al., 2006). Solid waste burning is common in low income communities with limited access to waste facilities where residents dispose of their waste in open pits which are burnt when they are

filled to save digging new pits (Boadi and Kuitunen, 2003). Incineration is a waste treatment process where raw or unprocessed waste can be used as feedstock.

Composting Facilities

At these plants biodegradable waste is recycled into composite or fertiliser. These can be done on large scale in plants that sell the composite as fertilizer but it can also be done on small scale at the backyard of households to use the product for gardening while reducing the volume of waste from the yard. All the waste that remains after being taken to the treatment facilities, go to landfills.

Landfill Facilities

Municipal solid waste (MSW) landfills represent the dominant option for waste disposal in many parts of the world (Laner et al., 2012). These facilities can be the final resting places of solid waste or can be the source of waste collection for waste to be taken for treatment. The uncollected waste at the landfill is either compacted into the soil or burnt. It is assumed that as the waste passes through the chain, the volume of the waste is reduced and becomes even less as it reaches the landfill. Apart from reducing the volumes of waste taken to landfills, a fundamental issue is to collect waste information from these facilities and to create proper information channels on waste as the waste passes through the waste chain. In South Africa waste information is supposed to be recorded and reported by these facilities which are responsible for routinely providing accurate data to SAWIS (DEAT, 2006).

Information collected from every facility at every stage of the waste chain, should ensure that there is no loss of information on waste. For instance, if waste is taken to buy-back centres for sell, on the receipts or delivery note, there are records showing the type, amount of waste and how much is paid for every waste that is delivered. This has worked in Thailand where when the recycling members take the recyclable materials to buy-back centres to sell, the weight and the type of the recyclable materials and the amount earned at the time are recorded into a passbook (Suttibak and Nitivattananon, 2008). This means that accurate waste information on quantities, classes and composition of waste is collected in accordance with what the facility does with the waste.

Within each treatment method the information includes type of waste the facility handles, number of facilities, location, capacity, function and status of the facility. This information can contribute to the database of waste information in the municipalities and be used to inform

authorities on the quantity, type and composition of waste that is used by the facilities. It can also be used in conducting census of facilities in terms of whether they are licenced or not, if the facilities are permitted or not (DEAT, 2005a). Most of this information is very useful for any individual or organization interested in planning, changing or implementing a waste management system in a city (Guerrero et al., 2013). Therefore, an assessment of available waste facilities across the waste chain should be conducted.

5.3 Results and Discussion

5.3.1 Waste facilities

Waste minimisation is a critical component of the government support in the waste hierarchy. Along the conventional waste stream, significant volumes of waste may be taken off the waste chain for purposes of waste recovery through different facilities (Mudau et al., 2013). The availability of waste information and the presence of waste facilities for example transfer stations, buy-back centres and treatment facilities provide ample opportunities for diverting waste that would otherwise be taken to landfills. Despite the fact that there are some waste collecting equipment such as skips, movable and fixed bins at waste generation stage, the study focused on transfer stations, buy-back centres, landfills and treatment facilities (recycling, WtE and composting). Mannie and Bowers (2014) reported that there are 2000 waste handling facilities in South Africa. In this study a survey was conducted to identify and determine the population of the types of waste facilities in the study area. A total of 37 waste handling facilities were identified. Out of the 37 identified facilities, 12 are landfills, 14 are buy-back centres, 10 are transfer stations, and 1 is recycling centre. There are no WtE and composting facilities. These results agree with the results that were reported by DEA (2011b) and Vice et al. (2014) in their surveys on waste facilities. Their results showed that in Cape Town and South Africa as a whole there are transfer stations, buy-back centres, recycling centres and landfills only. There are no WtE nor composting facilities.

The absence of some waste facilities in some areas is one of the technical factors that affect waste management (Moghadam et al., 2009) and the information about them. However, as stated earlier, there could be many more other waste facilities in the study area that are not known because the owners of the waste facilities were reluctant to share the information for reasons known to themselves. Moreover, waste information collection and submission is voluntary and not mandatory in South Africa.

5.3.2 Distribution trends

Distribution of the waste facilities differ across the municipalities, some municipalities have more of different types of waste facilities than the others. Fig. 12 shows the distribution population of the waste facilities in the municipalities in the study area.

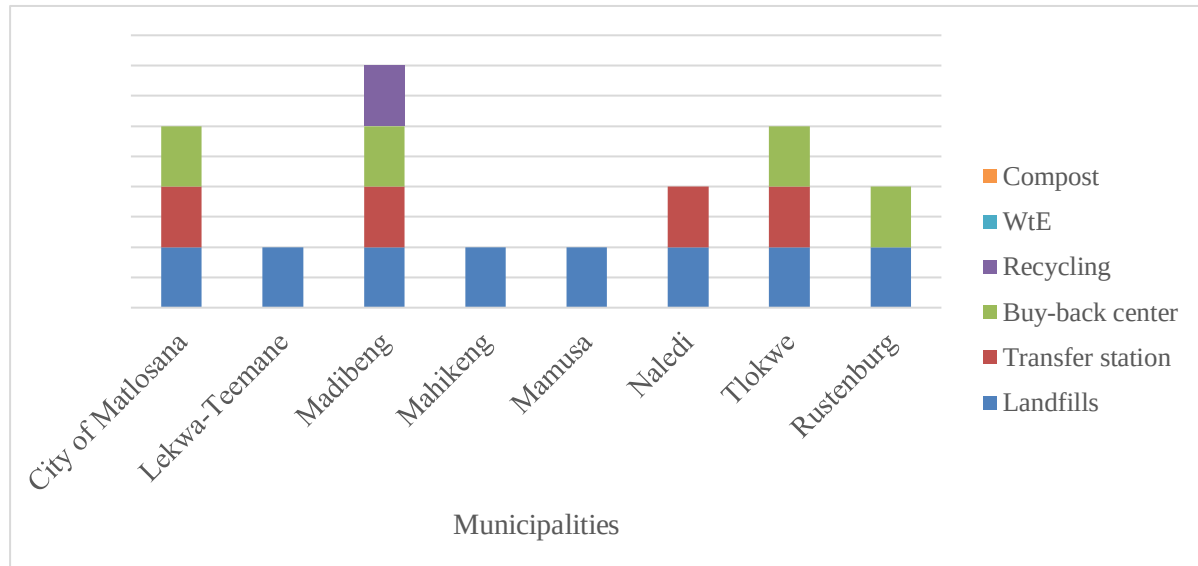


Figure 12: Distribution of waste facilities in municipalities

The results show that landfills are distributed throughout every municipality seconded by transfer stations and buy-back centres. The results also show that there is only one documented waste recycling facility in one municipality, there is no documented WtE nor composite facilities.

Landfill

Landfills are located in every municipality in the study area compared to the other waste facilities, which are only available in some municipalities, Fig. 12. Though the results show that there are landfills in every municipality, the population of the landfills varies from one municipality to another. Some municipalities that have more landfills than there are in others, Fig. 13. The results in Fig. 13 show that there are 3 landfills in one municipality and two municipalities have 2 landfills each while the remaining five municipalities have 1 landfill each. These results agree with Vice et al. (2014) who reported that in South Africa, on average 92.7 % of the generated waste in 2005 and 2007 was taken to landfills. This shows that most waste is taken to landfill than it is taken to other waste facilities. This could be attributed to either the presence of landfills in every municipality or that most landfills are documented.

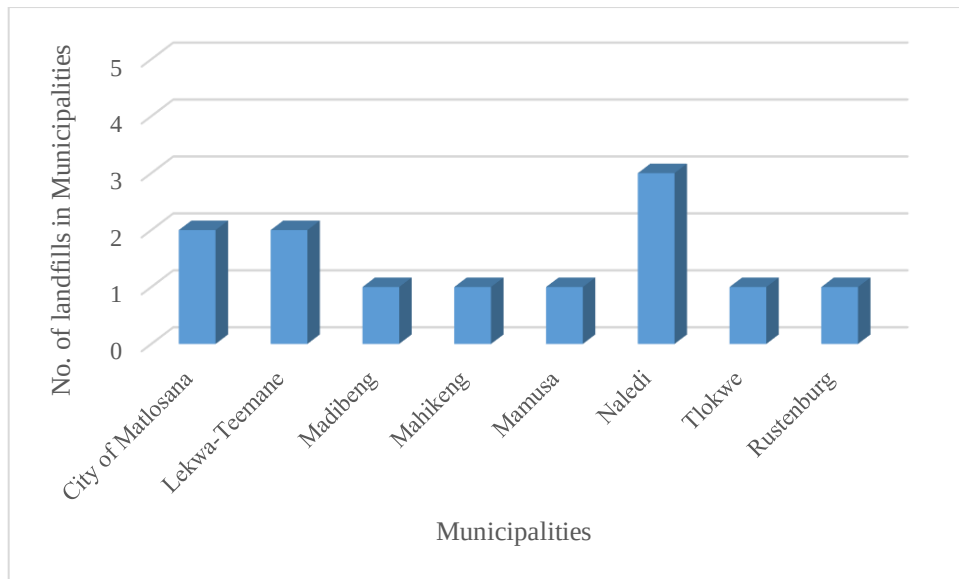


Figure 13: Landfills in each municipality

This create pressure on the landfill leading to poor management and care of the landfill as depicted in Plate 1 for a landfill in the study area. Observations have shown that city councils take the waste to landfills making landfills the most popular facilities for waste disposal.



Plate 1: Poor management of landfill. Delareyville landfill in Tswaing

Though it is assumed and practiced that landfills are the ultimate solution for waste disposal in the local municipalities, they are not the most ideal solution because if they are incorrectly sited and pressured, they could lead to negative environmental, social and economic costs (Gbanie et al., 2013). There is need to consider other waste handling facilities that can ease the pressure on the landfills as many landfills in the study area are not in good condition.

Transfer stations

The results of the study show that 10 of the waste facilities are transfer stations. The distribution of transfer stations in the study area is shown in Fig. 12, which reveals that the transfer stations are not found in every municipality. The number of transfer stations in each municipality is displayed in Fig. 14.

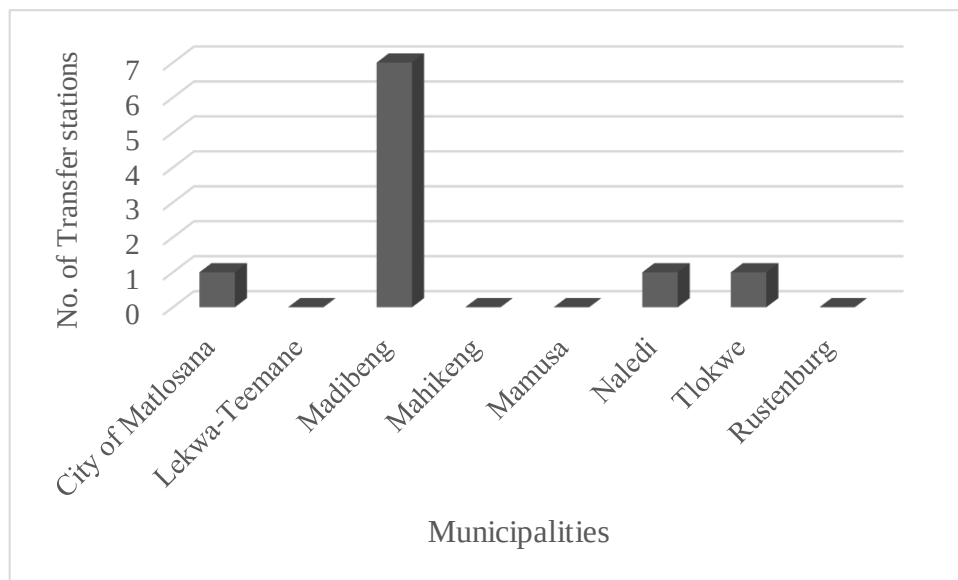


Figure 14: Transfer stations in each municipality

The results in Fig. 14 show that 7 of the transfer stations are found in one municipality, Madibeng, and the remaining 3 are evenly distributed in each of the 3 municipalities. The results also show that there are no transfer stations in four of the municipalities.

This means that in the municipalities where there are no transfer stations, the waste generated does not pass through transfer stations. The waste is taken straight to landfills or other waste facilities. This result agrees with the report by Vice et al. (2014), which showed that in 2005, very little waste in South Africa (2.2 %), was taken to transfer stations while in 2007 no waste was taken to transfer stations. Guerrero et al. (2013) reported that only 27.8 % of South African cities have transfer stations. Achankeng (2003) noted that transfer stations are not common in Africa, with no single transfer station being found in the whole of Cameroon. Looking at the number of municipalities that do not have transfer stations in the study area and the literature, it shows that transfer stations are rarely used.

The low number of transfer stations and the non-existence of these facilities in some cases, means that waste diversion as a formal program is not yet widely integrated in the waste

hierarchy of local municipalities. Nonetheless, the main aim of having transfer stations is to ease pressure on time and waste collection, and to serve as sorting points for the people that want to collect waste for recycling or any other waste treatment. Most of the transfer stations are not fully utilised for the purpose they were built to serve as there are limited activities at the stations. Plate 2 shows one transfer station in the study area where it was noted that only garden waste is taken to the facility.



Plate 2: Transfer Station in Vryburg, Naledi Local Municipality

Sharholy et al. (2008) indicated that in India transfer stations are not used except in very few cases in 5 cities. This could be due to the designed capacity of existing transfer stations which cannot cope with the actual waste transferred (Zhen-shan et al., 2009). In some cases, the presence and/or absence of transfer station is dependent on the availability of waste transportation facilities and the quality of the road network (Guerrero et al., 2013). It is therefore necessary to design and construct transfer stations that can accommodate the different classes of wastes and also improve the transportation and road facilities. The resources used for collection and transport, trucks and labour, can be utilized more effectively if waste is transported to the disposal area via transfer stations. Transport cost contribute to a large portion of the cost associated with waste management and the long distances to transport waste to landfills. This then calls for more transfer stations. Though the results have shown that there are landfills in every municipality, the landfills are far away from most of the generation points. The location of transfer stations becomes important when the daily average amount of solid

waste to be transferred is huge, for example around 6,000 tons and disposal areas are at least 30 kilometres away from the collection points (Kirca and Erkip, 1988).

Buy-back centres

The results show that there are 14 buy-back centres in the study area. However, the number population of the buy-back centres vary from one municipality to another. Fig. 15 shows the number of the buy-back centres in the municipalities in the study area.

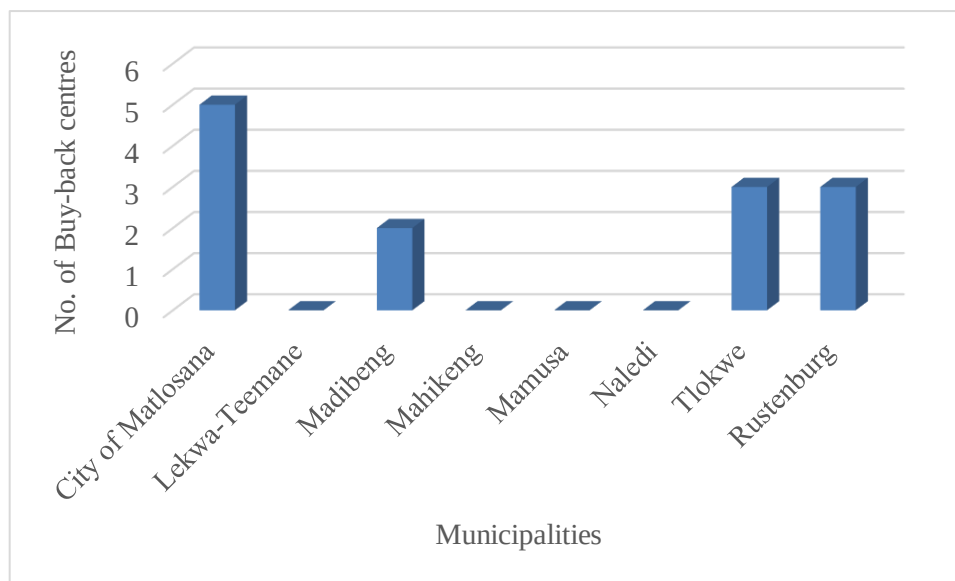


Figure 15: Buy-back centres in each municipality

The results in Fig. 15 show that there are more than one documented buy-back centres in some municipalities. In one municipality there are 5 buy-back centres. This study has shown that there is no waste information that is reported to SAWIS by the buy-back centres. Vice et al. (2014) also reported that there was no information on waste that was taken to buy-back centres in 2005 and 2007. Observations from this study shows that the buy-back centres are very active with daily operations of accepting, sorting and packaging the recyclables. The way the waste is packaged, Plate 3, shows that they are preparing for long distance transportation and this supports the findings of this study that there are few waste recycling or treatment facilities in the province. The lack of waste treatment facilities is further discussed in Chapter 6.



Plate 3: Buy-Buck Centre in Sannieshoff, Tswaing Local Municipality

Buy-back centres ensure relatively clean recyclable materials since the waste is collected, sorted and packaged. They are centres where waste is prepared in readiness for delivery to recycling and for alternative waste treatments. Moreover, buy-back centres act as a link between the formal and informal sector activities in the recycling industry and therefore promote informal and formal job opportunities (Viljoen et al., 2012). There are many buy-back centres in South Africa and all are linked to the formal recycling industry which provides support and guarantees to accept the material recovered. These facilities are private businesses which contribute to creation of employment and income for the workers and the owner (DEA, 2011b). Observations at the buy-back centres operating in the study area revealed that an average of over 10 employees were preparing the waste. This observation is not far from the results of the study by Viljoen et al. (2012) where they observed that in 50 % of the buy-back centres in Pretoria at least five people were employed and 20 % of the buy-back centres in Bloemfontein, they employ between five and eight employees.

However, several studies on household participation in buy-back centres at designated centres in Kuala Lumpur, Malaysia, showed low participation and inconsistency in the operational schedule of the buy-back centre due to the high operational costs (Zen et al., 2014). Sometimes, the low participation and inconsistency in the operation could be due to the location of the buy-back centre. Viljoen et al. (2012) stated that buy-back centres should be close enough and accessible to the informal waste reclaimers.

It has also been observed that the centres can buy all the different types of waste at the same time. The authorities at the buy-back centres listed all the different types of waste that they deal with the average prices that they pay for the most popular classes of waste. The listing of all

the waste provides opportunity for the collection of waste information from these facilities. The authorities were not comfortable to disclose the cost for the other fractions. The waste classes included 2 litre plastic bottles which they bought for R2.60 per kg, boxes they bought for R0.80 per kg and plastics cost them R1.05 per kg. They did not disclose the prices they pay for other plastic bottles, white paper, aluminium cans and metal scraps. It is estimated that on average, every month, an average buy-back centres deliver 30 bags of 2 litre plastic bottles, 20 bags of plastic and 10 bags of boxes to recycling centres.¹

Waste recycling

The results in Fig. 12 shows only one municipality that has waste recycling facility in the study area. Fig. 16 displays the population of the waste recycling centres in the municipalities.

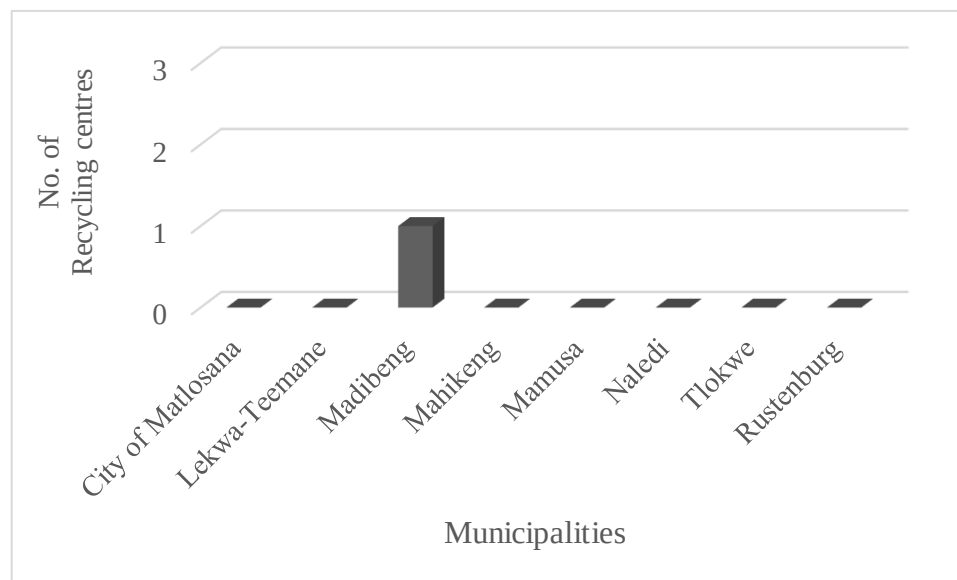


Figure 16: Recycling facilities in each municipality

The results that shows that there is recycling centre in the study area agree with the report by Vice et al. (2014) that there are waste recycling facilities in the study area and in South Africa. The survey that was conducted in South Africa showed that there was an increase in the waste taken to recycling facilities from 0.37 % in 2005 to 10% in 2007 (DEA, 2011b; Vice et al., 2014). In the 2012/13 financial year, Cape Town's recycling and waste minimisation increased significantly with 12-14 % of waste entering the municipal waste stream being diverted to

¹ 1 bag = 1m³.

waste recycling by City programs (Johannessen and Davison, 2014). However, both results show that the recycling industry is not yet widespread in South Africa and NWP in particular.

The success of recycling not only depends on participation levels but also on the efficiency of the equipment and facilities to produce valuable materials/goods from the recyclables. For example, the only one recycling facility in the study area (Madibeng municipality) produces insulated concrete construction blocks from waste. The blocks consist of recycled polystyrene which are used as a lightweight aggregate mixed with cement and additives to form insulated, soundproof, fireproof and water-resistant concrete blocks. The blocks are being used in construction of houses (Plate 4).



Plate 4: Recycling Products Hartbeespoort, Madibeng Local Municipality

Some municipalities in NWP are now gearing to try and introduce or improve recycling in the households in their municipalities. This will be achieved by creating enabling environment for recycling through a multi-prong approach of different initiatives. The initiatives will include raising awareness and provision of recycling facilities like drop-off centres located in towns which are easily accessible by the public (LTLM). This is in agreement with (Guerrero et al., 2013), who pointed out that information about the benefits of recycling, how to sort the waste, prioritising of solid waste issues by municipal leaders which include better facility and low cost recycling technologies, could motivate communities to participate in recycling campaigns.

Waste to energy

Results show that there are no WtE facilities in the study area, similar to the studies that were conducted in 2005 in South Africa on population of waste facilities (DEA, 2011b). Vice et al. (2014) reported in a study conducted in 2007, that only 1 % of waste was taken to WtE facility in South Africa. The WtE recovery technology remains an option of low priority for most African countries (Achankeng, 2003). Although the WtE technologies have been tried and tested in developed countries with positive results, in developing countries, such as India they are yet to get off the ground until the financial viability and sustainability is tested (Sharholy et al., 2008). WtE technology has not picked up fully yet in many developed countries where it has been introduced due to its high investment cost (Rand et al., 2000).

Composite sites

Results show that there is no composite facility that is documented in the study area. This result agrees with the result that was obtained from the census conducted in 2005 for South Africa (DEA, 2011b). However, from census conducted in 2007 on waste facilities in South Africa and Cape Town in particular, Vice et al. (2014) reported that only 2 % of waste was taken to composting facilities. Though composting activities are becoming more and more common, many large and small composting schemes fail because not enough attention is given to the marketing and the quality of the product (Zurbrugg, 2003).

Composting has been tried in various developing countries like Senegal and Cote d'Ivoire at different scales with very poor results leading to failure because of no demand for the final product (Achankeng, 2003). Shekdar (2009) argues that many composting facilities have been shut down due to inadequate monitoring of the quality of the compost being produced and inappropriate facilities. In other countries, composting facilities have been successful but with problems in the long run (Sharholy et al., 2008). For example, in India, large-scale composting projects with capacities ranging from 150 to 300 t/day that started in the early 1960s, set up in the cities of Bangalore, Baroda, Mumbai, Calcutta, Delhi, Jaipur and Kanpur became a concern to the environment during 1975–1980. And after 1980, the MSW compost was no longer used for soil enrichment (Sharholy et al., 2008). The reduction in the numbers of composting facilities was also reported in China, where there were 651 disposal facilities in 2002 of which 78 were composting plants and five years later (in 2007), the number of composting plants dropped to 17 (Zhang et al., 2010). Heavy metals tend to enter the food chain unhindered as

Hazra and Goel (2009) emphasised that the present system and compost quality are totally unacceptable by WHO standards and World Bank norms.

Experience with composting plants has shown that one of the major reasons many of them fail is quality and changes in production costing (Achankeng, 2003). Private sector composting is limited by lack of finance and technical know-how. In Kolkata, India, Hazra and Goel (2009) noted that farmers are rarely interested in buying compost but will accept it at no-cost. This results in a greater proportion of the solid waste being dumped, thereby putting much pressure on the inadequate disposal facilities (Boadi and Kuitunen, 2003).

5.4 Summary

This chapter identifies the type, numbers and locations of waste facilities in the waste chain. This is important for waste management and for planning of waste information collection through the chain. On the basis of the results, the objective on waste chain facilities has been adequately addressed. The results report that:

- ❖ Most landfills do not meet official standards in terms of specifications but remain the dominant facility for the bulk of waste disposal in municipalities.
- ❖ Transfer stations are found in only 4 of the municipalities; their small number points to the mean low stages of waste volumes generated in NWP.
- ❖ Buy-back centres are distributed across the NWP but are generally small in size and low technology operations.
- ❖ Apart from the facility at Brits in Madibeng municipality, there is no other documented industrial scale waste recycling plant in NWP.
- ❖ There is lack of information on facilities that handle waste at different waste chain stages such as transfer stations, buy-back centres, landfills and treatment facilities (recycling, compositing and WtE).
- ❖ Recycling industry, where waste is converted into industrial raw materials for further processing or into new products for the market is not yet well developed in NWP.
- ❖ Officially, local municipalities do not have formal waste composting and WtE facilities in any of the municipalities in NWP. Where this is taking place, it is small size and privately run by companies that produce manure for gardening to urban households.

STATE OF WASTE TREATMENT IN NWP**6.1 Introduction**

This chapter assesses the state of waste treatment in NWP by identifying the type and population of waste treatment activities in municipalities. It also assesses the spatial distribution of the solid waste treatment activities. For a long time, it has been assumed that landfills are the ultimate solution for waste disposal in local municipalities. However, due to the increase in generation and complexity of the waste stream, landfills are no longer the most ideal solution (Mannie and Bowers, 2014). The complexity of the waste stream directly affects its management. This situation has triggered the introduction of a large number of waste treatment alternatives and the drive to practice integrated waste management in the municipalities (Achillas et al., 2013). The integrated waste management approach involves the use of other waste treatment technologies such as incineration (WtE), recycling and composting (Messineo and Panno, 2008; Achillas et al., 2013; Chaliki et al., 2016). Waste treatment and processing should target minimizing the volume of waste to be landfilled whilst recovering as much resources out of it as possible (Arafat et al., 2015). Various technologies for waste treatment are chosen depending on the type of waste as well as the cost of the waste treatment technology (Messineo and Panno, 2008). Local authorities therefore should investigate potential performance of available waste treatment alternatives in order to adopt the appropriate treatment technology to overcome the complex nature of the waste (Antonopoulos et al., 2014).

Waste management policies have been developed and stated in European Union (EU) to set recycling and recovering targets, while avoiding the landfilling of waste as a waste management option (Antonopoulos et al., 2014). In South Africa National Environmental Waste Management Act (NEMA) requires that all municipalities prepare an Integrated Waste Management Plan (IWMP) with the aim of ensuring that the municipality provides waste management services that are compliant with the National Environmental Waste Management Act of 2008 (NEMA, 2008). The IWMP's goals are also set to focus on minimising waste that is disposed at the landfill site by encouraging waste minimisation, through re-use of waste and different other waste treatments to contribute to integrated waste management (Tlokwe City Council IWMP, 2015).

Waste treatment contributes positively to integrated waste management. It is one way of reducing the volumes of waste taken to landfill, lessening the impact on the already pressured landfill sites and saving landfill space since the need for landfilling is avoided.

Cutting the amount of waste going into landfill extends the lifespan of landfills and reduces the cost to municipalities of acquiring additional landfill sites (Jereme et al., 2015). Waste treatment facilities facilitate communities to generate wealth from the waste that they recover from the waste stream and sell to the treatment facilities. They also create employment for the people working at the waste treatment facilities (Ezeah et al., 2013). Waste treatments contribute to growth in waste recovery rates from the waste stream. This is a promising environmental benefit as the open spaces will no longer be used as waste dumpsites. They also improve the efficiency of the waste management system and minimize its possible health risks (Demirbas, 2011).

The waste produced in the waste streams contain recyclables (paper, plastic, glass, metals), toxic substances (paints, pesticides, used batteries, medicines), compostable organic matter (fruit and vegetable peels, food waste) and medical waste (blood stained cotton, sanitary napkins, disposable syringes) (Jha et al., 2003). All these types of waste can be raw materials for recycling, incineration, WtE and composting processes.

6.2 Recycling

All the waste treatments processes represent a way of waste recycling, they use materials that are regarded to be at the end of their life as raw materials to produce a product and they are part of the whole integrated waste management system recycling inclusive (DEA, 2012). Recycling is a process whereby discarded products and materials are reclaimed from the waste stream, refined or reprocessed, and converted into new or different products through physical and biological reprocessing (Demirbas, 2011). Waste recovery, re-use and re-sale are forms of recycling because these activities allow for such waste to be re-introduced into the environment without any processing or change in form. This forms the basis of the circular economy.

Waste recycling remains the most climate-friendly waste management option (Jamasp and Nepal, 2010). There are formal and informal waste collectors that contribute to recycling. The informal waste sector is alleged to be the contributor of spillage of waste around waste bins and disposal sites. Though the informal waste sector is perceived as the bad one, it is the more comprehensive and efficient than it is first taken to be because the collectors collect every

recyclable piece of waste that they see in order to earn a living (Chi et al., 2011). Sharholy et al. (2008) points that a survey conducted by the Central Pollution Control Board (CPCB) in 1996 in Indian cities revealed that informal waste pickers play a key role in recycling. They work day and night to collect the recyclable materials from the streets, bins and disposal sites for their livelihood leaving only a small quantity of recyclable materials behind them. Thus, taking about 40–80 % of plastic waste for recycling (Sharholy et al., 2008). An important step towards integrated MSWM, following the rules laid down by the European Union, is incineration (Morselli et al., 2005).

6.3 Incineration

Although there are many thermal processes, at present, incineration of waste materials is the most widely used technology that converts waste into ash, flue gas and heat (Chaliki et al., 2016). Incineration is the process of burning solid waste at temperatures ranging from 980°C to 2000°C. It can be used for energy recovery and it can also be used to destroy toxic wastes in mass-burn facilities, for example, waste from hospitals (Jha et al., 2003; Al-Salem et al., 2009). One of the most attractive features of incineration process is that it can reduce volumes of combustible solid waste by 80–90 % depending on composition and degree of recovery of materials such as metals and ash (Sharholy et al., 2008; Chaliki et al., 2016). The energy that is recovered from incineration can be in form of electricity (WtE generation).

6.4 Waste-to-energy

At present WtE represents an important strategy in the area of waste treatment (Tabasová et al., 2012). WtE process recovers energy from waste through controlled thermo-destruction of MSW (Morselli et al., 2005). The whole idea of the process is to extract the full energy and environmental value from the MSW before it is disposed in a landfill (Jamasp and Nepal, 2010). The energy is extracted in the form of heat or electricity (Chaliki et al., 2016). The first technologies that were used in WtE process caused concerns in relation to environmental safety such as pollution of the air, water and soil (Park and Heo, 2002). However, the current, modern WtE technologies are far much improved from their polluting predecessors. They use the modern combustion and pollution control technology which improves the retrieval of considerable amounts of energy from waste combustion while minimizing emissions (Messineo and Panno, 2008). However, the waste that has high organic content and high moisture content, are not ideal for WtE system, but they are suitable for composting.

6.5 Composting

Composting is the biological decomposition of organic waste such as food or plant material by bacteria, fungi, worms and other organisms under controlled aerobic (occurring in the presence of oxygen) conditions (Sharholy et al., 2008). The end result of composting is manure or fertiliser. In some countries the process has been successful while in others it has failed because the cost of producing the manure is more than the income generated from the sale of the product. Composting MSW is seen as a method of diverting organic waste materials from landfills while creating a product, at relatively low-cost, that is suitable for agricultural purposes (Wolkowski, 2003). It is reported that some users do not use the composite because they feel that it is expensive and also they fear that the composite is contaminated due to improper processes when composting (Sharholy et al., 2008; Hargreaves et al., 2008). Composting is important in waste management though it has challenges just like all the other waste treatments.

There are several challenges in waste treatment processes. The first challenge is the quantities of waste available, whether sufficient quantities of waste for waste treatments are produced in the area. If few waste is recovered from the waste stream, it will not sustain the available waste treatment projects in the area. The second challenge is composition of the waste. The composition of waste differs widely from urban to rural areas, and from higher income to lower income areas which create challenges in waste treatment methods (Bai and Sutanto, 2002). For example, the ratio of food waste, papers and moisture content of waste varies, in Singapore are 39 %, 20.6 % and 48.6 % respectively while the food for Yokohama, Osaka and USA are 9.8, 6.5 % and 6.7 % respectively; paper is 40 %, 33.7 %, 37.6 % also for Yokohama, Osaka and USA respectively (Bai and Sutanto, 2002). These composition differences have significant impact on the waste treatment systems in different countries. The third challenge is moisture content and calorific values of the waste. If the moisture content is high and calorific value is low, then the waste is appropriate for composting and cannot be used in WtE process. The fourth challenge that is faced in waste treatment include expertise and technologies used in the waste treatment. Expertise on the treatment processes and the technology used in waste treatment is a key to sustaining and improving the processes. Use of proper and up-to-date equipment improves the production and quality of the product. The fifth challenge is lack of waste information on quantities, type, composition, moisture content and calorific values of

the waste in the municipalities. Lack of waste information affect the allocation of waste to appropriate waste treatment, identification and location of waste treatment plants.

Availability of waste information will inform management on the available quantities, type, composition, moisture content and calorific value of waste and will provide the management with a rational basis for planning and executing waste treatment operations (logistics, disposal and treatment) (Karak et al., 2012). This study therefore sets out to assess the state of waste treatment in the province and integrate it with waste information. Specifically, the study seeks to (i) identify the type of waste treatments in the area (ii) to determine number of waste treatment facilities in municipalities and (iii) identify the location or spatial distribution of waste treatment facilities in NWP.

6.6 Results and Discussion

6.6.1 Waste treatment

Currently in South Africa there are waste activities that are identified and registered as: landfill sites, waste treatment facilities, waste recycling and waste exporters (DEAT, 2005b). Waste treatment encompasses recycling, incineration, WtE and composting with the aim of reducing volumes of waste that is taken to sanitary landfill (Fiorucci et al., 2003). Historically, very few of these activities are viable, alternative waste management options for the bulk of waste streams produced (Johns et al., 2014). This study therefore conducted an assessment on the availability and status of the waste treatment in selected municipalities in the NWP. Twelve waste treatment facilities were identified. It was observed that out of the 12 waste treatment facilities, there are only two different types of waste treatments namely: landfilling and recycling which makes up 91.7 % and 8.3 % respectively. There is zero percent for both composting and WtE generation. This shows that landfilling is dominant waste treatment technology in the study area compared to the other waste treatment activities.

Landfilling

Other studies have shown that reduced landfilling in favour of increased recycling of materials lead to lower environmental impact and economic costs (Eriksson et al., 2005). However, in this study, results show that landfill is the most common waste treatment method (91.7 %) compared to recycling (8.3 %) and both composting and WtE (0 %). This result is consistent with the information that was reported by DEA (2011b), which indicated that despite the

existence of a range of alternative waste management options, including waste recycling facilities, over 90 % of all South Africa's waste is disposed of at landfill sites. The 91.7 % landfilling recorded in the current study that was conducted in 2017 falls short of the 50 % reduction in waste to landfill by the year 2012 that the Polokwane Declaration of 2001 targeted. These findings support the conclusion of Couth and Trois (2010) that the target of the Polokwane Declaration 2001 was far too ambitious as progress made so far to meet those objectives has not been very encouraging. The reliance on landfilling is not only common in NWP, South Africa, it is also the most commonly used method for managing wastes in many European countries where in some cases this reliance surpasses the 80 % mark (Chaliki et al., 2016). The International Solid Waste Association (ISWA) reports that on a global scale, landfilling still represents the main disposal method for Municipal Solid Waste (Scarlat et al., 2015). Though the waste treatment activities are identified and registered with the Central Registry and the Department of Environmental Affairs, these activities have not yet been fully developed and have not been properly documented. As observed from the results of this study, the waste that is not taken to landfill is taken for recycling.

Recycling

Though the results from this study show that there is only 8.3 % of waste recycling in NWP, it is worth noting that there is a viable recycling industry in South Africa and that paper recycling rates match up to many developed economies. The only challenge is that the recycling industry in South Africa lacks recycling facilities and it is not well documented. Currently there is no adequate information on recycling and there are no laws to enforce recycling. Due to the lack of proper documentation the information on intensity of recycling in South Africa, is not consistent and the information that is available is often unreliable and contradictory (DEA, 2012). DEA (2011b) reported that in 2007, South Africa recycled 1.5 million tons of packaging and paper which amounted to a recycling rate of 40.8 % of all packaging and paper consumed, while the Paper Recycling Association of South Africa (Prasa) reported the paper recycling rates to be 38 % and 59 % in 2000 and 2011 respectively. Another study conducted by Larney and van Aardt (2010) shows that there is 34.8 % of recycling activities in South Africa and DEA (2012) reported that in 2011 of all waste generated in South Africa, 10 % was recycled. The association also had projected paper recycling rates to increase to 63 % by the end of 2017, but by December 2015 the paper and paper packaging industry exceeded this to 66 % putting South Africa well ahead of the global average of 57.9 % (ICFPA, 2015). There is need for this

information to be properly documented and reported to SAWIS for consistent and reliable information on the paper recycling rates. This information should be shared with the role players in waste to promote and support MSW recycling to reach its full potential and to maximise employment opportunities (DEAT, 2005b). Magrinho et al. (2006) states that the existing information that is disclosed by the responsible entities for both direct and non-direct MSW management is limited, restricted and not always reliable.

The results of the study show that most of the waste goes to landfill. Nevertheless, observations show evidence that there are other waste activities on MSW going on in the NWP. It has been witnessed that almost at every buy-back centre there is waste packed and piled ready for transportation to next destination of waste for treatment, Plate 5.



Plate 5: Buy-Back Centres in Brits, Madibogo and Wolmaransstad

Although recycling and reuse are considered the best method for waste treatment, the amount of waste that can be recycled is limited to less than approximately 40 % of the total volume (Park and Heo, 2002). There is need therefore, to introduce waste to energy technologies that can handle and treat the waste that cannot be recycled, reused nor landfilled but have high heating values. Eriksson et al. (2005) pointed out that even with a high degree of source separation, a large part of the waste have to be incinerated.

Waste-to-energy

The results in section 5.3.2 show that there are no WtE projects in the study area. However, Vice et al. (2014), in their study on potential of WtE in South Africa, concluded that in Cape Town there is significant quantity of waste streams that are generated in the metro that can be used in WtE projects. The findings of Vice et al. (2014) are in agreement with DEA (2012) report, which estimated that in 2009 about 1 % and 2 % of generated waste would be used for WtE in South Africa as a country and Cape Town as a city, respectively. The results of this study support the reasoning by Vice et al. (2014) that there are significant quantities of waste that could be suitable for WtE projects. However, it should be made clear that not every type of waste is ideal for WtE projects. Key determinants include the calorific values, moisture content and organic content of the waste. The waste with low calorific values, high moisture content and high organic content can be directly sent to a composting plant because it is ideal for production of compost for agricultural use (Fiorucci et al., 2003).

Composting

The results in section 5.3.2 also show that there is no composting in the study area. However, there are studies that have shown that South Africa is capable of managing and implementing composting projects based on the amount of organic waste that is generated. In 2010/11, the City of Cape Town (CoCT) found that organic waste generated within the City, (21 kg/household/month), had great potential for composting and needed to be diverted from landfill (Masilela and von Blottnitz, 2014). The study supports the argument that household kitchen organics are a potential waste resource for composting (Johannessen and Davis, 2014). However, it is not always the case that when there is more organic waste then composting can be the option. Ofori-Boateng et al. (2013) found out that although organic wastes form over 50% of total generated MSW in Ghana, composting has never succeeded as an option for waste disposal. Though studies on composting have been conducted in South Africa, there is no satisfactory information on the composting projects and the quality of their product, the composite. In addition, currently South Africa does not have legislation controlling the quality of compost or digestate that can be applied to land. There is need for implementation of appropriate legislation measures banning the deposition of organic wastes in landfill sites and controlling the quality of the compost (Daskalopoulos et al., 1998). The results from the two studies have shown that there is potential for composting in South Africa because the organic content of the waste is 58 % which is higher than the African waste organic content mean of

53.9 % (Couth and Trois, 2010). Nonetheless, the private waste collectors pay more attention to paper, metals and plastics than they do to organic or biodegradable materials, even though the paper, metals and plastics are present in much smaller percentages than the organic waste (Van de Klundert and Lardinois, 1995). Composting of municipal solid waste has potential as a beneficial recycling tool (Hargreaves et al., 2008). This then calls for need to maximise the production and quality of the compost by introducing legislation controlling the quality of compost and generating and sharing reliable information on composting.

Literature show that there are other waste treatments like recycling, energy recovery and composting that are done in South Africa. The question is: where are these waste treatment facilities, what information is available for these waste treatment projects? This remains a gap that needs to be properly documented so that the information on the different waste treatments is available, consistent and shared. The information will lead to the successful adoption of recycling, composting and energy recovery to form a unity of purpose in integrated waste management. This is echoed by DEA Guidelines for the Development of Integrated Waste Management Plans⁴² which stipulates that municipalities must keep records of the waste disposal facilities (also privately owned and private sector facilities) within their area of jurisdiction, and should indicate the status of these facilities and the types and quantities of waste disposed or handled at the facilities not in list). This study therefore seeks to develop a waste information-based platform that will address the shortfalls on the status of information on waste.

6.6.2 Waste treatment facilities

Municipalities have executive authority to perform their duties in relation to waste services. Around the world, collection, diversion (recycling and composting), and disposal operations of MSW are often run by municipalities within their political and geographic jurisdiction. (Cheng and Hu, 2010; Soltani, 2015). This gives them formal responsibility for solid waste management; this responsibility is generally assigned to the Health or Sanitation Department, but in certain cases also to the department of Public Works or Engineering (Van de Klundert and Lardinois, 1995). As stated earlier, there are 12 waste treatment facilities in the municipalities of the study area. Fig. 17 shows the number and type of waste treatment facilities in each municipality.

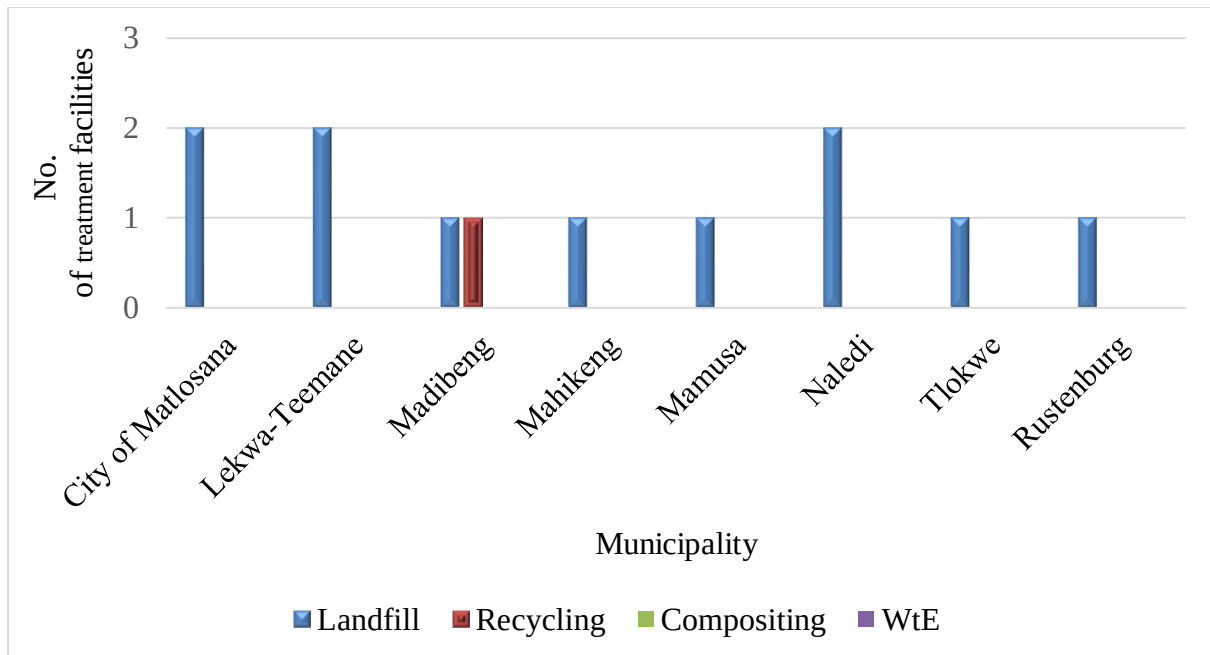


Figure 17: Number and Type of Waste Treatment Facilities in Municipalities

Fig. 17 shows that there are only two types of waste treatments (landfilling and recycling) and no any composting nor WtE facilities in the municipalities. 3 municipalities have 2 landfills each while 5 municipalities have 1 landfill each. The results in Fig. 17 also show that the only recycling facility is found in District of Bojanala. The result on recycling agrees with the results that were reported by DACE (2008) that in Bojanala, between 0.4 % and 1.3 % of waste disposed of in their landfills is recycled by scavengers. This echoes the challenges that were identified by the NWMS in 2012 that there are few waste treatment options that are available to manage waste and where they are available, they are more expensive than landfill costs (DEA, 2012).

Although municipalities in South Africa have control over waste management streams (Mudau, 2015) as mandated by NEMWA, DEA (2012); Alberts (2014) noted that a total of 87 % of municipalities do not have the capacity and facilities to pursue waste minimisation. It is estimated in 2007 that 95 % of household waste was directed to landfill (Mannie and Bowers, 2014). This shows that the municipalities cannot implement the waste treatment projects on their own, they need to involve other parties. Soltani et al. (2015) advises that for municipality to achieve the successful introduction of the other types of waste treatment, it needs to engage with those that are involved in waste treatment projects. The municipality should also have effective communication and waste information sharing. The role these partners play in waste management systems as partners for municipalities is slowly achieving international

recognition. For example, in Yala, Thailand, a program of recycling and garbage reducing was established through a relationship between poor communities and the municipal administration. Similarly, in India, the government had the cooperation with private sector and citizen in recycling (Dhokhikah and Trihadiningrum, 2012). Observations in NWP, South Africa have shown that municipalities team up with schools in recycling although most projects have been abandoned.

The presence of landfills in every municipality, in Fig. 17, could be due to the fact that municipalities own and manage disposal facilities (landfills) as stated by Alberts (2014). Nonetheless these facilities are not a secret though there is scanty information about them. The issue of landfill dominating the other waste treatments for waste disposal is a long time standing issue which was mentioned by Lee and Jones (1991) that although it is possible to significantly reduce the amounts of wastes that need to be landfilled, it is not possible to totally eliminate the landfilling of municipal solid waste. Barlaz (2006) concluded that nevertheless landfills will continue to play a significant role in MSW management throughout the world because it is relatively low cost compared to other disposal options agreeing with Cointreau (2006) who stated that other waste technologies are often regarded as too prohibitively high to be sustained. There could be many other privately owned waste treatments in the study area that are neither known by the public nor the municipality because they are either illegal, unlicensed or the owners' just want to protect their business. This could be due to the problems of prioritisation at the local municipal stage which means that issues of permitting of the other waste treatment facilities do not receive the necessary support (Mudau, 2015). Particular attention should be given to the treatment and proper management of MSW because of its abundance and impact on the environment (Santibañez-Aguilar et al., 2013). The municipalities should however be responsible for documenting these waste treatment facilities and sharing information on them to achieve the proper management of the MSW.

6.6.3 Distribution

Siting a municipal solid waste (MSW) treatment plant requires a comprehensive evaluation to identify the best available location(s) that can meet the requirements of regulations and minimise economic, environmental, health, and social costs. This section of the study aims to assess the distribution of the treatment facilities in the study area. Fig. 18 shows the type of waste treatments and the municipalities they are found in in the study area. The numbers 1-8 in Fig. 18 represent the municipalities in the study area. 1 represents City of Matlosana, 2 is

Lekwa-Teemane, 3 is Madibeng, 4 is Mahikeng, 5 is Mamusa, 6 is Naledi, 7 is Tlokwe and 8 is Rustenburg.

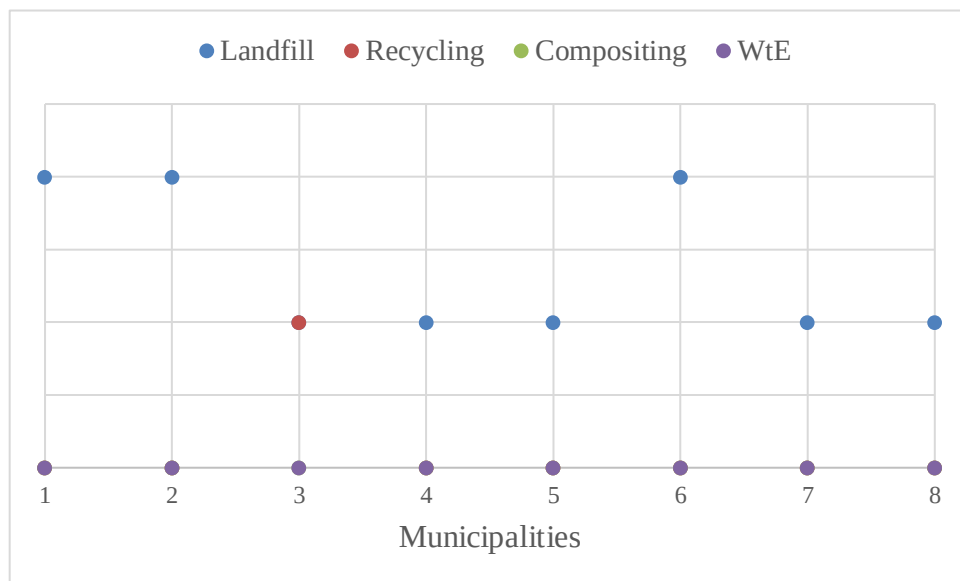


Figure 18: Distribution of waste treatment facilities

The result in Fig. 18 shows that landfilling is the only waste treatment that is found in all the municipalities in the study area. The other waste treatment facility that is found in only one municipality is the recycling facility. The results show no any documented WtE nor composite facilities in the study area.

Considering the location of the treatment facility and the distance to other municipalities, it is better for every municipality to have its own treatment facility or to have a waste treatment facility at a focal point than transporting waste to another municipality for treatment. Geng et al. (2010) emphasises that all wastes should be treated within the city's territory, without transferring this burden to other areas. There is need to introduce different types of waste treatment projects in the province to shorten the distances and to suit the type, composition and amount of waste that is generated in a location area of the suggested waste treatment plant.

There are three types of information that is important in identifying a new location for waste treatment, namely geographical information which includes map of the municipalities, land use, groundwater networks, road networks and locations of biopes; information related to waste treatment and disposal and information related to waste production (Haastrupa et al., 1998). To achieve the implementation of the new alternative waste treatment facilities, Fiorucci (2003) advises that there must be an integrated approach that integrates the costs of treatment plant

localization with the costs of transport, waste treatment and waste information system. Information concerning map of waste treatment sites will guide the local municipality management on the planning of location of the treatment sites during licensing. Tavares et al. (2011) mentioned that each type of waste treatment plant has its own specifics and, consequently, requires taking into account particular decision-making criteria. Criteria are very case-sensitive varying from country to country and even from region to region in the same country. There must be information on the annual quantities of MSW generated in the municipalities, the percentage landfilled or taken for treatments and information on the cost of the treatment equipment.

Though it is said that alternatives to the landfills are expensive for municipalities to purchase and run them, the cost refers to the initial cost of the waste treatment equipment which is a one of thing. The initial cost is better than the cost of transporting waste to a distant waste treatment facility that is far from the waste source or collection point. Transporting waste requires payment every time the waste is transported and the amount accumulates per month or year. This would be too much to bear compared to purchasing and installing waste treatment equipment in the area. For example, Ley et al. (2002) states that in American states where they do export and importing of waste from one state to another, the interstate transportation of estimated 20 million tons of MSW (about 10% of the total MSW generated) cost about \$900 million annually. Although the volume of waste seems small, the transport costs associated with it, every year, is very high in contrast to a one of cost of \$900 million for waste treatment equipment. The cost of transport is not the only disadvantage of having a waste treatment located at a distance from waste generation or collection point. There are other disadvantages like distance and resistance.

Long distance transporting of the waste could result in loss of the waste if it is not properly packaged, which can also lead to polluting the environment. In addition, Lejano and Iseki (2001) warns of adverse (physical or social) effects of these facilities, which can extend to considerable distances and negatively affect properties. The other problem that can be faced when siting a new waste treatment in an area is resistance from communities, environmental organizations, state legislators, and others who express concern about being a “dumping ground” (Ley et al., 2002; Gbanie et al., 2013). For example, in terms of an incinerator, urban communities often consider incineration facilities as sources of pollution and oppose local placement of new plants. As a result, new incineration plants are often located in less populated

areas (Geng et al., 2010). This then requires that siting waste treatment facility should utilize relevant available information and planners should arrive at results accepted by all key players (Gbanie et al., 2013).

Milutinović et al. (2014) concluded that introduction of waste treatment projects have some positive implications to the community in the area of project implementation. The facilities will provide some employment for a number of people in the area. For example, due to installation of waste treatment equipment, in Metro, Manila an estimated number of 17,000 people make their living as dump site scavengers. Also, the number of waste pickers in Bangalore is estimated to range from 20,000 to 30,000 and over 20,000 women work as paper pickers in Ahmedabad, India (Van de Klundert and Lardinois, 1995).

6.7 Summary

The aim of solid waste treatment is to minimize the volume of waste that goes to landfill and at the same time to recover resources including energy from the waste and thus reducing the use of landfills. However, many studies including this one have shown that:

- ❖ Landfills still remain the most used disposal sites showing that in spite of alternative policy developments with regard to waste management, municipalities still follow the pipeline approach to waste handling.
- ❖ Alternative waste handling methods have not been pursued by most municipalities across the province.
- ❖ There is little documentation on the waste treatment in NWP.
- ❖ There is almost no clear information on NWP with respect to the status of waste composition and waste to energy generation.
- ❖ Waste buy-back centres across NWP do sort, compact and package waste for onward transportation to recycling facilities. The actual transportation of such waste to facilities is handled by private vendors.
- ❖ Little information is available about what quantities of type and composition of waste are collected and prepared for transportation.

- ❖ The recycling industry is not as well developed as would have been expected given the annual volumes of waste that South Africa generates.
- ❖ There are constraints in the sharing of information across waste recyclers in spite of the existence of national associations of waste recyclers.
- ❖ Waste recycling facilities, except for *Wasteman* in Brits, are located either in Gauteng, Western Cape and KZN provinces.

On the basis of the results, the objective on state of waste treatment in NWP has been effectively addressed. There is need, therefore, to have proper information on the quantity, type, composition of the waste and type of waste treatment so that new waste treatment plants can be planned for in the municipalities or some waste treatment plants can be put at strategic locations so that they can be reached and accessed by all waste collectors. The next chapter, Chapter 7 discusses the potential of energy generation as a waste treatment option and its requisite waste information.

POTENTIAL FOR WASTE-TO-ENERGY GENERATION AND RECYCLING

7.1 Introduction

The chapter assesses the potential for waste-to-energy generation and recycling in NWP, South Africa, by relating the information on classes of waste, quantity, moisture content, calorific values of waste WtE generation technologies to WtE generation projects and waste recycling. In this chapter waste fractions represent classes of waste like food waste, leather, textile, garden, wood, plastics, paper, glass, rubber. The chapter then assesses the potential for WtE generation and waste recycling. MSW is often regarded as a nuisance due to its polluting effects of the air, soil and water (Tabasová et al., 2012). Today, most forms of waste can be converted into a diversity of by-products. The relevant methods for this chapter appeared in chapter III, section 3.5.

7.2 Waste-to-energy (WtE)

7.2.1 Process dynamics

Most developed countries have adopted a hierarchical approach to solid waste management. Accordingly, waste should first be reduced, otherwise recycled or reused, next incinerated with energy recovery and, only if nothing else works, landfilled (Dijkgraaf and Vollebergh, 2004). There are 2 types of waste incineration. The first type is the *mass-burn incineration*, incineration without energy generation potential. Most incinerators at medical facilities belong to this category. The second one is incineration where energy is recovered from burning of the waste in a process called WtE generation (Rand et al., 2000; Tan et al., 2015). Unlike the mass-burn one, the incineration with energy generation requires appropriate type of waste. The study narrows down its focus to the second type of incineration with the WtE generation option. This type of incineration process takes places between 750 °C to 1000 °C and can be coupled with steam and electricity generation process (Singh et al., 2011). The plants consist of: thermal part, heat recovery block and a system for cleaning of generated flue gas (off-gas in this case) (Tabasová et al., 2012).

WtE generation is a process where the combustible waste flux is converted to a gaseous phase, while aggregates and non-combustible material remain as solid residue (bottom ash and tar) of the process. The generated hot flue gases from the combustion stage pass through a boiler

where it heats water to generate steam (Antonopoulos et al., 2014). The superheated steam that is produced from the boiler can either be used for space heating or it can be pressurized and directed to rotate blades of a steam turbine which is coupled to a generator to produce electricity (Singh et al., 2011). Fig. 19 summarises the process for generating electricity by incineration.

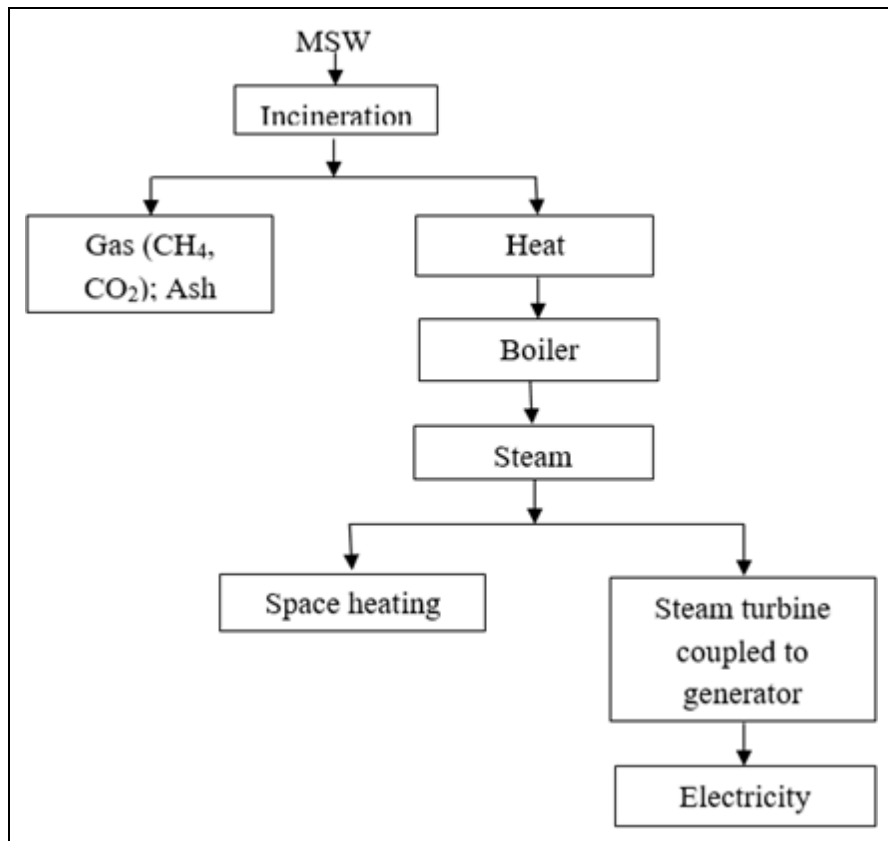


Figure 19: Electricity Generation from MSW by Incineration

Sustainability of these WtE projects heavily depends on four major factors that justify the case for electricity production from waste. These are: the quantity of waste generated, characteristics and quality of the wastes, the type of technology used for the energy production and economic conditions of the location of the WtE plant (Ofori-Boateng et al., 2013). Accurate information on these factors needs to be considered in the waste incineration process for efficient energy recovery projects as they are discussed below. If information on these factors is available then it will be easy to plan for energy generation plants and other alternative forms of waste treatment.

7.2.2 Waste for WtE generation

All combustible classes of waste like plastic, papers, cardboards, plastic bags, plastic bottles, wood, rubber, food waste, leather and clothing material can be incinerated though they differ

in characteristics that are required for optimum energy generation. The incinerators can receive only waste satisfying some requirements (Fiorucci et al., 2003). The most popular waste that is available and can be incinerated are the plastic materials which if left at landfills occupy an enormous volume of space for ages since they are non-biodegradable (Passamonti and Sedran, 2012) and paper, which represents 30–40 % of the total municipal solid waste (Santibañez-Aguilar et al., 2013).

The quantity of waste available will determine the sustainability of the WtE generation project and other waste treatment projects. That is looking at the sufficiency of the waste to continuously feed the incinerator without suffering from some discontinuity of the WtE plant operations at the same time considering the material flow to various plants or competing interests (Fiorucci et al., 2003). The WtE generation plants are designed to operate under loading of the waste. If there is insufficient supply of the correct type of waste for the WtE process, the plant will be forced to stop until another lot of waste is generated, which is costly in terms of time, production output and income. Under this circumstance the generation of energy will then be more expensive than the selling cost of the energy generated. WtE generation requires adequate waste with optimum moisture content, calorific values and high efficiency of the WtE technology in order to be beneficial.

7.2.3 Moisture content of MSW

Moisture content has great impact on WtE generation processes. When the moisture content of the waste that is to be fed in an incinerator is high, it affects the output of the energy generation in that the process will require more energy to remove the water from the waste before the energy generation process starts. The high moisture content therefore results in slow burning of the waste and incomplete combustion which slows down and reduces the energy generation. For example, in China, because of the high concentration of food waste in the waste, the moisture content of the waste is high and this result in the majority of Chinese incineration plants depositing the original waste in the waste pit for five to seven days before it is fed into the furnace in order to keep stable burning and combustion (Zhan et al., 2010). It is important to have information on the moisture content of the waste.

7.2.4 Calorific value of MSW

Calorific values of the MSW vary substantially, depending on the source, moisture content of waste and the period of the year (that is wet or dry season) (Bai and Sutanto, 2002). Calorific value of the waste is important because it indicates the amount of energy that can be extracted

from different types of waste. Waste can be highly combustible, but not suitable for incineration to generate energy. An example is in Singapore where about 85 % of the solid waste generated was combustible, but the moisture content was considerably higher 48.6 % for incineration (Bai and Sutanto, 2002). The ideal situation for WtE generation is when the calorific value is higher and the moisture content is low. Availability of information on calorific values will aid the planners to identify the type of waste that has the optimum calorific values for maximum WtE generation.

7.2.5 WtE generation

Selection of the WtE technologies must be based on an accurate analysis of the plant and must consider environmental impacts, capacity of the WtE technology, investment and operation costs, flexibility, material and energy recovery, plant surface area and maintenance requirements (Messineo and Panno, 2008). The first generation of WtE plants came with a lot of negative environmental concerns such as emissions of dioxins and ash. The new generation plants have a high initial cost but are far more improved than their polluting predecessors. Some of the challenges that were tagged to the first generation of the WtE technologies have been improved (Merzeder and Brandstetter, 2014), so much so that the technologies are now environmentally friendly and are beneficial to communities. To be able to meet strict emission limits, the new generation of WtE plants involve newer and more effective solutions which have lowered the discharge rate of pollutants and are among the cleanest and most reliable sources of energy in the form of heat as well as electrical power (Stehlik, 2009). Fig. 20 shows the diagram of a modern WtE plant.

Fig. 20 is a layout of a typical WtE plant that is used to generate energy from waste. The waste is burnt to generate heat, the heat heats water to produce steam. The steam is either used for space heating or it is used to drive the steam turbine to generate electricity.

The WtE process tremendously reduces the amount of waste taken for landfilling (Singh et al., 2011). The energy generated from the waste could provide an opportunity to diversify energy supply to reduce dependence on fossil fuels and contribute to economic growth in a sustainable manner. The renewable energy that is generated from the waste could result in reducing the consumption of the fossil fuel by about 20 % (Merzeder and Brandstetter, 2014).

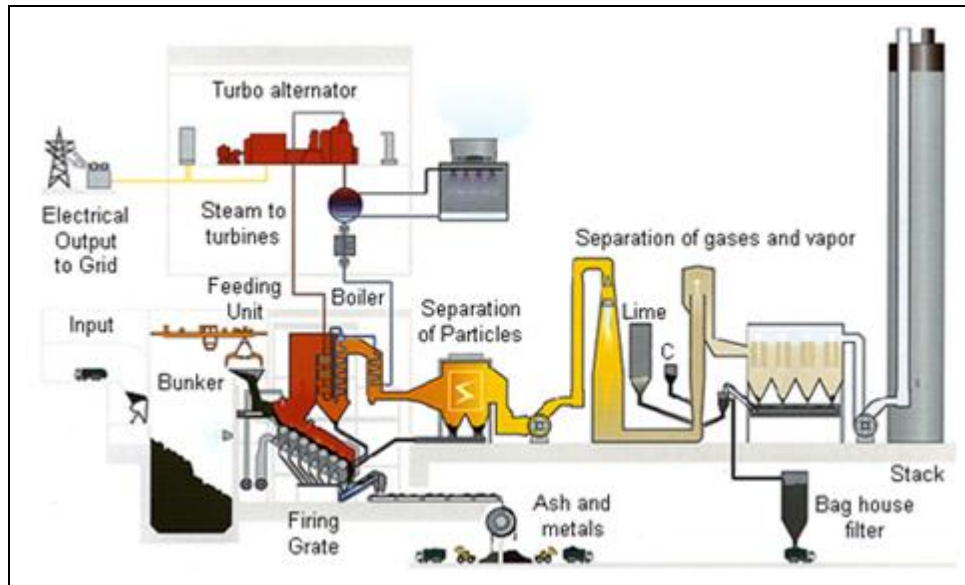


Figure 20: Schematic of WtE generation plant

Source: Burruss, 2013.

The WtE projects create employment for the people that work for the projects. It also generates income for the communities that pick waste from the landfills or waste generation points to sell to buy-back centres or directly to the WtE plants. If the process produces by-products like ash, a portion of the ash can be used as raw material in construction industry.

7.2.6 Information on WtE generation

Several studies have been conducted on the use of MSW for energy production and some even provide estimates of the energy potential of the waste. However, there are no reliable datasets on the waste generation, collection and the use of waste for energy production for the African continent, where this exists, the coverage is only for a few countries (Scarlat et al., 2015). To select a WtE technology that will suit the environmental, social and economic situation, it is important to understand the specifications, cost, efficiency, lifespan and impact on the environment. This is only possible if there is information on the waste and the technologies to be used. Therefore, for sustainability of the WtE projects there is need for integration of information on the WtE technology with that on the factors that affect the WtE generation. These factors are the quantity of MSW generated, characteristics and quality of the wastes and economic conditions of the location of the WtE plant. The availability of accurate information on all the factors that affect the WtE process and the waste is the key in evaluating the possibility of energy recovery from the waste. An example of the layout of this type of information is shown from results of a study on Beijing city where the typical characteristics

of waste show the moisture content is 61.21 %, combustible waste is 91.51 %, recyclable waste is 25.18 %, compostable waste is 77.08 % and calorific value is 4564 kJ/kg (Zhen-Shan et al., 2009). In South Africa this type of information is not available. The only information that can be found is on percentages of the waste that is taken to treatment facilities like: the percentage of waste that was taken for landfilling as 88 %, 10 % recycling, 2 % composting and 1 % WtE (DEA, 2012; Vice et al., 2014). Without this information, energy and material recoveries may be conflicting objectives. For example, if materials with high heating values are taken for recycling, the remaining refuse is likely to be not very significant in WtE generation (Fiorucci et al., 2003). This calls for a form of strategic apportionment of waste streams between recycling and energy.

Information on the quantities, type, moisture content and the calorific values of waste that is ideal for each of the waste treatments is important information that is required for estimating the potential of energy generation. The observations from the study (section 4.3.2) have shown that this information is not available in NWP. However, this information is decisive in determining the sustainability of waste treatment projects, selection of the correct waste treatment for particular waste, selection of the correct technology for waste treatment and in the case of this study, the potential and sustainability of WtE projects in relation to other waste treatments.

7.2.7 Current status of WtE generation

More than 200 million tons of MSW are produced every year worldwide (Dong et al., 2014) of which about 60 % is normally burnt in more than 800 WtE plants to generate electricity and steam for heating purposes (Ofori-Boateng et al., 2013). However, WtE projects for disposal of MSW are a relatively new concept in developing countries and the facilities are not common because the technology is expensive. In Africa, the production of electricity from MSW remains largely untapped notwithstanding the fact that large amounts of MSW are generated and not managed properly (Ofori-Boateng et al., 2013). In South Africa it was estimated that 53 million tonnes of general waste are generated annually (DEA, 2012; Friedrich and Trois, 2013) and on average 89 % of the waste is taken to landfills (DEA, 2011a; DEA, 2012; Vice et al., 2014). However, observations made in this study indicate that in NWP there are no WtE generation projects. A review of the role of independent power producers (IPP) in supplying electricity to the Eskom grid system by the department of minerals and energy in South Africa has created doubts about sustainability issues.

7.3 Waste recycling

7.3.1 Process dynamics

Recycling produces raw materials for further industrial processing, semi-finished goods for further processing and often final consumer goods ready for the market. Waste diversion for both composting, incineration and waste to energy conversion are not essentially part of the recycling process but provide the means to recover significant waste streams from the waste chain. The 3R... recovery, reuse and resale applies at each of these stages and all along any point on the flow path of waste recycling, Fig. 21.

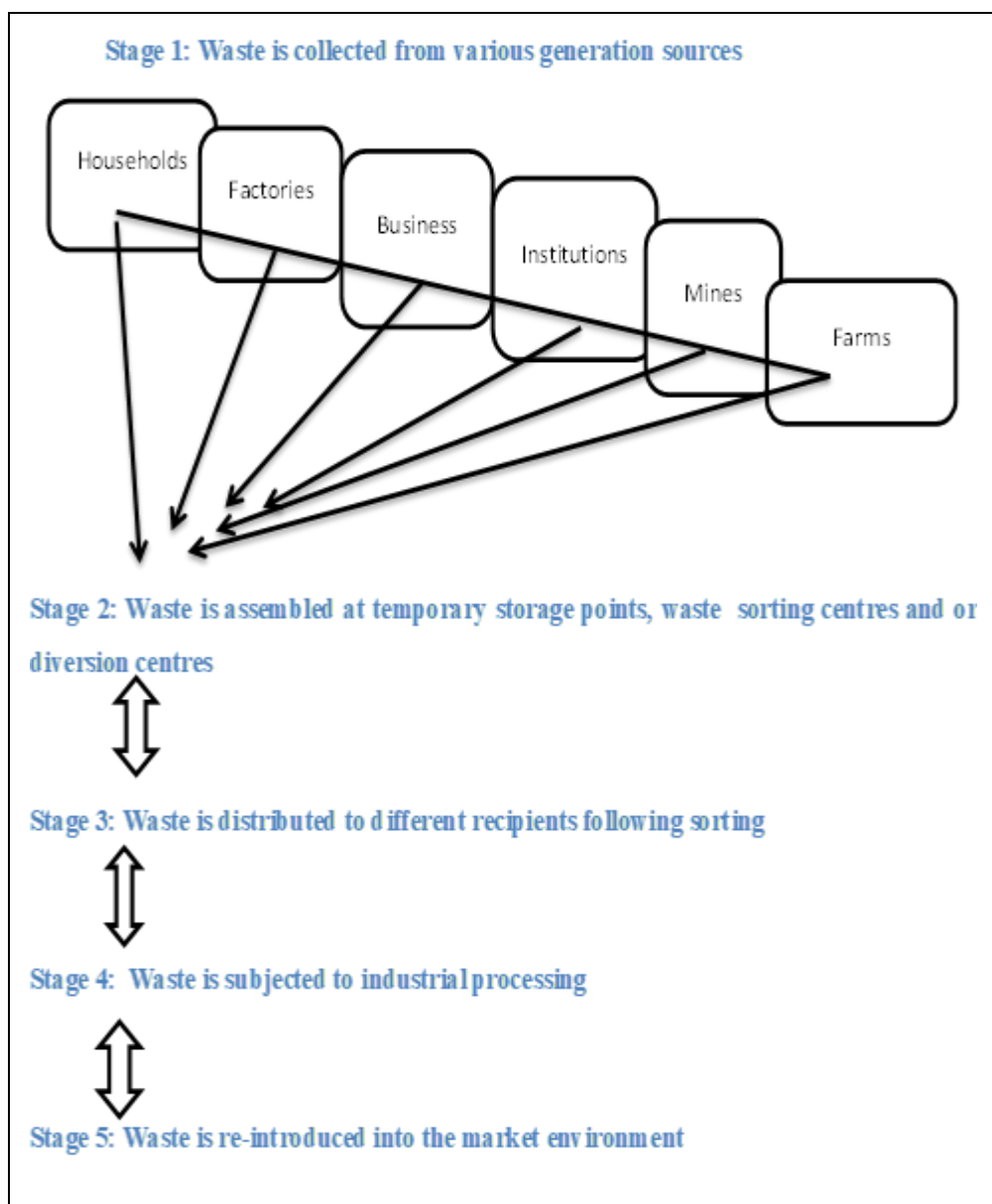


Figure 21: Flow path for waste recycling

Source: READ, 2018b

Where waste is not generally sorted at base, in stage 1, then this activity moves either to stage 2 and or 3 as the case may be. A significant volume of waste in South Africa is sorted at the landfill sites. This, however, creates particular constraints as it tends to reduce the potential for full waste recovery along points on the waste chain.

7.3.2 Waste streams for recyclables

Certain classes of waste may not be suitable for recycling: These include toxic & hazardous waste and non-recyclables. The remaining waste classes, potentially suitable and available for recycling are delivered to landfill sites and transfer stations as mixed waste. Evidence from the field indicated that waste pickers only deliver particular classes of waste to buy-back centres. This practice is based on the payment received as per unit weight per class of waste. Paper, steel, lead, copper wire, metal cans/tins and plastic bottles are the dominant waste classes delivered. Yet, the range of possible recyclables is far greater than this. This shows that the existing demand for waste from established recyclers is so narrow as to eliminate significant waste types that would otherwise be recycled.

Non-recyclable waste

Changes in production technology may increasingly indicate the types of non-recyclables currently landfilled which could be turned into useful by-products. Two classes of non-recyclables are recognised. First, because of the structure and nature of the South African economy, certain waste classes are not at present recycled on an industrial scale. They can be recycled once there is demand for their by-products. These include used tyres, car batteries, plastic bags, plastic packaging and e-waste. Second, certain classes of waste are not recycled at present partly because of the economies of cost or technology constraints. This includes all recoverable waste types found dumped at municipal landfills which could be converted into useful products. This classification, however, is variable across countries and stages of industrial development.

Toxic and hazardous waste

Two types of waste fall into this category: (i) toxic waste from medical facilities, laboratories, pharmaceutical plants and chemical factories that cannot be recycled. (ii) radio-active materials from the mines, nuclear power stations and military installations. Each of these classes poses particular challenges in collection, handling and safe storage. They should not end up at any of the municipal landfill sites. The mining industry is a special case because radio-active rich

mining dumps that dot the landscape in Gauteng, North West and Free State provinces do pose a direct health risk to settlements and livestock in close proximity.

7.3.3 Waste segregation at source

The conventional approach requires that waste be segregated (sorted) primarily at source. Six classes of waste are identified: households, business, factories, institutions, farms and mines. Sorting at source by any of these waste generators remains low-key, insignificant and often erratic. Some business outlets do sort and package waste to be collected by vendors as per agreement. Others, after sorting do deliver such waste to landfill sites. But the landfills have no segregated sections for particular waste classes. Local municipalities still follow the pipe-approach in forwarding mixed waste to landfills.

7.4 Results and Discussion

7.4.1 Waste generation in NWP

Reliable information on the quantity of the waste that is generated or available per day, week or year is useful in determining the sustainability of the WtE projects in relation to other waste treatments that also use waste as input for production. Additionally, information on composition of waste which shows the type, moisture content and calorific value of the waste, is important for the planners or users for them to allocate or use the correct waste type depending on the treatment the waste is subjected to. Recently the quantity of waste produced by households, institutions, and industries is significantly growing (Stehlik, 2009). However, results from this study, on the state of waste information in NWP show that currently there is no precise information on the quantities of waste and the other mentioned factors.

There are 4 districts in North West Province and a population of 3,509,953 (StatsSA, 2012) which was estimated to be 3,539,042 for 2016 and projected to be 3,562,899 for 2020. Since there is no comprehensive information on the waste quantities and the classes of the waste in the province these estimated population sizes and the rates of generation of waste that were reported by DEA in 2012 are used in estimation of the quantities of the MSW and their classes in NWP. The rates from DEA are used because DEA is part of government and the mother body that takes care of all the information on waste in South Africa through SAWIC and SAWIS. The information on population size is important in WtE generation because the population size has an impact on the MSW generation. As the population increases the generation of waste also increases (Sumathi et al., 2008; Messineo and Panno, 2008). In order

to operate the WtE generation plant continuously, waste generation must be fairly stable during the year (Rand et al., 2000). Table 21 summarises the estimated quantities of MSW for each district for the years 2011, 2016 and 2020.

Table 21: Estimates of Quantities/Year of Municipal Waste for each District in NWP for 2011, 2016 and 2020

Waste generation by districts in NW Province (tonnes)			
District	2011	2016	2020
DRRM	95503.67	95910.00	96235.07
DRKK	156779.59	157965.46	158914.16
NMMD	179810.02	180698.82	181409.86
BOJANALA	340282.94	344607.73	348067.57

Source: READ, 2017a

The results in Table 21 shows that of the 4 districts in NWP, Bojanala is the one that generated more waste in 2011, 2016 and the one that is projected to generate more waste in 2020, 348,067.57 tonnes.

The estimated quantities were also calculated for the whole province. Fig. 22 shows the estimated quantities of the waste in NWP for 2011, 2016 and 2020.

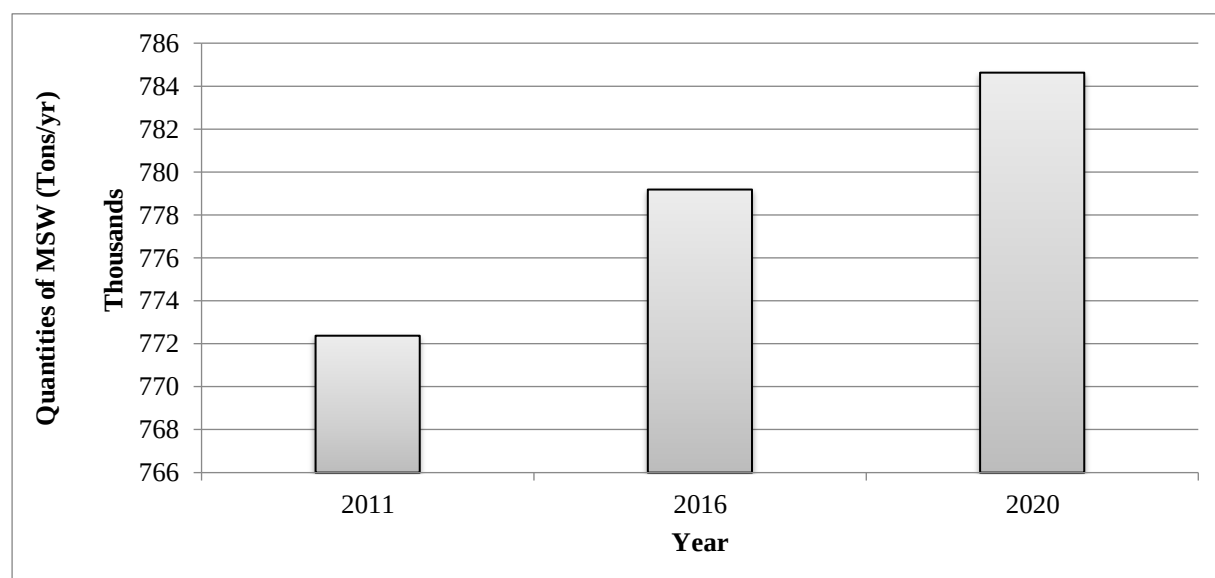


Figure 22: Estimates of quantities of municipal waste for NWP

The results in Fig. 22 show that there is an increase in generation of MSW in the province from 772376.22 tonnes in 2011 to 784626.66 tonnes in 2020. The quantities of classes of waste were also calculated and the results are presented in form of graph, Fig. 23.

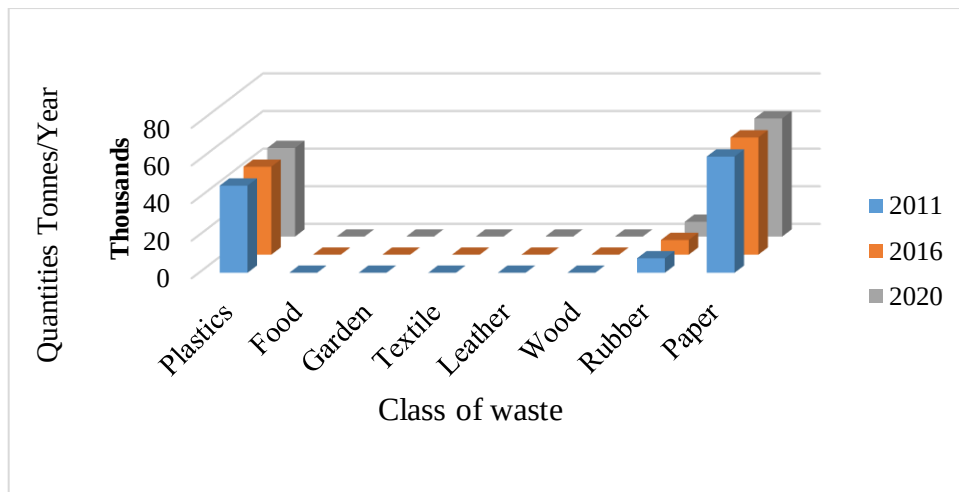


Figure 23: Estimated Quantities of Waste Classes

The results in Fig. 23 show increase in generation of different classes of waste with time which agrees with most of the studies which have indicated that waste generation is becoming a nuisance as it increases with the increase in population. The increase in quantities of classes of waste that are ideal for WtE generation is important. Although the results show missing data on some of the waste classes, the results for those classes that have information show that there is high generation of papers, followed by plastics with few rubbers generated. The result on quantities of the paper and plastics is different from the observations that have been made at the landfills. Observations from the landfills and illegal dumpsites have shown that plastic papers dominate the landfills but the results show that by weight, there is high generation of papers than the plastics. This result could be explained by the fact that the plastics could be more than the papers at the landfills but papers are heavier than the plastics. The rubber that is listed in the tables in some landfills has been observed in forms of used tyres, pipes and shoe soles. There are no data for food, garden, textile, leather and wood in Fig. 23. The lack of data on these classes of waste can be explained by the fact that there is no information on their generation percentages to the total waste generated in South Africa that have been reported by DEA. It should be noted that these classes were observed and noted at the landfills that were visited as part of the study. It has also been observed that there is a lot of garden waste especially in the illegal dumpsites that are in open spaces in locations and institutions. However, there is a problem in using the garden waste for generating energy because of the

bulky nature of the waste. As pointed out by Demirbas (2001) that biomass has a low bulk density, which makes transportation and handling difficult and costly. If they are to be used assuming that they have the optimal conditions for incineration for WtE generation, then Demirbas (2001) suggests that the WtE plant should be located close to a concentrated source of the garden waste. Plate 6 shows the tyres, plastics and garden waste as observed at some of the dumpsites.



Plate 6: Tyres at Schwaizer-Reneke landfill, plastics at Delareyville landfill and garden waste at Mafikeng dumpsite

The information that has been generated on the quantities and classes of the waste will be useful in planning of waste treatments and disposal of the waste. There is need to investigate the impact of the increase in quantity and characteristics of the generated waste in terms of moisture content, calorific values on the efficiency of WtE generation process. Moisture content of the waste is crucial on WtE generation. If the moisture content is high, then the WtE generation will be negatively affected because the higher the moisture content the more inefficient the WtE generation technology and the more expensive the energy generation becomes. For example, food waste is high in organic and it is high in moisture content which renders it unsuitable for use in WtE generation processes.

7.4.2 Moisture content of MSW

One distinct characteristic of MSW in developing countries is its high moisture content stage (typically around 50 %), which is much higher than that of the MSW in the United States (20-30 %) and European countries (Cheng et al., 2007). High moisture content waste is not ideal for incinerators whose purpose is for WtE generation. To estimate the potential of WtE generation, the study measured the moisture content of each class of waste from the landfills that are in low, medium and high rainfall regions in the NWP. Fig. 24 shows the variations in overall averages of moisture content of mixed waste based on the rainfall regions.

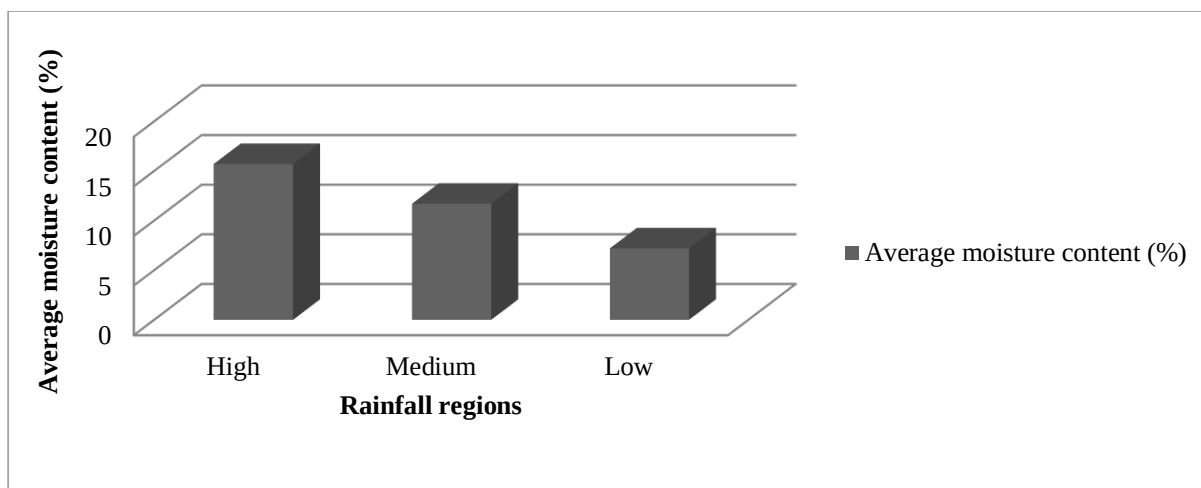


Figure 24: Average Moisture Contents of Waste in Different Rainfall Regions of the NWP

The results in Fig. 24 shows that the moisture content of waste is higher in high rainfall regions and low in low rainfall regions. Evapotranspiration is the key factor to the moisture content of the waste in these different rainfall regions. Evapotranspiration is related to temperature, wind, humidity, atmospheric pressure, soil moisture content, and solar radiation (Al-Yaqout and Hamoda, 2003). If the region has high rainfall and lower temperatures, the dumpsites are wet and evapotranspiration rate is low, so the waste that is dumped in such areas take long to lose the water in them, hence high moisture contents (Gawande et al., 2003). The effect of rainfall on moisture content is supported by Belsky et al. (1993) whereby high moisture content was associated with high rainfall in a study on high- and low-rainfall savannah in Kenya. In Indian cities of Shillong, Kohima, Simla and Agartala, a higher moisture content in the MSW was observed (65 %) due to heavy rains (Kumar et al., 2009). The situation is different for the regions that have low rainfall and high temperature. In such areas, there is less water accumulation and the evapotranspiration rate is so high causing the water to evaporate from the waste fast, leading to low moisture contents. This shows the relevance of climatic information so that site managers are able to correctly plan the source of collection of wastes to be used in WtE plants during different seasons.

For the NWP, the overall moisture contents of each class of waste are shown in Table 22. On average, food waste has the highest moisture content at 39.6 %; while plastics has the lowest average moisture content at 0.23 %.

Table 22: Averages of Moisture Contents of each class of Waste in NWP

	N	Minimum	Maximum	Mean	Std. Deviation
Plastics	4	0.0	0.7	0.225	0.3304
Food	4	33.2	48.1	39.575	6.2729
Garden	4	8.3	24.0	14.925	6.6365
Textile	4	0.7	2.4	1.480	0.6969
Leather	4	0.0	1.0	0.500	0.5774
Wood	4	8.5	22.2	15.800	5.6291
Rubber	4	0.0	3.7	1.800	1.6021
Paper	4	2.0	5.9	3.975	1.5924
Valid N (listwise)	4				

The results in Table 22 shows that five of the waste classes have moisture content of <10 %, the lowest being 0.2 % and the other three have >14 % with the highest being food waste (39.6 %). This shows that on average the moisture content of waste in NWP is between 0.2-39.6 %. The moisture content of the food waste (39.6%) is almost the same as that of developed countries like the US which is between 20 and 30 % but it is less than that of Singapore, which is 48.6 %. Climatic differences play an important role on the moisture content of waste which can be explained by comparing the situations of the moisture contents of the waste in the study area (which is low) to Singapore's (which is high). Singapore has average temperature ranging from 24.7 °C to ~31.3 °C, daily average humidity at 84.4 %, and annual average rainfall of 2134 mm (Bai and Sutanto, 2002) while NWP of South Africa is a dry area and has higher average temperatures (ranging between 22 °C to ~34 °C) and lower annual average rainfall (432 mm) (Walker and Schulze, 2008). The low rainfall and high temperatures result in low moisture content of MSW for NWP.

McKendry (2002) cautioned that fuel with moisture content >30 % makes ignition difficult and reduces the calorific value of the fuel due to the need to evaporate the additional moisture for efficient combustion. On the contrary, Cheng et al. (2007) pointed out that incinerators could adapt to MSW with a wide range of moisture contents of up to 55 % because modern technology can remove the moisture without extra fuel. Iakovou et al. (2010) indicated that it is possible to burn any type of biomass, but noted that in practice, combustion is feasible only for fuel with inherent moisture content of less than 50 %. This shows that the waste generated in the NW province is eligible to be used in incinerators for WtE generation since the moisture content is below 50 %.

Moisture content is one of the factors that affect the calorific values; the higher the moisture content the lower the calorific value (Komilis et al., 2014). Pearson's correlation analysis was run to assess the effect of moisture content on calorific values. The results are shown in Table 23.

Table 23: Relationship between Moisture content and calorific value

Correlations			
		Moisture content	Calorific value
Moisture content	Pearson	1	-0.739*
	Correlation		
	Sig. (2-tailed)		0.036
	N	8	8
Calorific value	Pearson	-0.739*	1
	Correlation		
	Sig. (2-tailed)	0.036	
	N	8	8

*. Correlation is significant at the 0.05 level (2-tailed).

Pearson's correlation analysis in Table 23 revealed that there is a significant relationship between moisture content and calorific value ($R^2=0.036$; $P\leq 0.05$). However, the relationship is negative ($R^2= -0.739$), indicating that the higher the moisture content of the fuel, the lower the calorific value.

Cointreau (2006) and Kumar et al. (2009) concluded that most of the waste from developing countries do not have sufficient calorific value to self-sustain incineration, that is, it will not burn without addition of fuel. Based on income, South Africa is placed in the upper middle-income level, which could be identical to the waste generated by higher income countries (Table 24). The estimated highest moisture content for the NWP is about 39.6 % which is slightly above the 35 % for high income countries and slightly below the 40 %. This implies that the calorific values of waste for South Africa could be ≥ 6000 kJ/kg and ideal for incineration.

Table 24: Income Stages of a Country, Moisture Contents and Calorific Values of Waste

Waste characteristics	Low income country	Middle income country	High income country
Moisture %	40-80	40-60	20-35
Lower heating kJ/kg	3000-4000	4000-6000	6000-11000

Source: Cointreau, 2006.

7.4.3 Calorific value of MSW

The basic assumption for utilising MSW as fuel in an incinerator for WtE generation is its sufficient heating value (Tabasová et al., 2012). As such, information about the calorific values of the waste is required to derive the viability of the waste to be used for WtE generation. Calorific value is the energy content of the waste, it indicates how much energy is contained and can be extracted from the waste for maximum and efficient energy generation (Rand et al., 2000). The optimum calorific values appropriate for WtE generation ranges from 7000 kJ/kg and above (Demirbas 2001, Zerbock 2003). Otherwise, any value below 7000 kJ/kg, the WtE generation technology will first need external fuel to reduce the moisture content from the waste (Demirbas, 2001).

In this study, the missing gap is the information on the calorific values of the MSW in the NWP. Such data could not be collected during the study because of the high cost of the equipment for measuring calorific values. As such, this study makes use of calorific values of waste from the countries that are in the same geographical region and have climatic similarities with South Africa. The countries include Mexico, Argentina, Australia, India, China, Sri Lanka and Thailand. Visvanathan and Tränkler (2003) in their study on MSWM in China, India, Sri Lanka and Thailand concluded that waste generated in the developing countries is similar in composition. This was also echoed by Greben et al. (2009) who related the conditions in South Africa to China and other Asian countries in their study on potential of organic waste as source of energy. The search of calorific values from literature resulted in a range of calorific values that are listed in Table 25.

The results in Table 25 shows that the calorific values of mixed MSW for the region where South Africa falls range from 1,900- 15,500 kJ/kg. The calorific values from 3 authors are less than 6000 kJ/kg and two authors reported calorific values above 15,500 kJ/kg. The low calorific values could be attributed to lack of separation of the waste at source (Narayana, 2009); although Abu-Qudais and Abu- Qudais (2000); and Kumar et al. (2009) attributed the low calorific values to high moisture contents and organic contents of some of the waste.

Table 25: Calorific Values of Waste in Countries in the same Climatic Region as South Africa

Calorific value (kJ/kg)	Region	Author(s)
11,500	Jordan	Abu-Qudais and Abu-Qudais (2000)
2000-4000	Asia: India, Sri Lanka and China	Visvanathan and Trankler (2003)
1900-2600	Pondicherry, India	Sumathi et al. (2008)
2000-15,500	India	Kumar et al. (2009)
3400-4500	China, India, Brazil and Argentina	Unnikrishnan and Singh (2010)

However, the data in Table 25 reports on mixed waste which is not helpful in assessing the energy generation potential of the waste. To have a true picture of the calorific values of waste and their potential for WtE generation, calorific values of waste have to be calculated for each waste class. Rand et al. (2000) compiled the calorific values of classes of MSW from literature for the region with the same geographical and climatic similarities as South Africa (Table 26).

Table 26: Calorific Values of Waste Classes

Classes of waste	Calorific value (kJ/kg)
Food and organic waste	1,912
Plastics	20,144
Textiles	11,789
Paper and cardboard	6,440
Leather and rubber	14,265
Wood	9,310

Source: Rand et al., 2000

The average calorific values in Table 26 shows that the values range between 1,912 kJ/kg and 20,144 kJ/kg. Plastics have the highest calorific value (20,144 kJ/kg) while food waste has the lowest (1,912 kJ/kg). Demirbas (2001) and Zerbock (2003) suggested that for incineration to be efficient, the minimal heating value must on average be at least 7000 kJ/kg, and must never fall below 6000 kJ/kg. Therefore, from the calorific values in Table 26, the eligible classes of MSW that have the optimum calorific values with potential of WtE generation are wood, leather and rubber, textile and plastics.

7.4.4 Potential of energy generation in NWP

Available and reliable information on quantity, classes, moisture content and calorific values are helpful in the planning of WtE projects easier. Any combustible waste can be used in incinerators but only those with the optimum moisture content, calorific values and adequate quantities could be used for efficient WtE generation process. This study shows that mixed waste is not ideal for the WtE generation projects. Such waste will affect the moisture content and calorific values, which are not adequate for energy generation.

The study also indicates that some of the classes of waste have the required calorific values that are above 7000 kJ/kg, entailing that they have the ideal characteristics for them to be used in WtE generation projects. These classes are wood, leather and rubber, textile and plastics (Table 26). The feasibility of the classes to be used in WtE generation projects also depend on quantity available. The classes may have the optimum moisture contents and desired calorific values, but are their quantities sufficient to keep the production of energy going for a period of one year or more? Table 27 summarises the average moisture contents, calorific values and quantities of classes of the waste for 2011 for South Africa; estimated waste quantities for the study area generated in 2016 and the projected quantities for 2020 for the study area.

Table 27: Summary of the Moisture Content, Calorific Values and Quantities/Year of Classes of Waste

Class	Moisture content (%) [*]	Calorific Value (kJ/kg) ^{**}	Quantities (tonnes)			
			2011 SA ^{***}	2011 NWP [*]	2016 NWP [*]	2020 NWP (projected) [*]
Plastics	0.2	20,144	1 308 637	46342.6	46750.6	47077.6
Rubber	2.4	14,265	246 631	7723.8	7791.8	7846.3
Paper	4.0	6,440	1 734 411	61790.1	62334.6	62770.1

^{*}Study 2017; ^{**}Rand et al., 2000, ^{***}DEA, 2012

The results in Table 27 shows that out of the 8 classes of waste that are listed in Table 26, only 3 have information on quantities, and these are plastics, rubber and paper. The estimation of WtE generation will be based on these three classes of waste. The gaps confirm the reported lack of adequate information on waste composition and quantities in South Africa as well as NWP. The results on moisture content and calorific values have been discussed in sections 7.4.2 and 7.4.3 and they show that the moisture content for all classes of waste are in the proper and ideal ranges for WtE generation. The values are lower than the 55 % which is regarded as

the ceiling moisture content for WtE generation. Nonetheless, the classes of waste will also be mentioned in this section in relation to the third factor, (quantities of classes of waste) to provide complete information on factors required for determination of potential for WtE generation projects (Table 28).

Table 28: Quantities for the Classes of Waste after removing Waste for Recycling

Classes	Estimated Quantities (tonnes) 2011, 2016 and 2020 projected in NWP					
	Recycled 2011	Balance 2011	Recycled 2016	Balance 2016	Recycle 2020	Balance 2020
Plastics	4,634.3	41,708.3	4,675.1	42,075.5	4,707.8	42,369.8
Rubber	772.4	6,951.4	779.2	7,012.6	784.6	7,061.7
Paper	6,179.0	55,611.1	6,233.5	56,111.1	6,277.0	56,493.1

Table 28 shows the balance in terms of quantities per classes of waste after removing waste for recycling for the years 2011, 2016 and the projected quantities for 2020. Information on quantities of waste is an important factor for determining the sustainability of WtE generation plants. Rand et al. (2000) estimated that an incinerator requires at least above 50,000 metric tonnes of waste to operate for a year to produce 0.726 GWh. Zsigraiová et al. (2009) and Tavares et al. (2011) stated that for incineration with energy recovery, the total amount of waste should be 75,000 tonnes/year. Based on individual quantities of the classes of waste, the results in Table 27, shows that none of the classes individually reaches the recommended quantity (50,000 tonnes/year) to sustain energy generation. This means that for the NWP, WtE technologies that require small quantities of waste per day are ideal. Different sizes of WtE generation technologies have been adopted for energy generation in WtE plants. The size and amount of energy that is generated is determined by the capacity of the incineration technology. Capacity of the incineration technology indicates the quantity of waste (in tonnes) that is fed into the technology per day. Table 29 shows different sizes of WtE generation technologies, conditions that affect the energy generation and the estimated energy that they generate per day. Hence, apart from moisture content and calorific values, energy generation also depends on the capacity of the technology. Assuming all conditions are optimal, the higher the capacity of the incineration technology, the more the energy that is generated.

Table 29: WtE technologies and energy generation

Capacity of incineration technology (tonnes/day)	Moisture content of waste (%)	Calorific value of waste (kJ/kg)	Energy generated (GWh)	Author
600	< 55	9630	0.247	Otoma et al. 1997
960	< 55	9000	0.726	Rand et al. 2000
240	< 55	10400	29.500	Zsigraiova et al. 2009
24000	< 55	8800	14.940	Tsai & Kuo 2010
700	≥ 55	9204.8	0.192	Kadir et al. 2013
154,000	45-65	3000- 5000	62.400	Zheng et al. 2014

For situations similar to the NWP where the generation of waste is less than 50,000 tonnes/year (~137 tonnes/day), there is a need to identify appropriate technologies with ideal capacities. The study therefore adopted as a standard for the NWP the technology capacity of 240 tonnes/day from Zsigraiova et al. (2009). Technologies with this capacity can be used as stand-alone WtE generators in households, farms and factories. Based on the estimated quantities of individual waste classes for the NWP (Tables 27 and 28), calculations were done to determine the number of days of operation for the selected WtE generation technology. Furthermore, energy generation from the 3 classes of waste was also estimated for the NWP. The energy calculations were based on Zsigraiova et al. (2009) assumptions that a WtE technology of 240 tonnes/day, moisture content of < 55 %, and calorific value of 10000 kJ/kg generates 29.500 GWh. The results summarised in Table 30 shows the number of days the different quantities of waste classes would take if used in the 240 tonnes/day WtE generators and the estimated energy that would be generated from each of the 3 classes of waste.

Table 30: Potential of energy generation in NWP

Capacity of a technology (tonnes/day)	Class of waste	Estimated quantities 2016 (tonnes)	Projected quantity 2020 (tonnes)	Estimated period (days)		Power generation (GWh)	
				2016	2020	2016	2020
240	Plastics	42,075.5	42,369.8	175.3	176.5	5,171.4	5,206.8
240	Rubber	7,012.6	7,061.7	29.2	29.4	861.4	867.3
240	Paper	56,111.1	56,493.1	233.8	235.4	6,897.1	6,944.3
Total		105,199.2	105,924.6	438.3	441.3	12,929.9	13,018.4

The results in Table 30 shows that using paper as fuel in the 240 tonnes/day WtE technology would cover more days of operation of the technology than the other two waste classes. Paper would cover 233.8 days of operation in 2016 and 235.4 days in 2020 while the plastics would cover only 175.3 days for 2016 and 176.5 days for 2020. The results also show that rubber would cover just a month of operation (29.2 for 2016 and 29.4 for 2020) if used as fuel in this technology. Adding up the quantities of the different classes of waste, the results show that the total quantities can sustain operation of the WtE technology for over 365 days (1 year). This shows that there is potential for WtE generation projects in NWP.

The results in Table 30 also shows the energy that is generated in the number of days the classes of waste are used as fuel in the operation of the 240 tonnes/day WtE generation technology. The results show that papers would generate more energy than the other two classes. Papers would generate 6,897.1 GWh for 2016 and 6,944.3 GWh for the projected 2020 followed by the plastics and then lastly rubber generating 861.4 GWh for 2016 and 867.3 GWh for 2020. It shows that there is potential for energy generation in NWP. The results show that total energy that is estimated to be generated from the waste in 2020 is 13,018.4 GWh. This energy would contribute to the energy supply in NWP in particular and South Africa as a country. Residential energy demand in South Africa is growing as population levels rise and the number of households increase. The energy demand is growing at a rate of 1 GW per year (Mzini and Lukamba-Muhiya, 2014). Eskom South Africa is struggling to meet the increasing energy demand. Hence, the results on the potential of WtE generation in NWP highlights an opportunity that can help to ease the pressure on the energy demand that is haunting South Africa. The by-products from the energy generation process and the remaining waste can be recycled.

7.4.6 Waste recycling

Conventional inputs

Waste recycling is treated as a normal industrial scale process. To this end, certain inputs-irrespective of size and geographical area apply. These are listed as follows:

Direct inputs:

- Land
- Labour
- Capital
- Technology
- Organisation (includes management)

These are the common factors of production to which may be added other drivers critical in the production process:

- Market
- Transportation networks
- Access
- Energy
- Commercial services
- Legislation
- Regulation
- Taxation
- Law, order, safety & security
- Governance & economic/industrial policy

Waste generation statistics

The volumes of waste generated per municipality were presented in section 7.4.1 of this study. Observations in this study have shown that in NWP, recycling and other waste treatments that are not known due to lack of documentation, require waste for their operations. This represents competition for the same quantities of waste that is generated. There is need to document the treatment and the quantities of classes of waste that are used in different waste treatments to assist with distribution of the waste. The study calculated the quantities of waste generated, recycled and the amount remaining waste after recycling. The calculations were done based on information that was reported by DEA (2012) which indicated that in South Africa, 10% of

general waste is recycled. The quantities of the remaining classes of waste after recycling was calculated and the results are shown in Table 31.

Table 31: Quantities of classes of waste before and after removing waste for recycling in SA

Class	Quantities (tonnes) South Africa, 2011		
	Generated	Recycled	Remaining waste
Plastics	1 308 637	235 555	1,073,082
Paper	-	-	-
Textile	-	-	-
Leather	-	-	-
Steel	-	-	-
E-waste	-	-	-
Wood	-	-	-
C&D	-	-	-
Rubber	246 631	9 865	236,766

Source: READ, 2018b

The study used the information in Table 31, to estimate the quantities of waste recycled and the remainder of it for NWP.

7.4.7 Potential of waste recycling projects

On the basis of the findings of this study, there is ample evidence in support of the potential for waste recycling projects within NWP. The following issues are informative: the total volume of recyclable waste generated within the province can support and sustain a medium size recycling facility. So far, less than 10 % of the waste generated is currently recovered for recycling and most of the waste produced in the province is dumped at landfill sites. There is a lot of construction and demolition rubble that is disposed off indiscriminately, however, the possibility of stockpiling construction and demolition rubble at designated sites for future use has not been pursued to date. In terms of scale, the current state of the industry at the national stage means that there are opportunities for new investors setting up recycling facilities in the NWP.

7.4.8 Options for the NWP

Several options are noted for the NWP with respect to waste management in general and waste recycling in particular. The options include maintaining the current approach where the bulk of the waste is forwarded to landfill sites for final disposal; institute an aggressive programme of waste sorting at source and build into such a programme lower rates for refuse removal by those participating. In addition, as a means of rationalising the informal sector, community co-operatives could be initiated for all those engaged in waste recovery. This could facilitate development of a support vehicle for all local industries willing to change from traditional raw material sources to the use of existing waste streams. As a means of supporting poverty alleviation projects through the setting up of waste recycling projects in the NWP, conversations with civil society and business could trigger the growth of entrepreneurship skills which is more sustainable than job creation; thereby providing the much-needed formal employment to most of the population in the province. Waste management and waste recycling points towards an investment opportunity whereby the province could partner with private business. Such investments could be direct in the form of acquiring participating shares in the facilities or indirect through guarantees of subsidised industrial premises, grace period for bulk electricity and water supply.

7.5 Summary

This chapter has looked at the potential for waste-to-energy generation and waste recycling in NWP. On the basis of the results, it shows that this objective has been sufficiently addressed. It has been shown that there is potential in the NWP for both waste recycling projects and waste to energy generation.

DESIGN OF A WASTE INFORMATION-BASED PLATFORM**8.1 Introduction**

This chapter summarises the key findings of the study focusing on waste information and the systems for collecting and generating waste information. It also focuses on the use and importance of waste information in MSWM. Chapters 2, 4, 5, 6 and 7 identified and analysed a waste information system that is in use in NWP and South Africa as a country. The system is called South African Waste Information System (SAWIS). SAWIS is an information system that was approved by the Department of Environmental Affairs and Tourism in June 2005. The main purpose of SAWIS is to support the collection, generation and dissemination of waste information and data in South Africa. However, the analysis of literature and results from this study identified some gaps in the operation of the SAWIS.

This chapter then uses the identified gaps to design and develop an efficient and effective waste information system called waste information-based platform. The waste information-based platform is developed based on the key findings from chapters 2, 4, 5, 6 and 7 of this study. It is designed and developed in a way that it can be integrated into the existing operating system of SAWIS in order to improve on the operations and performance of the SAWIS.

8.2 Key findings

While there is a challenge in availability of proper waste information in most developed, and developing countries (Seng et al., 2010; Wilson et al., 2015), it should be appreciated that in South Africa:

- There is an information system that is already in existence, SAWIS, which was designed for generating waste information.
- The system was designed in a way that it allows different facilities to register, collect and report waste information to SAWIS and
- The system protects the information collection and submission by screening the facilities involved in information collection before registering them into the system.

The study focused on the operations of this information system, mainly looking at the methods of collecting and generating waste information, state of waste information, facilities in the

waste chain, and waste treatments (recycling and WtE generation). This section lists the research gaps and key findings that are identified for global, developing countries, Africa, South Africa and North West Province. The gaps and key findings are grouped into two themes (i) methods of waste information collection and (ii) governance concerns with regard to waste information systems. The key findings for each chapter are listed in Table 32.

Table 32: Key findings

Chapter 2: Literature Review
Waste information that is available is scanty, causing difficulties in decision making concerning management of waste.
Waste activities contribute to global warming due to greenhouse gas emissions which is becoming an important environmental issue.
In developing countries, there is improper collection of waste information, leading to generation of incomplete and unreliable data on generated waste.
There is lack of information on classification, volume, emissions, moisture content and calorific values of waste. This negatively affects the planning, handling and management of waste.
Due to different collection methods, there is lack of standardised data to allow comparison on proportions of waste generated per capita.
Incineration of waste remains a low option practice for Africa.
Waste is subjected to different types of treatment such as recycling, composting, WtE, however, these treatment options are not documented
There is ineffective waste information collection systems in South Africa.
There is no mandatory reporting on waste activities for persons conducting certain waste management activities.
Due to the complications on the waste information collection template, it is a challenge for some role players in waste management to collect and report waste data to SAWIS.
Not all the recorded quantities of waste are measured using weighbridges and pads
Chapter 4: State of waste information in the NWP
Apart from the regulated waste information from SAWIS, municipalities use unstandardized waste information collection tools to record waste information. Tools used by municipalities have important information gaps; for example, there is no information on waste characterisation. .
Some of the waste indicators on the collection tools are left uncompleted by officers.
No data-bases have been compiled on moisture content and calorific values of waste.
The results show that the municipal landfill is the only facility that collects and report waste information to SAWIS.

On handling of waste information, the results show that 62.5 % of the municipalities collect waste information but only 25 % of them collect and report the information to SAWIS.
Chapter 5: Components of the waste chain facilities
Municipal waste directorates do not keep an up-to-date record statistics on transfer stations, buy-back centres, landfills and treatment facilities (recycling, compositing and WtE)
Recycling industry, where waste is converted into new products for the market is not yet widespread in NWP.
Officially, local municipalities do not have formal waste composting and WtE facilities
Out of the 37 identified waste facilities that handle waste, 35.1 % are landfills, 35.1 % are buy-back centres, 27% are transfer stations, and 2.7 % are recycling centres.
Chapter 6: State of waste treatment in NWP
Landfills still remain the most used form of waste treatment
Little information is reported on the other forms of waste treatment activities in NWP.
In NWP, baseline activities related to waste collection, recovery, sorting and delivery at buy-back centres and forwarding to industrial recycling plants are dominant. Actual waste recycling plants are mainly located outside of the NW province
Private waste treatment facilities that are members of several recycling associations do not share information on waste that they handle.
Chapter 7: Potential for waste-to-energy generation and recycling
For the potential of WtE to be established, several types of information are required. The results indicate gaps in the status of requisite information for sound decision making about potential of WtE.
There is no documented WtE generation project in NWP.
The available quantities of each class of waste in the study area can only sustain energy generation using smaller technologies (for example 150-250 tonnes of waste per day).
There is no information on the calorific values of the MSW generated in the NWP.
Climatic variations form an inherent part of decision making as far as potential locations of WtE plants is concerned.
Moisture content of waste in NWP range between 0.2 and 39.6 % lower than some developed countries where WtE is already an established industry.

The findings presented in Table 32 shows that there are some weaknesses in SAWIS. The weaknesses emanate from the non-standardised waste information collection methods, which include among others personnel in waste management departments, equipment and information collection tools. These weaknesses result in lack of collection, generation of reliable waste information and proper waste information management. Drawing from these weaknesses, a waste information-based platform (WIP) was developed. (WIP).

The design of WIP is based on a few selected gaps and key findings (explained in Table 32) which are considered as critical to waste information collection. The proposed WIP is standardised to facilitate the collection of required and reliable information, process it and generate up-to-date waste information. It is assumed that the generated waste information will contribute to the improvement of MSWM. Table 33 lists the findings that have been carried forward into the design of WIP.

Table 33: Key findings carried forward

There are no standard instruments for collecting waste information
There is absence of information on quantities, classes, moisture content and calorific values of waste.
There is no information on waste at different levels of the waste chain which gives a deficit of quantities, location and distribution of waste and facilities through the waste chain.
There is no reliable information on waste facilities and waste treatments

8.3 Rationale

The waste information-based platform is an information resource that brings together the important waste information that is standard, reliable and up-to-date. This platform is developed in response to the gaps that have been identified during the study and the requirements by National Environmental Management Act: Waste Act 2008. The Act requires obtaining reliable data and information to support integrated waste management planning through successful implementation of the waste information system. Accurate data is therefore required to proactively determine the need for waste handling, treatment and additional waste facilities and equipment.

8.4 South African Waste Information System (SAWIS)

8.4.1 SAWIS Framework

The current SAWIS framework has been used in waste information collection since 2005. SAWIS has three main operations that are involved in the information generation. The framework has a template for collecting waste information. The template requires to be completed depending on the cells that are on it and the information on waste that is available at a facility. Two of the operations are completed on computer where the completed information on the template is captured into SAWIS. The captured information is processed by

a processor to generate information on waste. The waste information that is generated depends on the waste information that is inputted into the system. That is the information collected on template and captured into the system determine the reliability and relevance of the information to be generated. SAWIS has a template that has the information that is required to be collected as per the regulations. The information in Table 34 is the information that is currently being collected, unless some role players use their own collection tools.

Table 34: Data collected by SAWIS

Data Required	Level of detail required
Facility ID	DEAT Reg. No. (issued following successful registration on the Central Registry)
Time Period	Month and Year
Waste quantity	Tonnes
Waste type	General waste, or paper/cardboard/plastic (priority recyclables), or hazardous waste or health care risk waste
Waste source	Province or country within which waste originates
Waste destination	Facility ID (reprocessor, landfill or treatment facility to which waste is taken)

(Source: DEAT, 2006)

This represent the information that is on SAWIS template that is currently fitted in the SAWIS design flow path. The complete process of the SAWIS from collection to dissemination of waste information using the SAWIS template is shown in Fig. 25.

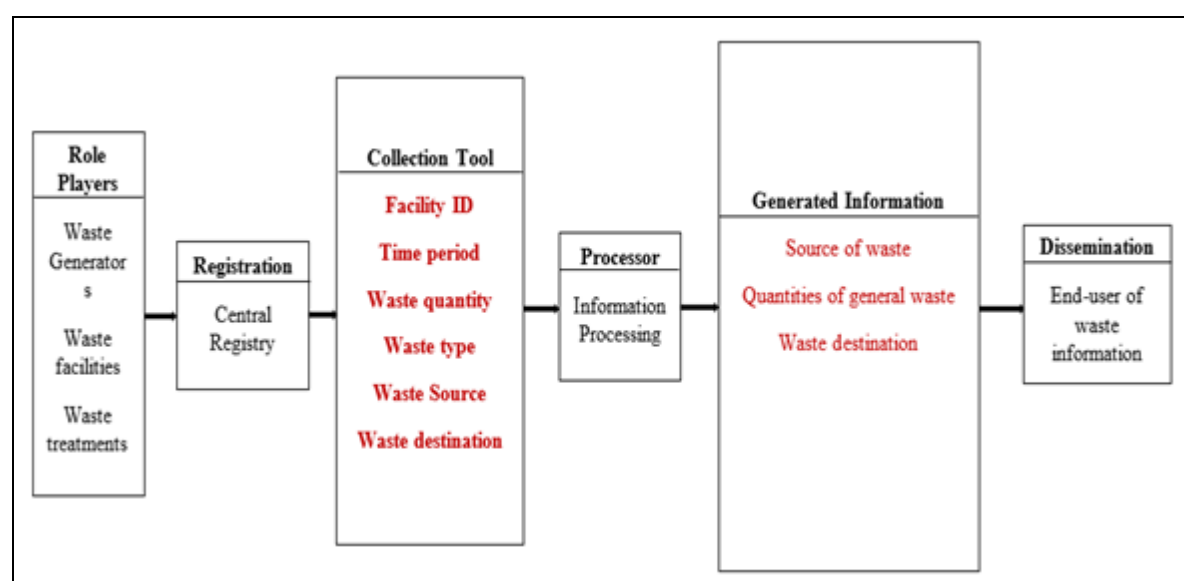


Figure 25: South Africa Waste Information System (SAWIS)

SAWIS is the current waste information system which is used in generation of waste information in South Africa. The information is collected by responsible facilities. The obligation of SAWIS is to receive the information, process it and generate information. The information is then disseminated to end-users who require it for different purposes. The system has inputs that support it.

8.4.2 SAWIS design inputs

SAWIS comprises of two information structures which support the collection and generation of waste data. These are the Department of Environmental Affairs' *Central Registry* and *Waste Information System* (WIS). The system is internet based and it is accessed directly via the internet through the DEA web site. The software was developed and operated by the national Department of Environmental Affairs and Tourism (DEAT) in 2005. SAWIS is designed to allow all users, with varying computer systems with internet and email access to log into the system. Information is collected by facilities and reported to SAWIS. However, not all of them are eligible to report information to SAWIS. Facilities have to register with Central Registry before they can be accepted to collect and report information to SAWIS. Fig. 26 shows the registration page of the Central Registry.

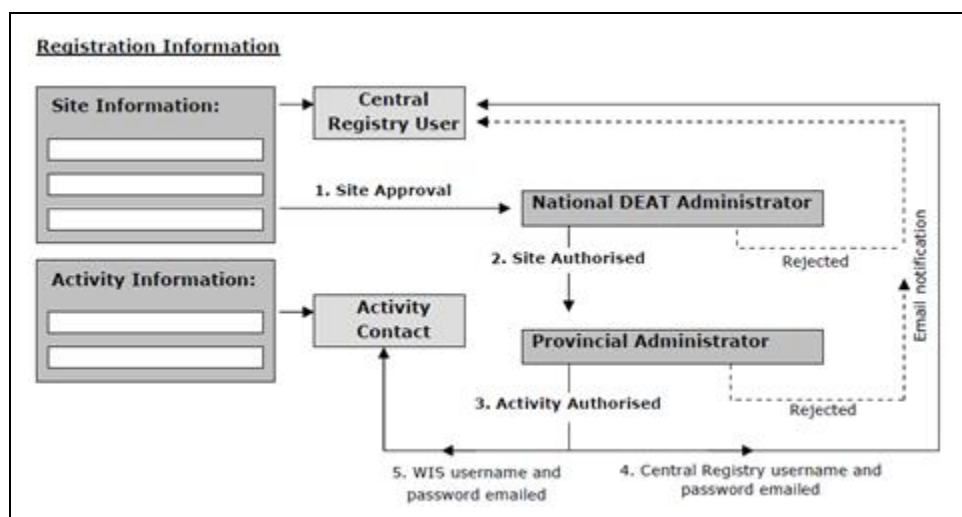


Figure 26: Authorisation process for the Central Registry

(Source: DEAT, 2005a)

8.4.3 SAWIS design flow paths

The information is captured into SAWIS where it is processed. The processed information is then disseminated to end-users. Fig. 27 shows the flow path from registration to information

generation. In the current information system, the information collection tool is the SAWIS template.

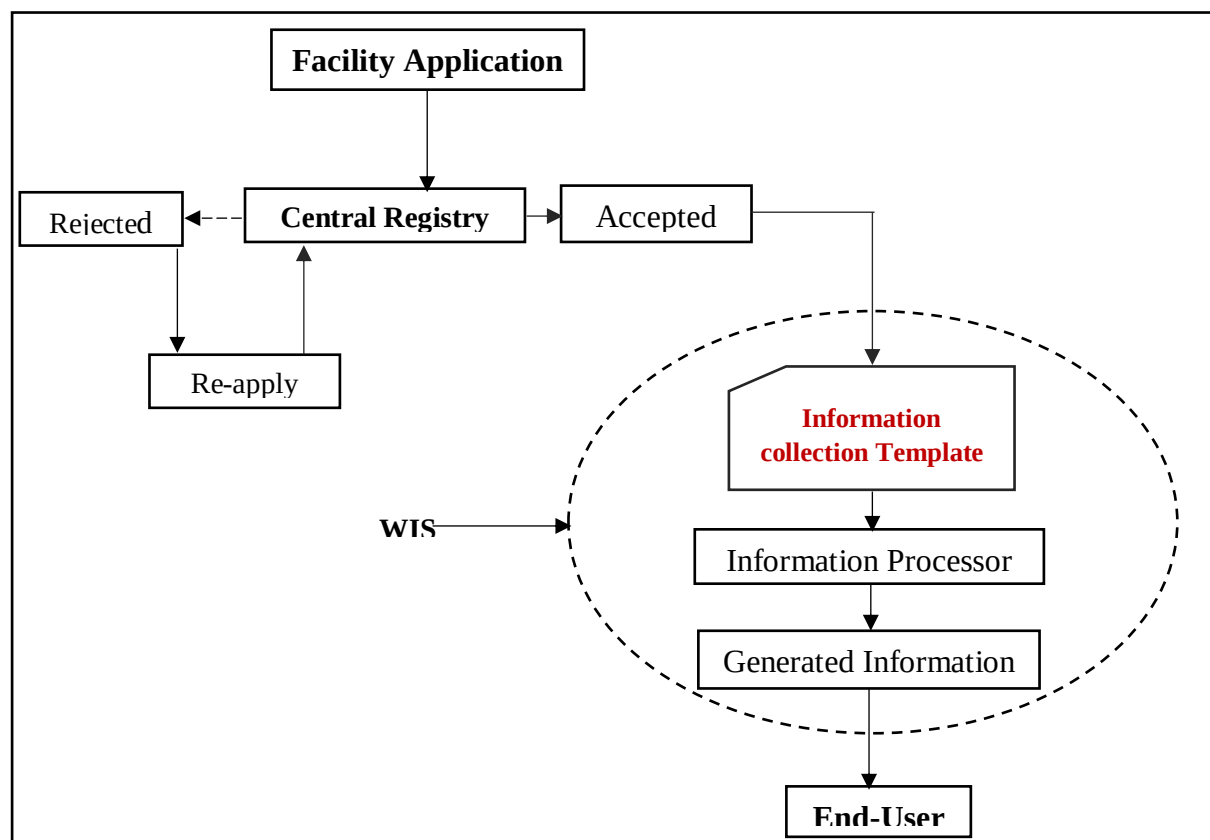


Figure 27: Flow path of SAWIS

8.4.4 Shortfalls in the SAWIS Operations

Although SAWIS collects and generates waste information, the key findings of this study shows that there are shortfalls in its operations:

- SAWIS does not generate adequate information on quantities, classes, moisture content, calorific values and composition which affect the planning, handling and management of waste.
- The system falls short of generating information on the available and other alternative waste treatments apart from records that show the 90 % landfilling and 10 % of recycling activities in South Africa. The alternative waste treatments do not even show in phase 4 of the implementation of the SAWIS, instead the system shows possibility of treatment of hazardous waste only (DEAT, 2006).
- SAWIS does not generate clear information on waste classification.

- SAWIS does not generate any information on waste at different levels of the waste chain which gives a deficit of quantities, location and distribution of waste and facilities through the waste chain.
- The system generates unstandardized information due to its flexibility in accommodating other information collection tools. In DEAT (2006) there is a note on SAWIS template that states that these forms can be modified to better suit the operating conditions at the waste facility.

In order to manage the MSW properly and effectively, there is need to have reliable information on quantities and composition of the waste. From an information perspective, Buchanan and Gibb (1998) emphasised the importance of waste information systems that are properly designed to manage information collection, generation and supply of the information to the end-user. Therefore, the rest of this chapter provides explanations of the components of the WIP and how it is embedded into SAWIS to improve on the quality of waste information.

8.5 The Proposed Waste information-based Platform (WIP)

8.5.1 Background

The proposed platform is named waste information-based platform (WIP). It is a waste information system that is developed to improve on the operations of SAWIS. WIP is designed in a way that the waste generators and handlers will be able to implement it easily. It is also designed in a way that it will generate reliable waste information with more variables compared to the current SAWIS. Hicks (2007) points out that re-engineering and optimisation of the overall information processes are central to achieving the importance and reliability of the information. Therefore, the operations of SAWIS are re-engineered to design and develop WIP.

8.5.2 Assumptions

The following assumptions are put forward for the waste information-based platform to fit and perform effectively in SAWIS:

- There is active participation in the National WIS to ensure that all waste facilities are registered and report on their respective waste activities.
- There are functioning weighbridges at landfills, so that all waste being routed to that site can be correctly captured.

- There is training of waste handlers on how to use the WIP
- There are functioning portable in-motion weighing systems at waste handling facilities or at landfills if their weighbridges are not functional.
- There is waste separation/classification at every level in the waste chain.
- That moisture content is periodically measured and recorded for input into the WIP.
- That calorific values are measured and recorded into WIP.

8.5.3 WIP design

The WIP is developed on the basis of key findings that appeared in section 8.2 carried forward from all the five objectives of the study. It is also based on the corrective actions/interventions to ensure that information flows are directed as per the dynamics of the platform. The platform itself represents processes that are self-sustaining, i.e. once initiated, pre-programmed interactions between key stages should ensure a continuous supply of data across the relevant municipal, district, provincial and national waste systems. Guerrero et al. (2013) stressed on how vital it is to produce reliable data and to create proper information channels within and between the municipalities. Fig. 28 is schematic diagram of the design of the WIP template and the type of information it generates for dissemination.

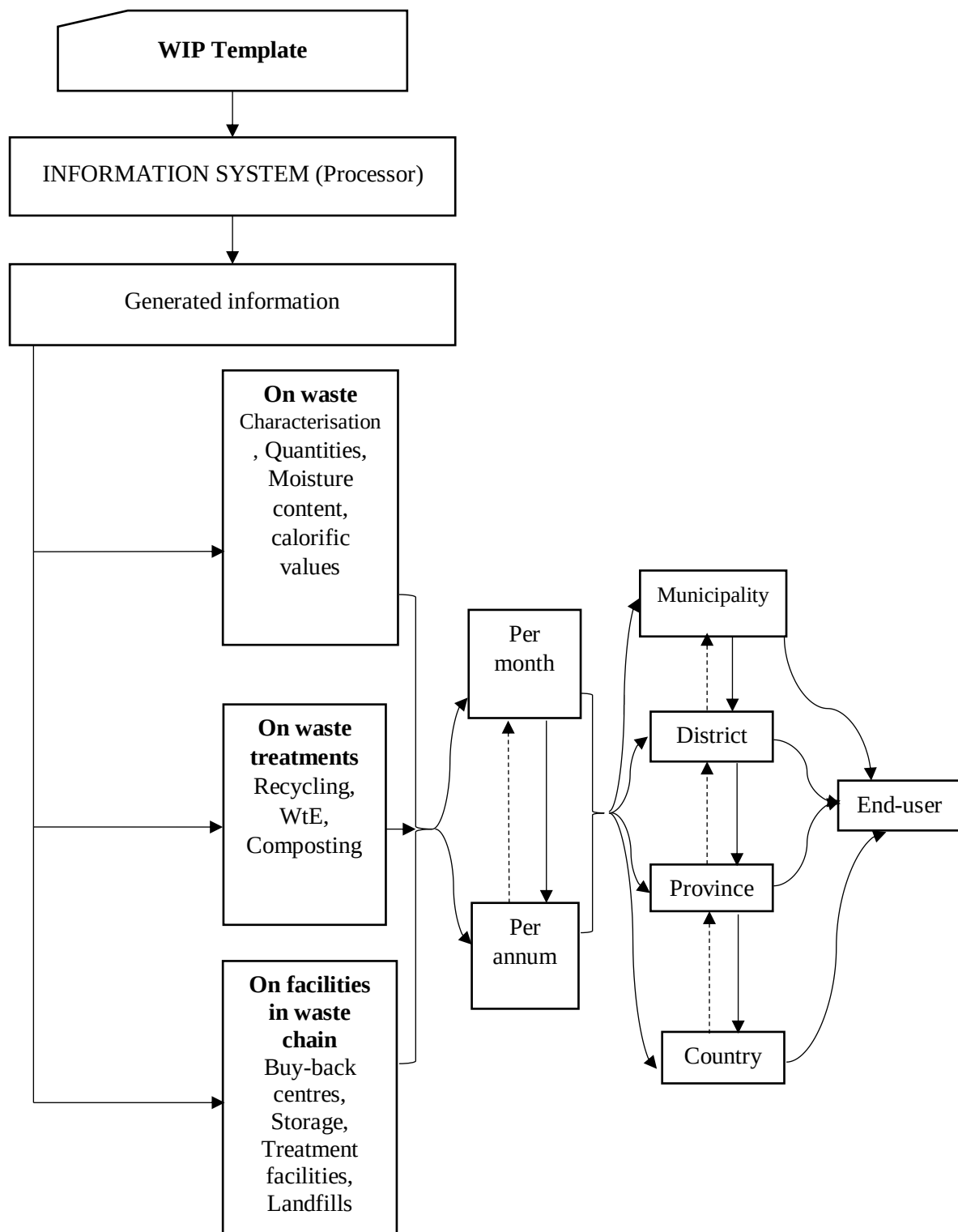


Figure 28: Design of waste information-based platform

The information collection tool that is used for collecting information in this system is called WIP template. Information will be collected on the template and captured into the current information system, SAWIS, where it will be processed. Processing of the entered information in the WIP includes calculating the total quantities, averages for moisture contents and calorific

values of each class of waste and that of mixed waste. It also includes identifying and calculating the facilities and waste treatments and grouping them so that their locations are shown and they are counted for each municipality, district, province and country.

The information generated will include information on total number and type of waste facilities, total number and type of waste treatment, quantities and composition of waste. This information depends on the WIP template. The template is the most important tool that needs to be carefully designed so that WIP can make use of web services to generate information that is elaborate, comprehensive, easy to analyse and easy to share.

8.5.4 WIP data collection template

The WIP template will be accessed from the SAWIS page. It will be printed into hard copy on which the waste information collected from different waste sources in the waste chain is recorded. The most notable change on the WIP template compared to SAWIS template, is the inclusion of cells that record information that is not available on SAWIS template. Collection of information is the critical step in the entire process surrounding the waste information system. DEAT (2006) noted that due to the difficulties often experienced in collecting accurate data, this step is considered the potential weak link in the process. And this study observed that the information that is collected by SAWIS template is not representative of the important waste information that is required for waste studies and waste management. The study also observed that most of the information is not collected at all. Therefore, the aim of WIP is to improve on the information that is collected by SAWIS by adding cells for the important waste variables. The WIP template also includes cells for all the role players throughout the waste chain to improve on the coverage of the collected and generated information in WIS. Table 35 is the WIP template that displays the differences in quality and quantity of information that is collected using WIP compared to using SAWIS template (Table 34) in section 8.4.1.

The way the information is recorded on the WIP template is in the same order that it is entered onto the data capturing sheet in the computer. That is when the WIP template is printed (hard copy) it is called information collection template while when it is in the system (soft copy) it is called WIP data entry sheet but they are identical. This is useful because, those entering the information into the computer do not see any difference between the information collection template and data entry sheet since they are replica of each other. The information from the

template is then transferred into the WIP data entry sheet, which is integrated into the SAWIS for processing.

Table 35: WIP template

Waste Facility/Treatment								
GPS Coordinates								
Municipality								
District/Town								
Province/Country								
Date								
(1) INFORMATION ON CLASSES OF WASTE								
	Plastics	Food	Garden	Textile	Leather	Wood	Rubber	Paper
Quantity (Kg)								
Moisture 1 (%)								
Moisture 2 (%)								
Moisture 3 (%)								
Calorific (kJ/kg)								
(2) INFORMATION ON MIXED WASTE								
Quantity (Kgs)								
Moisture 1 (%)								
Moisture 2 (%)								
Moisture 3 (%)								
Calorific (kJ/kg)								

This information is captured into the WIS. However, it must be noted here that the WIS has a cell for waste type marked as *G* meaning *general waste*. This is not the case when WIP is integrated in WIS, because the cell that is marked *G* will be marked with the classes of waste as it is on the WIP template. The officer capturing the information into WIS will select the class of waste that they need to record the information on. This information will then be processed.

8.5.5 WIP and SAWIS integration

The WIP is designed in a way that it is embedded into the already existing SAWIS framework without disrupting its operations. This aims at improving on the SAWIS to generate superior information for SAWIC in order to improve on the data precision and quality. Fig. 29 shows the flow diagram of WIP design and how it is integrated into SAWIS. The developed WIP-SAWIS system uses the same website page and all the internet processes that are used for accessing into SAWIS.

The WIP will use the Central Registry for registering members. It will also use the same page that is used for capturing of waste information into SAWIS Figs. 29 and 30. Fig. 29 shows the integration of WIP template into SAWIS.

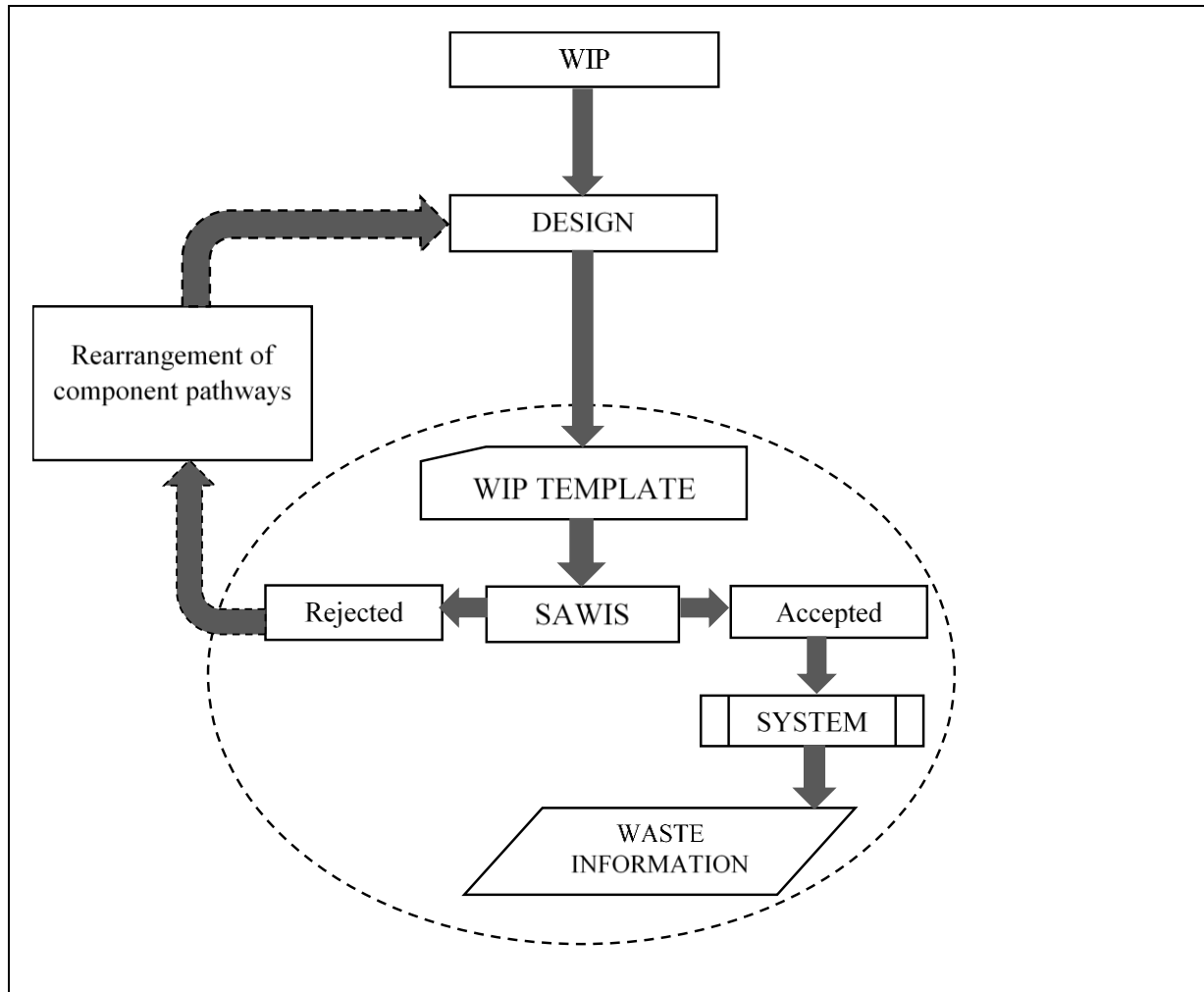


Figure 29: Integration of WIP into SAWIS

Fig. 30 shows WIP using the registration system of WIS and WIP template embedded in SAWIS.

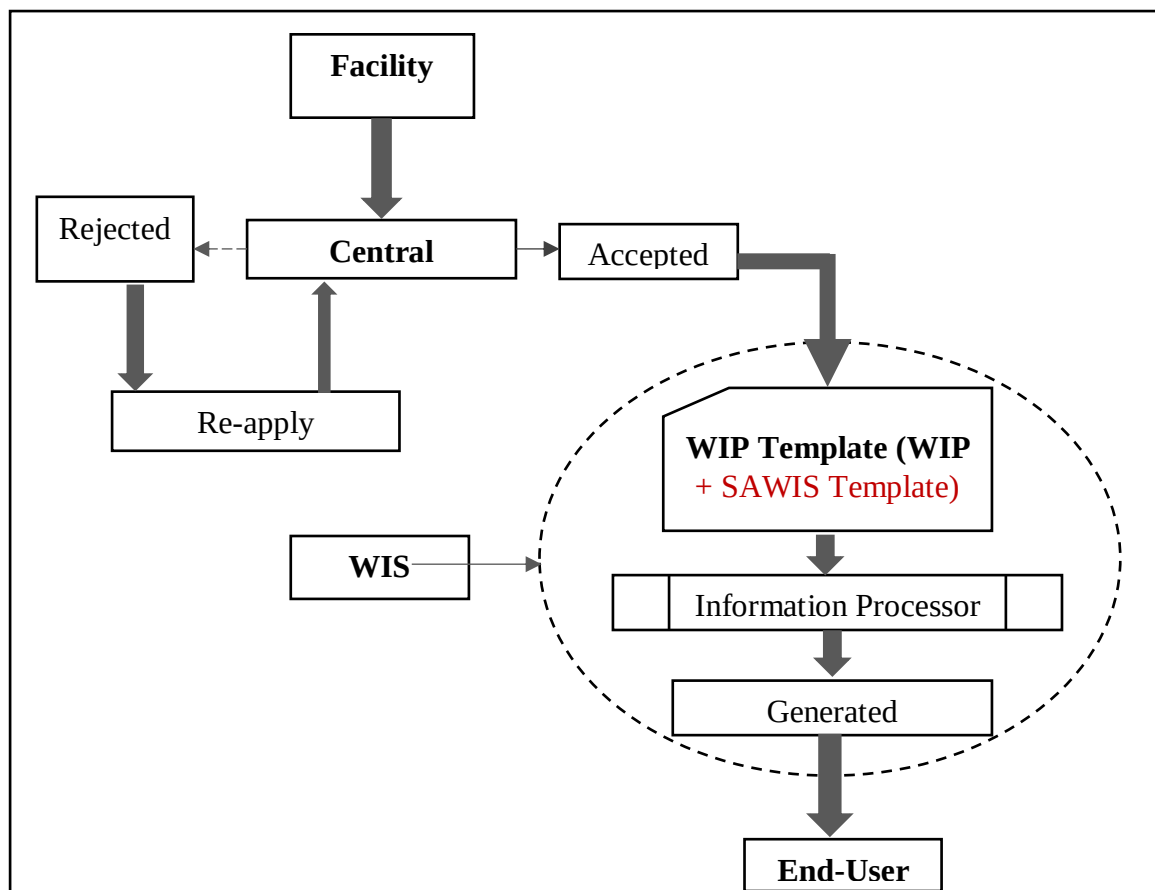


Figure 30: WIP

8.5.6 WIP information generation

The WIP is designed in such a way that it collects and generates all the information variables that SAWIS does not collect and does not generate. As it is stated that the output of the processed information depends on the information that is inputted into the system. Fig. 31 shows diagram of sample of waste information platform.

The information generated by WIP include information on waste quantity, classes, moisture content, calorific values, facilities, waste treatment systems (such as recycling, WtE generation, composting and landfilling) that will be available to information end-users (public and the government). However, the differences between the two systems, SAWIS and WIP are the improvements that have been effected on the WIP template in relation to the SAWIS template. It is believed that the information that is collected and generated using the WIP template will be rich in content of the waste variables than it is the case with SAWIS template.

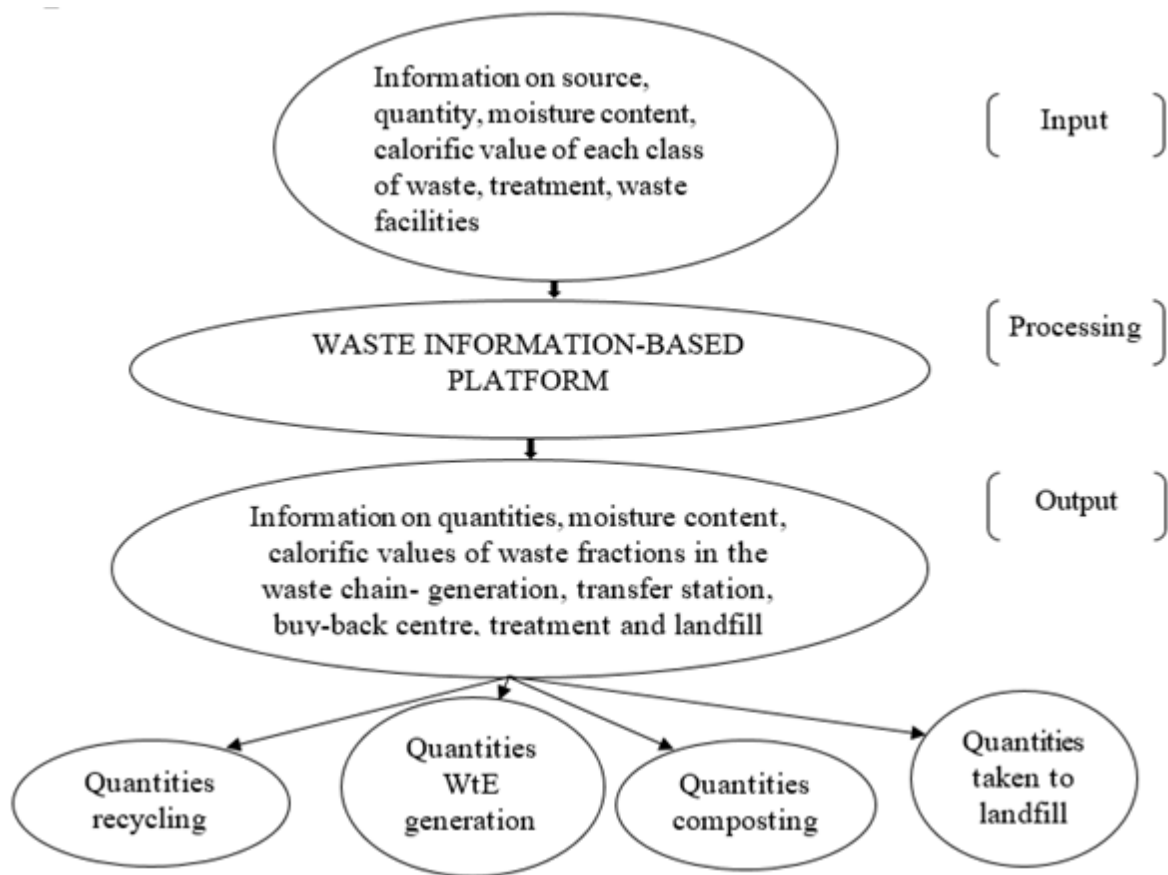


Figure 31: Sample of WIP

However, as explained that the WIP is integrated in SAWIS. Fig. 32 shows WIP in black colour integrated into SAWIS. The red information shows the information that is collected and generated by SAWIS template. The figure shows that there is more information on waste that is collected and generated when WIP is integrated into SAWIS. There is information on 14 waste variables that are generated compared to the 3 variables that are generated when using SAWIS only. This points out at what this study and other studies have pointed out in their results that SAWIS does not generate much information on waste.

The information is displayed in different windows showing the information for facilities, municipalities, district, province and country. Table 36 shows the generated information from the SAWIS-WIP integration. The period for which the information is displayed can be per day, per month or per year, depending on the end-user's requirement. This information is updated every time the role players report the information into SAWIS.

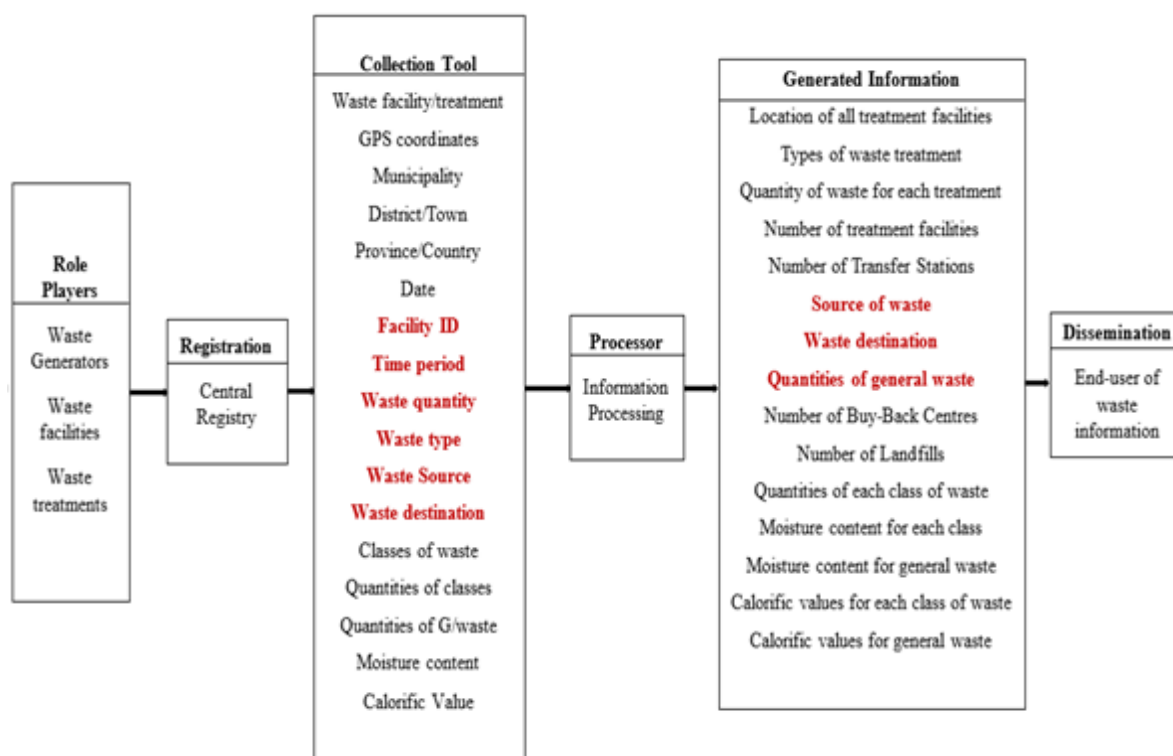


Figure 32: Integrated SAWIS and Waste Information-Based Platform (WIP)

The information generated by WIP (Fig. 32 and Table 36) is an improvement on the information that is generated by SAWIS. It meets all the requirements for project planning, policy making and MSWM. The information include totals or averages of the information on waste for each Facility in a municipality, municipalities in a district, districts/towns in a province/country and lastly for the whole province/country. It generates information on classes of waste (plastics, food, garden, textile, leather, wood, rubber and paper), their quantities (tonnes), calorific values (kJ/kg) and moisture content (%). This information is for the facilities, municipalities, district/town and province/country per day per month and per year. WIP generates information on waste facilities showing the locations, total number of each waste facility (transfer stations, buy-back centres, recycling facilities, WtE generation facilities composting facilities and landfills) in a municipality, district/town and the whole province/country. It also generates information on waste treatments showing the type of waste treatment that is done in the province. It also shows the total numbers and location of the waste recycling, WtE generation and composting in municipalities, districts/towns and the whole province/country.

Table 36: Waste information generated by WIP

Municipality								
District/Town								
Province/Country								
Date								
(1) INFORMATION ON WASTE								
Quantity Moisture Calorific	Classes of Waste							
	Plastics	Food	Garden	Textile	Leather	Wood	Rubber	Paper
(2) INFORMATION ON WASTE FACILITIES								
Total	Waste Facilities							
	Transfer Station	Buy-back Centre		Recycling	WtE	Composting	Landfill	
(3) INFORMATION ON WASTE TREATMENT								
Total	Waste Treatment							
	Recycling		Waste to Energy			Composting		
(2) INFORMATION ON MIXED WASTE								
Quantity								
Moisture								
Calorific								

8.5.7 Applications potential of WIP

WIP is designed as a response to field conditions in the NWP but is an interface with the national waste information system (SAWIS). Waste information conditions in NWP are not unique, meaning that other provinces in RSA present more or less similar conditions. The WIP can therefore be deployed across any part of country. It can also be deployed in those countries with similar waste challenges as South Africa. The WIP template has provision for collection of information through the waste chain, from the generators to the landfills. There is need to introduce the WIP to all the parties that deal with solid waste. However, for the effectiveness of the WIP, before implementing the system, there is need to introduce the weighing of waste, classification of waste at source, measuring of moisture content and calorific values. The quantities, classification of waste and measuring of moisture content can be done by the generators of large quantities of waste, storage facilities, buy-back centres or waste treatment facilities because these exercises are easy to conduct. The measurement of calorific values can be set to be done either by municipalities or a central post in the department of environmental

affairs. This one can be rolled out in phases, starting from for the whole country, province, district then municipality since the cost of the equipment is high.

From the key findings, there is potential implementation constraints that could arise from individual municipalities. Most of the municipalities do not have waste management departments. In addition, they also do not have trained waste management officers. This leads to lack of expertise in waste management. Some municipalities have shortage of equipment for example, they have shortage of waste collection fleet, they do not have operating weighbridges at the landfills, and most of the landfills do not have controlled access. This can jeopardise the collection of the required information on the WIP. Therefore, there is need for municipalities to design and implement interventions to reduce (over-ride) the retarding effects of these constraints. Without these constraints then the WIP will perform effectively to overcome the lack of waste information that has been experienced for a long time. It can generate up-to-date information that has not been generated by SAWIS on waste for planning, management and treatment of waste.

8.6 Summary

In this chapter WIP is designed and developed based on knowledge gaps and the key findings identified in chapters 2, 4, 5, 6 and 7. These are listed in Table 32 and summarised in Table 33. WIP has addressed most of these knowledge gaps and the key findings. In terms of the gaps, WIP will improve on the availability of reliable waste information and waste treatment activities (Fig. 32). It has also addressed the challenges that were identified from the key findings. WIP includes a standard waste information collection tool (Table 35) that is supposed to generate standard, accurate, reliable waste information on all the important waste variables at every level across the waste chain (Table 36 and Figs. 30, 31 and 32).

WIP is developed to successfully address the difficulties in planning and management of complex waste, maintaining environmental health, sanitation and sustainability. It ensures generation of standard waste information on quantities, classes, calorific values, moisture content and composition (Fig. 32). Subsequently, increasing waste treatment options thereby reducing pressure on landfills. Incorporating WIP is essential for the development of modern waste delivery services through improvements on the information outcomes that align the services with waste management. WIP also contributes to generation of reliable information on waste facilities and waste treatments, waste at different levels of the waste chain which are discussed in the next chapter on contribution, conclusion and recommendations of the study, Chapter 9.

CONTRIBUTION, CONCLUSION AND RECOMMENDATIONS

9.1 Introduction

This chapter covers three important components but broken down into sections: It deals with knowledge gaps, key findings, knowledge gaps addressed, limitations, contribution of the study, conclusions, areas of further research study and a set of recommendations.

9.2 Knowledge gaps

The specification of knowledge gaps is informed by the focus of this study, which is ‘waste information in the context of the WMS, waste recycling and waste-to-energy generation’. Several gaps in the state of the waste information system in NWP, South Africa and beyond have been established by the literature review. The two gaps are: (i) waste information methodology and (ii) governance concerns with regard to waste information systems.

Waste information Methodology:

It was noted that the *methodological gap* centres on the related issues dealing with waste collection, waste characterisation, waste classification, instruments, data reliability and landfills. Underlying this was that the state of waste information across countries suffered from particular methodological constraints, which in turn had a negative effect on the potential use of such waste data. *Therefore, better methodologies are developed to diminish (reduce) these inherent constraints.*

Governance:

In short, two constraints stand out: the use of waste estimates and the packaging of waste information. These two enter into governance structures at the municipal, city, metropolitan, provincial and national levels of government. The problem with waste estimates is that they are fundamentally flawed given the diversity of input parameters used in their construction. Second, estimates were often based on assumptions about changes in population, standards of living, consumption patterns and projections of change thereof. The deviation between estimated values and actual values generated from ground measurement should not in principle be ignored. The success of government structures and the private sector with reference to

planning for service delivery, waste recycling and WtE depends on reliable data. The packaging of waste information, too, should be such as to allow for input into decision making with regard to WMS. *It should immediately be noted that improving the packaging of waste information at all levels remains handicapped if the methodological knowledge gap is not addressed. The second knowledge gap on 'governance' is therefore intertwined with methodological issues.*

9.3 Key findings of the study

Standard instrument for collecting waste information

South Africa Waste Information System (SAWIS) developed SAWIS template for collecting waste information. However, this study observed that most of the municipalities have developed their own instruments' that they use for waste information collection. Notably are the disparities between the templates that are used by the different municipalities resulting in differences in information that is collected. The study has uncovered six information collection tools across the municipalities. All the six tools collectively have the basic waste information indicators (section 4.3.1). The information that is on the tool is document number, the date information was collected and page number where the information is recorded. The vehicle registration is also recorded together with its tonnage, type of waste categories, name of person delivering waste, name of company delivering waste, time in and out at the landfill, and the number of trips for each vehicle. Other information recorded on the tools include: number of waste bags collected or delivered, source of waste, type of waste, loads of waste and number of households from which waste is collected. The challenge is that this information does not talk of classification, volumes generated, moisture content, calorific values and emissions from storage and treatment works. Lack of quantification and characterization of MSW is common in developing countries (DEAT, 2006; Troschinetz and Mihelcic, 2009) where the information on MSW generation have a short history and usually insufficient for the nation or province.

Only 33.3 % of the six tools have half of the indicators that are on the SAWIS template while the monthly waste report does not have any of the indicators prescribed by SAWIS. Moreover, by using any one of the six tools to collect information on waste, on average about 23 % of information required by SAWIS is collected. This shows that not all the important information is collected by the municipalities when they use either of the six tools rather than the SAWIS template. The results point towards incomplete and waste information deficit in the NWP.

Information on quantities, classes, moisture content and calorific values of waste

Information on quantities, classes, moisture content and calorific values is not collected for the province. This arises as a result of the failure to develop a standardized methodology for collecting, reporting and disseminating waste information. In this study, the quantities of waste were estimated by using the generation rates of waste and the population of the province using population census of 2011, 2016 and projected population of 2020. Moisture content of waste is the percentage of water in the waste. The moisture content was measured using moisture meter. Calorific value is the energy content of the waste, it indicates how much energy is contained and can be extracted from the waste for maximum and efficient energy generation. In this study, the missing gap is the information on the calorific values of the MSW in the NWP. Such data could not be collected during the study because of the high cost of the equipment for measuring calorific values. As such, the study used the calorific values of waste from the countries that are in the same geographical region and have climatic similarities with South Africa. Lack of this information results in lack of necessary information that is vital in determining the potential of adopting waste treatments like recycling and WtE generation.

Information collected through the waste chain

Waste chain is the path travelled by waste from generation to the point of disposal. Waste chain is a very important source of collection of reliable waste information which is collected as the waste passes through different levels. This can collect information which contribute to information at each level of the waste chain. There are facilities that are supposed to be available at the different levels of the waste chain. The facilities include waste generators, transporters, transfer stations, buy-back centres and treatment facilities. These facilities can be used as waste information collection sources. In this study, the waste information collection sources are divided into three categories: (i) those that collect and report information to SAWIS, (ii) those that collect waste information but do not report to SAWIS and (iii) those that do not collect waste information at all. If all the facilities collect and report information, then the available information will be representative of information from all the levels of waste chain. However, results revealed that out of all the waste facilities in the study area, information is collected and reported to SAWIS only at landfills though some landfills do not collect information at all. The results show information is collected and reported only at a quarter of the landfills. The small fraction of operating waste facilities reporting into the system renders the SAWIS data incomplete for the purposes of establishing a national waste baseline (DEA,

2012). However, due to some factors, not all municipalities and private waste facilities manage to collect and process the information as per SAWIS's regulations. This shows lack of information collection through the waste chain.

Information on waste treatment and treatment facilities

The availability of waste information and the presence of waste facilities for example transfer stations, buy-back centres and treatment facilities provide ample opportunities for diverting waste that would otherwise be taken to landfills. Information collection at these facilities is important for planning of waste treatments. In the study area, there are not many waste facilities and there is shortage of information on waste treatment apart from the scanty information on waste recycling. The information shows that out of the 37 identified facilities, 12 are landfills, 14 are buy-back centres, 10 are transfer stations, and 1 is recycling centre. There is no any information on compositing and WtE projects or facilities. There is very little waste treatment activities in majority of African countries (Couth and Trois, 2012). However, there could be many more other waste facilities in the study area, but are not known because they are not documented. If these facilities do not collect and report information, there will be no information on the facilities and the treatment they do.

9.4 Knowledge gaps addressed by this study

This study has developed an intervention in the form of the WIP (detailed in Chapter 8). The WIP could be used to improve the methods of *waste information collection*. This could in turn provide the means to upgrade the type of information generated by SAWIC. This is in response to the knowledge gaps (i) and (ii). It is argued that the development of the WIP addresses the missing link in the quality of data that the SAWIS deals with. In incorporating WIP within existing tools for waste data collection and reporting, municipalities should have the means to generate high quality waste information for own use and for submission into the SAWIS.

Knowledge gap (i) Methodological

The study noted that the current system allows municipalities to modify the SAWIS template which results in generation of unstandardized waste information. The study proposes the use of a standardised waste information collection tool across all the municipalities. Hence development of WIP. WIP proposes information collection at all levels of the waste chain and provides space for feedback pathways, adaptation and enhancement to take care of diverse

differences in the waste information collection and generation through the waste chain. It is envisaged that WIP will address the information gaps pertaining to collection methods which translates to up-to-date information on status of waste for assessment, management and treatment of solid waste. This would streamline the accuracy of information collected in terms of units of measurements and the classification of waste. Moreover, information of waste classes, moisture content and calorific values of the different wastes is incorporated. In addition, the upgraded information is important for identifying alternative *waste treatment opportunities* which would help ease the pressure that is currently experienced in landfills and the environment (Arafat et al., 2015).

Knowledge gap (ii). Governance

Availability of accurate and reliable information affects the governance structures which include waste measurements and waste treatment options. Different types of waste treatments compete for the same type of waste. However, the performance of different treatment processes depends on the quantity, type and conditions of the waste. Some waste treatments favour waste with high moisture content and low calorific values while others favour the opposite conditions. Couth and Trois (2010) reported that there is little comprehensive and reliable data on waste variables such as calorific value, class, volumes and moisture content especially in Africa.

WIP is designed to address this knowledge gap in that it is envisaged that once in operation, it will generate the missing information which include calculations on the total quantities, averages for moisture contents and calorific values of each class of waste and that of mixed waste. It also includes identifying and calculating the facilities and waste treatments and grouping them so that their locations are shown and they are counted for each municipality, district, province and country. On the basis of this information the knowledge gap on governance is covered in terms of improvement on issues relating to: (i) policy (ii) planning (iii) programmes (iv) waste recycling projects (v) waste-to-energy generation (WtE) and, (vi) budgeting for waste management at different levels of government. This will then widen *the opportunities of alternative waste treatment* other than landfill. For example, if the information on quantity, class, moisture content and calorific values of waste is known, this information is adequate to be used for selecting whether the waste should be subjected to recycling, composting or WTE generation. Moreover, information on quantities of different classes of waste, will be vital in assigning the correct quantity of waste to different treatments with competing interests. The information will help waste managers across the municipalities in the

NWP and beyond to effectively distribute the required waste quantities for different projects that could be operating concurrently.

9.5 Limitations of the study implementation of WIP

As observed from the key findings in section 8.2, there is no information on calorific values in the study area and in South Africa as a country. During the study it was required to measure the calorific values of the waste in order to estimate the potential of WtE in the NWP. However, the calorific values were not measured for this study but the study adopted calorific values from other regions with similar climatic conditions as South Africa. This is a proof that there is scarce information on waste in the study area. All in all the WIP does not have any design limitations. The system is compatible with SAWIS, allows municipalities to use it to keep a lot of waste information and it is flexible that is it can be changed in terms of data capture.

Limitations that can be anticipated for WIP are from external constraints. These may arise with respect to the implementation of the WIP on the ground. The WIP calls for a radical restructuring of waste data collection by municipalities. This would include:

- Waste sorting at source
- Installation of functioning weighbridges at each landfill site
- Waste information collection to cover the entire waste chain.

9.6 Contribution of the study

This study was triggered by the recognition that: (i) there could be design limitations in the current SAWIS system in place and that such limitations may impact on the effectiveness of waste data collection, (ii) information is required to establish the character and volumes of the waste streams produced in NWP as a basis for testing the potential for waste-to-energy projects. To this end, and built on the findings from each of the chapters, a set of critical inputs was assembled to constitute the building blocks for a new waste information-based platform. The contribution of this study to knowledge centres around four pillars:

Methodological:

* This study used the concept of a “waste chain” as a conveyor belt to trace volumes of waste collected, transported, leaked back into the environment, and recovered for re-use, recycled, incinerated and finally landfilled. In using moisture content and calorific values of different waste streams, it was possible to isolate those waste types suitable for energy generation. This information was then input into data sets showing volumes of data generated per local municipality and to compute the waste segment potentially suitable for large scale energy generation. The findings indicate that economic fundamentals of the NWP present risks should the province decide to invest in waste-to-energy projects to feed electricity into the national power grid. *The methodology developed in WIP could be used as template for parallel and similar investigations in other parts of South Africa and beyond.*

*This study used empirical methods in observing, collecting and recording critical data units along the entire waste chain across a set of local municipalities each representing a diversity of physical and socio-economic indicators. The collected data was imposed on the SAWIS system to ease out data limitations. *To my knowledge, no study on waste management has used this methodology to assess the design efficiency of SAWIS.*

Data use optimization:

* The essence of the findings of this study is that the current tools deployed through SAWIS to *collect, capture and transmit waste data* to a central registry are inadequate. *This is the first study of its kind to report such an outcome.* The implication of this finding is that the state is limited in its capacity to deploy SAWIS data for any province or even a single city on environmental planning. Why? The SAWIS system captures data that is critically short of inputs which local governments and municipalities can use to plan for the present and carry out projections into the future. The SAWIS does not report significant data details, without which, planning becomes problematic. It is worse when programmes and projects are based on such insufficient waste information. *The WIP developed in this study addresses this data shortfall by incorporating additional data units to improve the reporting outcomes of SAWIS.*

Applications of WIP in decision structures:

This study establishes that at the level of local municipalities, there are technical, managerial and financial constraints that undermine the development of a modern waste delivery service.

These constraints in turn translate into budget allocations for the waste directorate and the deployment of qualified personnel. Beyond these, it is noted that there is an urgent need to move away from the dominant view which sees waste as a problem or a nuisance that municipalities have to deal with. There is need to replace such thinking with a radical view of waste as *a wealth-creating resource* rather than a problem. This means that the term waste itself is misleading as it implies products that attract no monetary value. *Decision making structures and the resulting outcomes that talk to waste management consistently show a lack of alignment with the goals of national government.* This study has established that local governments attach low priority to the need to develop reliable waste information and use this for planning waste management. This problem is not unique to NWP, it is a national issue.

Turning to the potential for energy generation from waste, the findings do indicate that the NWP cannot simply initiate waste conversion into energy. The current information system does not provide important information that is needed for one to estimate the potential for the energy generation. For investments to be pulled into NWP, there has to be ample proof that there is adequate volumes available to sustain energy plants and that there is the information on moisture content and calorific values of waste. The proof can only be through the availability of waste information. This could be achieved through the introduction of WIP because WIP will generate information on calorific values, moisture content and quantities of waste.

WIP compatibility with SAWIS:

Perhaps, one of the greatest innovations of the WIP is that it is compatible with the existing SAWIS. It represents additional waste details that can be incorporated into SAWIS without disrupting its operations. From a systems management perspective, this is very critical because innovations often receive hostile reception when they appear to threaten existing systems and or structures that are already in place.

Obtaining reliable data and information to support integrated waste management planning is imperative for the successful implementation of the waste information system as is required by the National Environmental Management: Waste Act, 2008. The WIP is capable of generating important information that provide factors that influence solid waste management systems. The information is very useful for any individual or organization interested in planning, changing or implementing a waste management system in the NWP and beyond. WIP generates a

standardised, uniform and reliable waste information that is from and for all the levels in the waste chain.

DEAT (2006) recognised that the SAWIS template requires customising of the system that is used for capturing data for easy capture and export of this data in the required format for uploading into the data entry sheet. The WIP template is more user friendly because it is already customised to data entry web page and if adopted, it can easily be accessed and downloaded by all the parties and municipalities that are registered to SAWIS.

The WIP template has more valuable information for waste management than the complicated SAWIS template. The WIP template has cells that need to be completed with information for quantities, classes, moisture content and calorific values of waste. This information if available will be useful in determining other opportunities on waste treatment. WIP also collect and generate information on numbers and locations of waste facilities through the waste chain which include generation points, transfer stations, buy-back centre, recycling, WtE, composting or landfill. This information is important for route and vehicle optimisation and determination of waste treatments.

9.7 Conclusions

The key findings from chapters 2, 4, 5, 6 and 7 show that there is lack of waste information in NWP, or if there is, then the information is not reliable and not available to the end-user. Analysis of the study through the listed chapters points to the design of the current SAWIS template, as the main source of the gaps on waste information in South Africa. The inherent gaps identified in the SAWIS template, have created several factors that contribute to the collection of the unreliable waste information. The data collected by municipalities may be indicative of conditions relating to the collection tools, personnel, operational vehicles, roadway infrastructure and conditions, and status of disposal sites. this is supported by the rejection of the two null hypotheses that were stated in 1.5. The first hypothesis shows that there is relationship between the information available and the indicators within the six collection tools. The second one shows that training of the personnel handling waste on waste information can improve on the waste statistics collected and generated. Lack of suitable facilities (equipment and infrastructure) and underestimates/overestimates of waste generation rates, improper bin collection, and route planning are responsible for poor collection and reporting of waste information. The non-adherence to the SAWIS information collection tool

means that information collected by municipalities is not standardised and does not meet the requirements of SAWIC. Moreover, the information that is generated does not include information on waste facilities and waste treatment for the province. The system also falls short of generating reliable information on quantity, classes, moisture content and calorific values of waste.

Lack of this information affects all the key players in waste management in that they cannot plan for handling of the waste. For example, the municipalities cannot plan for waste collection and dumping, waste facilities cannot plan for the treatment of the waste, waste reclaimers cannot decide on which type of waste to deliver to particular waste treatments and waste treatment projects cannot plan for treatment of waste. Overall it affects the MSWM. To address this problem, the WIP has been designed to offset the weaknesses of SAWIS. The WIP system is considered to improve the information system by collecting and generating standardized and reliable waste information.

The contribution of the WIP to the state of knowledge in waste information collection, generation and management affords the variables that are required to collect and generate complete waste information through the waste chain. The information generated by WIP is anticipated to be standard, to cover the whole waste chain, to indicate the quantities, moisture content, calorific values of waste, population of waste facilities and that of waste treatment projects. The information that WIP will generate is very important for planning of waste management and can be used for estimating the potential and sustainability of alternative waste treatments such as recycling, composting and WtE generation.

9.8 Areas of further study

There are some issues that have been highlighted by this study that require further investigation to advance the waste information system for generation of information that is reliable for planning of waste collection, transportation, storage, treatment and landfilling in NWP and beyond. These are listed as three issues:

- Determination of the calorific values of MSW in developing countries including South Africa
- Design of suitable system for waste separation at source

- Assessment of the structure of waste management departments in municipalities in relation to the need to achieve higher levels of productivity and efficiency
- Conduct the study on waste data by taking a case study of a municipality at micro level.

9.9 Recommendations

A set of recommendations are made based on the findings from chapters 2, 4, 5, 6, and 7. The recommendations include further research possibilities to advance the waste information systems in order to improve MSWM in NWP and beyond. The relationship between waste information institutions and waste management in WIP system is a complete circle. Collection and generation of waste information cannot be useful without linking it to waste management. Waste information plays a big role in planning of waste management by institutions, while institutions contribute by providing the information on waste that they collect to SAWIS.

Specific recommendations therefore are as follows:

- The Department of Rural, Environment and Agricultural Development (READ) should monitor mechanism to ensure compliance and timely reporting. The core business of the department is to improve on the environment which requires dealing with the disposal and management of waste. But it has shown that without information on waste, the management of waste becomes complex and inefficient in terms of collecting, transportation, storage and disposal.
- In order to have a standardized waste information, the department that developed SAWIS should put in place restrictions that do not allow all the role players that deal with waste to use any other tool of their own to collect waste information. By enforcing the restrictions, the waste information collected will have the same units and classes. This is in line with the proposed WIP which has been designed to generate standardized information.
- Facilities should take a step in registering and collecting waste information that will be reported to SAWIS. There are waste facilities that deal with waste recycling but they are not registered with SAWIC. These facilities do not collect any waste information or they collect but do not share the information. Some of the reasons for not participating in collection and reporting could be related to tax evasion or they do not have valid license.

- To collect information on the classes of waste, municipalities should take the leading part in introducing the sorting of waste at source. Although this seems a farfetched system, it can be achieved by sensitising the communities on the benefits and advantages the system will bring to them. They could also ensure compliance by all generators in order for them to benefit from other services of the municipalities. There is need for civic education through TV, radios or plays to sensitize and enlighten the communities on the need to separate the waste from their households, businesses, schools, offices, etc.
- To enhance the waste information collection, municipalities should maintain the fences around the perimeters of all the waste holding facilities like transfer stations and landfills. The municipalities should also repair the equipment like weighbridges and compactors at the landfills. This will stop the collection of information on quantities of waste by estimation method which is currently in use at most of the landfills.
- The municipalities should create a register for all the facilities across the waste chain. This will help to map and locate all the role players involved in waste in terms of waste handling or treatment and will encourage the facilities to register for waste information collection and submission to SAWIS. This will support WIP in generating information on waste facilities and treatments at all the levels through the waste chain. This information in turn will benefit the municipalities by creating a clear picture of volumes of waste generated. The volume of waste will help the municipalities to plan for collection and transportation of waste.
- The study recommends regular equipment maintenance such as weighbridge servicing, maintenance of broken facilities and installation of functional equipment for continuous collection of waste information at all disposal sites.
- There is an urgent need for competent personnel in waste management in all the municipalities to handle the various aspects of waste information, so that accurate and correct waste information is collected. This calls for training and refresher courses for waste personnel.

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APPENDICES

APPENDIX A

Observation Schedule for Waste Management

1: INSTITUTIONAL ORGANISATION OF WMS												
LM:												
GPS												
DATE												
RESEARCHER												
CONTACT												
No. of Landfills												
No. of Buy back centre												
No. of Recycling centre												
No. of Transfer Station												
1(i) Workforce Local Municipality (LM)												
	Number of employees of the LM	Number of employees in the waste directorate	Number of directors	Number of Managers	Number of supervisors	Number of technicians	Number of casual labourers					
(ii) Facilities LM												

	Number of front-end loaders	Number of rear-end compactors	Tractor-drawn trailers	General trucks	Bulk bins	Plastic bins	Weighbridges	Repair workshop	Mobile workshop	Number of Landfills	Number of Recycling	Energy generation
Operational												
Non-operational												
(iii) Information status LM												
(a) Source												
	Households	Business	Factories	Institutions	Medical	Construction & demolition						
Volume estimate												
Volume measured												
Time coverage												
Area coverage												
(b) Class 1												
	Glass	Paper	Plastic	Metal	Chemical	C&D	E-waste	Garden	Food	Medical	Others	
volume estimate												
volume measured												
time coverage												
area covered												
Moisture content												
Calorific value												
Organic fraction/nutrient content												
2: LANDFILL SITE												
LM:												
Site Name												
Site GPS												
Date												
Researcher												

Contact												
1(i) Workforce Landfill												
	Number of employees	Number of Managers	Number of supervisors	Number of technicians	Number of casual labourers							
(ii) Facilities Landfill												
	Number of front-end loaders	Number of rear-end compactors	Tractor-drawn trailers	General trucks	Bulk bins	Plastic bins	Weighbridges	Repair workshop	Mobile workshop	Number of Landfills		
Operational												
Non-operational												
(iii) Information status Landfill												
(b) Class 1												
	Glass	Paper	Plastic	Metal	Chemical	C&D	E-waste	Garden	Food	Hazardous	Medical	Others
volume est												
volume ms												
time coverage												
area covered												
Moisture content												
Calorific value												
Organic fraction/nutrient content												
3 STATUS AND HANDLING OF WASTE INFORMATION												
Municipality	Name Facility	Recording of information		Information collection frequency/week		Information storage	Information type			Information management		

		Papers	Computer	Books	every load	At intervals	> twice	computer	files	Type	Class	Source	Quantity	who records	who manages
Ventersdorp															
Tlokwe															
Klerksdorp															
Wolmaransstad															
Stella															
Vryburg															
Taung															
Christiana															
Schweizer-Reneke															
Delareyville															
Ottosdal															
Lichtenburg															
Zeerust															

APPENDIX B

Percentage of Indicators that are on the Six Tools and are on SAWIS Template

Indicators on SAWIS template	Waste information collection tools in municipalities						Information present on the six tools
	Daily Waste Report	Volume Report	Waste Collection Schedule	General Waste: Municipal Trucks	Waste from Public to Landfill	Monthly Waste Report.	
Vehicle Number	1	1	0	0	0	0	1
Vehicle Type	0	0	0	0	0	0	0
Cubic meters of vehicle	0	0	0	0	0	0	0
Number of load	0	1	0	1	0	0	1
Type of waste	1	1	0	1	1	0	1
Density kg/m ³	0	0	0	0	0	0	0
Tonnage	1	0	0	0	0	0	1
Total waste/day	0	0	0	0	0	0	0
Date	1	1	1	0	0	0	1
Name of landfill	1	1	0	0	0	0	1
Total count (yes/no)							Yes= 6 No= 4
Percentage (%) (yes/no)							Yes= 60 No= 40
1= tool also has it 0= Tool does not have it							

APPENDIX C

Number of completed and blank indicators on waste information collection tools

Indicators on collection Tool	Gaps on the collection tool
Document number	0
Date	1
Page number	0
Vehicle registration	1
Company name	1
Tonnage	0
Waste categories	1
Name of person	1
Time in out	1
Number of trips	1
Number of bags	1
Source of waste	1
Type of waste	1
Loads of waste	1
Number of households	1
Class of waste	0
Total count (indicators)	16
Percentage (%) (gaps/no gaps)	Gaps= 25 No Gaps= 75
1= Yes	0= No

APPENDIX D

Facilities and their status on information collection at different levels of the waste chain and submission to SAWIS

Status of Information	Waste Facilities in the Study Area						
	Landfills	Recycling	Transfer station	Buyback	Composite	WtE	HH
Collect	1	1	0	1	1	0	0
Collect and report	1	0	0	0	0	0	0
1= Yes	0= No						