Perceptions on the adoption or use of waste to energy (WtE) technologies among waste managers in Gauteng

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ABSTRACT

The Gauteng Province, increase in population growth, urbanisation, industrialisation and economic activity has resulted in increased amounts of generated municipal solid waste (MSW). There are concerns about landfill airspace depletion, energy poverty, environmental concerns that create greenhouse gases, air pollution and water contamination. The province also requires electricity to keep its economic activity functional, while providing its citizens with electricity.

The research is a qualitative study, with the purpose of understanding how waste managers in the waste industry perceive the adoption or use of waste to energy (WtE) technologies in Gauteng.

Semi-qualitative interviews were held, face-to-face and on Microsoft Teams. The sample chosen were waste managers who were knowledgeable on the research topic. Thematic analysis was used to analyse the data from the semi-qualitative interviews. Data triangulation was used to establish the credibility/validity of the interview findings.

The findings in the study from the semi-qualitative interviews and literature review were aligned with regards to the role waste managers' play in procuring waste to energy technologies as well as the benefits on the uptake of WtE technologies, which are improved waste management practices, less environmental challenges and the introduction of new revenue streams. Waste managers are also viewed as researchers, collaborators and educators.

The study found that some of the factors that influence the perceived ease of use as well as perceived usefulness of WtE technologies include the feasibility and affordability of these technologies, access to finance, the availability of technical, training and skills transfer, potential employment opportunities and the need to diversify the energy supply

The challenges observed by the participants were the lack of stakeholder engagement and sufficient education, lack of adequate legislature and poor governance as well as lack of access to capital. The enablers were noted as equipment tax returns, introduce landfill tax, high landfill entry gates, energy sales, carbon credits as well as educating and involving all waste generators and recyclers.

To attract investors, participants noted that there should be transparency and simplified contracts, having relevant collaborations, the need for grants and assurance on return on investment

KEYWORDS

Gauteng, Waste Managers, Waste to Energy technologies, Energy, Technology Acceptance Model, Waste Hierarchy

DECLARATION

I, __INGRID MOKGOLOBOTHO__________________________, declare that this research report is my own work except as indicated in the references and acknowledgements. It is submitted in partial fulfilment of the requirements for the degree of Master of Management in …ENERGY LEADERSHIP…………… at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination in this or any other university.

Name:	Ingrid Mokgolobotho	Signature: IM

Signed at …………Edenvale…………………………………………

On the …………27…………….. Day of …………February……………… 2024

DEDICATION

My research is dedicated to my family, Mosima Mokgolobotho (Mother) and Molefe Mokgolobotho (Brother). A special dedication goes to my Father, Makabane Mokgolobotho who kept me motivated throughout my degree. To my nephews and nieces, I hope this degree inspires you to want to reach all your goals

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My cousin Makabane Mokgolobotho who helped with the editing of my research report, you attentiveness and patience in ensuring I have a well presented document did not go unnoticed.

I would also like to acknowledge my colleagues and the participants of my research study for making the time to sit with me and sharing your knowledge. I truly appreciate it

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LIST OF ACRONYMS

AD	Anaerobic digestion
GHG	Greenhouse gases
CAPEX	Capital Expenditure
CoE	City of Ekurhuleni Metropolitan Municipality
CoJ	City of Johannesburg Metropolitan Municipality
CoT	City of Tshwane Metropolitan Municipality
DIT	Diffusion of Innovation Theory
ETAM	Extension of Technology Acceptance Model
IPCC	Intergovernmental Panel on Climate Change
IRP	Integrated Resource Plan
PPP	Public-Private Partnership
IM	Igbaria's model
LFGE	Landfill gas extraction energy
MM	Motivational Model
MSW	Municipal solid waste
MPCU	Model of PC utilisation
NGO	Non-governmental organisation
OECD	Organisation for Economic Co-operation and Development

OPEX	Operating Expenditure
PESTEL	Political, Economic, Social, Technical, Environment and Legal
ROI	Return on Invest
TRA	Theory of Reasoned Action
WtE	Waste-to-energy
SCT	Social Cognitive Theory
SA	South Africa
SDG	Sustainable Development Goal
UN	United Nations
US	United States
UTAUT	Unified Theory of Acceptance and Use of Technology
TAM	Technology Acceptance Model
TPB	Theory of Planned Behaviour

CHAPTER 1. INTRODUCTION

1.1 Purpose of the study

This research is a theory based qualitative study, with the purpose of understanding how waste managers perceive the adoption or use of waste to energy (WtE) technologies in Gauteng. The definition of ‘perceive’ in the context of this study’ is based on the understanding of waste to energy (WtE) technologies by the professionals in the waste industry and the challenges and enablers related to the adoption of WtE technologies.

1.2 Context of the study

This research focuses on the waste industry in the Gauteng province, the adoption of waste to energy technologies in the sector and how these technologies are perceived by waste managers.

Overpopulation, industrialisation and urbanisation have increased the pressure on urban infrastructure and services, thus making the management of waste in present day more challenging (Mbazima, Masekameni, & Mmereki, 2022).

The management of waste in South Africa is one of the many challenges faced by the government and environmental practitioners. The mismanagement of waste poses various socio-economic risks, which can lead to negative impacts on human health and the environment at large. The mismanagement of waste generates heavy metal pollution which affects water, soil and plants(Ferronato & Torretta, 2019). Open burning of waste causes air pollution by releasing carbon dioxide and carbon monoxide among other gases(Ferronato & Torretta, 2019), while the toxic chemicals and dust can cause respiratory diseases, congenital and reproductive disorders and possibly cancers (de Titto & Savino, 2024).

This challenge is more evident in developing countries due to the lack of institutional and policy framework, technical and financial capacity (Dlamini, Simatele, & Serge Kubanza, 2019).

The Effects of fossil fuels as an energy source has caused global climate changes and there are also shortages in the availability of energy sources as well as conflicts around energy sources has prompted the need to diversify the energy mix (Kothari, Tyagi, & Pathak, 2010).

Landfill airspace is also becoming a limited resource, a lack in improving current waste management techniques, bottleneck in the collection, disposal and overall waste management as well as deteriorating infrastructure have added to the challenges experienced in the waste management sector (Mbazima et al., 2022).

Landfills have been regarded as a contributor to anthropogenic climate change accounting for approximately 5% of GHG emissions(Zhang, Xu, Feng, & Chen, 2019). South Africa is regarded as the 12th largest emitter of greenhouse gases and the waste sector contributes 2 – 4.3 % of national greenhouse gas emissions (Mbazima et al., 2022). According to the Intergovernmental Panel on Climate Change (IPCC) (Lee et al., 2023), greenhouse gases are the cause of global warming and the effects of global warming are known to be extreme floods, droughts, fires and a rise in sea temperatures.

The production of landfill gas is caused by microorganisms in landfills that breakdown waste in anaerobic conditions. The gas mainly comprises of methane, carbon dioxide, nitrogen, ammonia as well as non-methane organic compounds. Other known effects of the production of landfill gas are bad odours, low air quality as well as human and animal health impact (Mbazima et al., 2022).

Overtime waste has been viewed as a resource that can contribute to sustainable development, based on the 5Rs (reduce, re-use, recover, recycle and refuse) of sustainable developments. Waste generation and management are directly related to goal 11 (Sustainable cities and communities) 12 (Responsible consumption and production) and 13 (Climate Action) of the UN sustainable development goals SDGs (UN, 2015). Converting waste to energy can be seen as one of the solutions that can explored to improve waste management services, whilst promoting clean air and generating energy.

There are three types of WtE technologies (Khan, Chowdhury, & Techato, 2022):

- Thermochemical – Incineration, gasification and pyrolysis
- Biochemical – Fermentation, anaerobic waste, landfill with gas capture, microbial fuel cell
- Chemical - Esterification

It is estimated that there are around 800 thermal waste to energy projects that are being run in almost 40 countries globally and that 11% municipal solid waste has been used to generate around 429 TW/h of power (Dlamini et al., 2019).

Investment in WtE technologies as well as the implementation of the correct institutional policy frameworks can have a major impact in the implementation and research of using waste as a source of energy in the province considering the current environmental, economic and social concerns around energy.

The Gauteng province is divided into three metropolitan municipalities (City of Ekurhuleni (CoE), City of Tshwane and City (CoT) of Johannesburg (CoJ) and two district municipalities (Sedibeng district municipality and West Rand district municipality).

The province generates 45% of municipal solid waste (MSW) and is producing the highest waste per capita in South Africa (Mbazima et al., 2022). The province is still highly dependent on landfilling to manage waste. The government in the province has been seeking practical measures to improve the current state of waste management. Several landfill gas to energy (LFGE) projects have been implemented in the province around the CoE, CoT, CoJ to diversify the energy mix and transition to a green economy(Mbazima et al., 2022). The progress and contribution of LFGE projects into the electricity grid has not been fully evaluated.

The slow adoption of these interventions has been due inadequate policies, lack of data on waste, high capital and maintenance costs, limited knowledge and technical ability, poor research and development, cheap and affordable coal and low landfill tax (Mbazima et al., 2022).

1.3 Research problem

There is a shortage of sustainable energy sources, lack of landfill airspace in Gauteng, methane gas emissions from landfills and lack of innovation with regards to treating waste (Mbazima, Masekameni, & Mmereki, 2022). The exploration and development of WtE technologies might be a viable route to take in Gauteng. The research investigates how waste managers perceive the adoption of waste to energy technologies in South Africa.

The uniqueness of this research is that it will assist in understanding the low uptake of WtE technologies. The chosen people that participated in the study, have a broad understanding on the waste and energy industry in Gauteng, how it operates and the legislation that govern the sector. They offered a view on how the industry would feel about the introduction of WtE technologies and this would likely have an impact on the adoption or non-adoption of these technologies in Gauteng as well as the impacts there-of.

1.4 Research questions

1. What is the role of waste managers in advancing WtE technologies in waste management in Gauteng?

2. What are waste manager’s opinions on the ease of operating WtE technologies and the perceived usefulness of WtE technologies?

3. What do waste managers think the challenges and enablers would be, with regards to the implementation of WtE technologies in Gauteng?

1.5 Significance of the study

The uniqueness of this research is that it will assist in understanding the perceptions of waste managers, with regards to the adoption of WtE energy technologies. The chosen people that participated in the study, have a broad understanding on the waste and energy industry in Gauteng, how it operates and the legislation that govern the sector. They offered a view on how the industry would feel about the introduction of waste to energy technologies and this would likely have an impact on the adoption or non-adoption of these technologies in Gauteng as well as the impacts there-of. Apart from waste managers, the energy sector, researchers, investors, policy makers, authorities the communities and public, non-governmental organisations (NGOs,) urban planners, waste generators and sorters are likely to benefit from the findings of this study.

The uptake of WtE technologies will assist in the management of waste, improve health and environmental challenges related to the mismanagement of waste and contribute to the diversification of the energy mix (Mbazima et al., 2022).

1.6 Delimitations of the study

The study is to understand the perceptions of waste managers on the adoption and use of waste to energy technologies in the industry within Gauteng

The delimitations of the research study are:

i) The study is limited to a small group of professionals in the waste and energy sector.

ii) Only waste managers with a technical and technical sales background are to be interviewed.

1.7 Definition of terms

Landfill: A site located to dispose of waste designed and equipped to limit harm to the environment (Young, 2010).

Municipal solid waste: waste “garbage generated from households, commercial business and schools”(Young, 2010).

Technology Acceptance Model: “explains the motivation of users by three factors: perceived usefulness, perceived ease of use and attitude toward use (Taherdoost, 2018).

Waste Management: it is a process of managing waste through the collection, recycling, re-using, reducing and disposal of waste (Reno, 2015).

Waste-to-energy: generation of energy from MSW conversion by either biological or thermal technologies(Taherdoost, 2018).

1.8 Assumptions

The following assumptions were made about the study

a) The participants reflected their normal perspectives and experiences.

b) The participants were co-operating while the study was conducted.

c) The participants were truthful and gave information according to their knowledge.

1.9 Structure of the Report

This research report made of six chapters which are as follows:

1. CHAPTER 1: This chapter gives an outline of the purpose of this study while giving the reader context to the topic. It discusses the study purpose, the context of the study, research problem, research questions, and significance of the study delimitations and assumptions.

2. CHAPTER 2: This chapter analyses the literature on the subject where the crucial terms and concepts regarding the study are elaborated. The chapter includes the theoretical framework of the study. At the end of the literature, review, propositions are stated as possible answers to the research questions presented in Chapter 1.

   CHAPTER 3: This is chapter outlines the methodology followed in this study, it describes the approach where the research questions of the study were addressed and how the data was analysed. The areas covered include research approach, research design, data collection method, population and sample, research instrument, the procedure for data collection, data analysis and interpretation, limitations of the study, and ethical considerations.

3. CHAPTER 4: This chapter presents the research findings from the data collected on the semi-structured interviews from various experts sampled based on a purposive sampling approach. Data is analysed by the generation of initial codes, followed by categorisation of codes which gives rise to the various themes.

4. CHAPTER 5**Error! Reference source not found.**: This chapter discusses findings of the qualitative study within the context of the literature review conducted in Chapter 2, integrated with the findings in Chapter 4.

5. CHAPTER 6: This chapter integrates findings of the propositions into the original research questions in Chapter1, responding to each research question.

CHAPTER 2. LITERATURE REVIEW

2.1 Introduction

The research is a qualitative study with the aim to understand how waste managers in Gauteng perceive the adoption of WtE technologies.

This chapter mainly focuses on the literature of this subject. First the background on the evolution of energy and waste management to present day is given. The global waste composition as well as the evolution of WtE technology patterns globally, in Africa, South African and Gauteng context are explored. The sections that follow look into -

- Types of WtE technologies that are available to divert away from landfilling
- Challenges with the adoption of WtE technologies
- Challenges and enablers with the implementation of WtE technologies
- Consequences of not introducing WtE technologies in waste management

The last section is the theoretical context of the study which explains the technology acceptance model (TAM) is presented in this chapter.

2.2 The Evolution of Energy

Humanity has always struggled to attain and use energy for their basic needs such as food, warmth and shelter. Energy sources used since the dawn of civilisation range from the sun, wind, water, biomass, animal dung and fats, human and animal muscle and eventually fossil fuels(Solomon & Krishna, 2011)

The shift between the different energy sources has been mainly due to local resource availability or scarcity, cost, convenience, pollution, technical innovation, energy quality and storage (Solomon & Krishna, 2011).

The first major transition from using biomass to fossil fuels was driven by the British in the early 1700s. By the end of the 19th century, fossil fuels had become the primary energy source globally (Zou, Zhao, Zhang, & Xiong, 2016). The transition between the different energy sources happened at different time rates from 80 – 400 years ago. Rapid growth of cities such as Manchester, London, Liverpool and Birmingham encouraged the use of cheap coal as prices of wood was becoming too expensive to afford (Zou et al., 2016).

During the first industrial revolution in Britain, we see the first major use of coal as a primary energy source. Before then animal labour as well as wind and water were used to generate energy and by the 11th century the use of watermills and windmills started to decrease across Britain (Mokyr, 2018).

The industrial revolution saw the development and use of the steam engine. Steam pumps were first developed to assist in the coal mines in the 1600s. The development and further improvement of steam engines that used coal allowed for increased mechanisation of the industry and a revolution in the transport sector (Mokyr, 2018).

Coal mining also transitioned from the use of charcoal to coke to smelt iron ore in blast furnaces.

Fossil fuels were the major driver of technological, socio-economic development during the industrial revolution and this drove urbanisation, commerce and technological innovation (Mokyr, 2018)

In the 20th century internal combustible engines started to replace the use of steam engines, due to the big size of the steam engines as well their inefficiency making them unsuitable to be fast on the road (Mokyr, 2018)

The discovery and use of liquid fuels to fire engines also drove the change in the landscape of the automobile industry in a major way

Until 2017, fossil fuels (coal, gas and oil) were the major primary energy sources and in recent years have become the major source of greenhouse gases emissions which have led to challenges in climate change (Mokyr, 2018).

In the 21st century, to combat climate change, the energy sector is going through another transition from a centralised carbon intensive energy systems to decentralised renewable energy systems as well as technologies which are energy efficient and have sufficient storage systems(Rohit et al., 2023). Renewable energy sources such as solar, wind and geochemical energy has been seen as solutions for sustainable energy development (Rohit et al., 2023). Renewable energy is intermittent, therefore to make the technologies viable, efficient energy storage is required. Energy storage solutions have also been evolving but are still considered expensive (Ma et al., 2023).

2.3 The evolution of waste management

Newly discovered energy sources led to increased urbanisation and industrialisation the cities. This led to people going to cities for job and business opportunities to improve their living standards (Dlamini et al., 2019).

Due to the rise in population, urbanisation and industrialisation, Municipal Solid Waste (MSW) generation increased, it led to MSW systems being put into place. Dirty water, air and soil yielded germs and this pressured town administrators to put into place systems that could ensure citizens were supplied with clean water and sewerage systems (Dlamini et al., 2019).

By the 19th century formal collection and disposal on solid waste started to happen. Newer challenges in the management of waste started to occur and the authorities started to impose regulations that restricted waste to be disposed only at designated locations (Young, 2010). The first waste regulations were formulated in the United States (US) by the Federal Government in 1929, whereby the disposal of waste in rivers was prohibited (Young, 2010).

Overtime there was increased concern that landfills would soon fill up and land to construct these landfills would also become a restriction due to rapid urbanisation.

In the 21st century, waste managers is a critical public service mostly in a heavily populated areas although it remains a low priority in some countries(Maalouf & Agamuthu, 2023). In recent years, waste disposal challenges, environmental and health challenges have led to solid waste management systems supported by waste regulations and the waste hierarchy (Awino & Apitz, 2024). Figure 1 shows the waste hierarchy which outlines the preference on how waste should be managed, with prevention being the most favourable manner to manage waste to disposal being the least favourable (Kumar & Samadder, 2017).

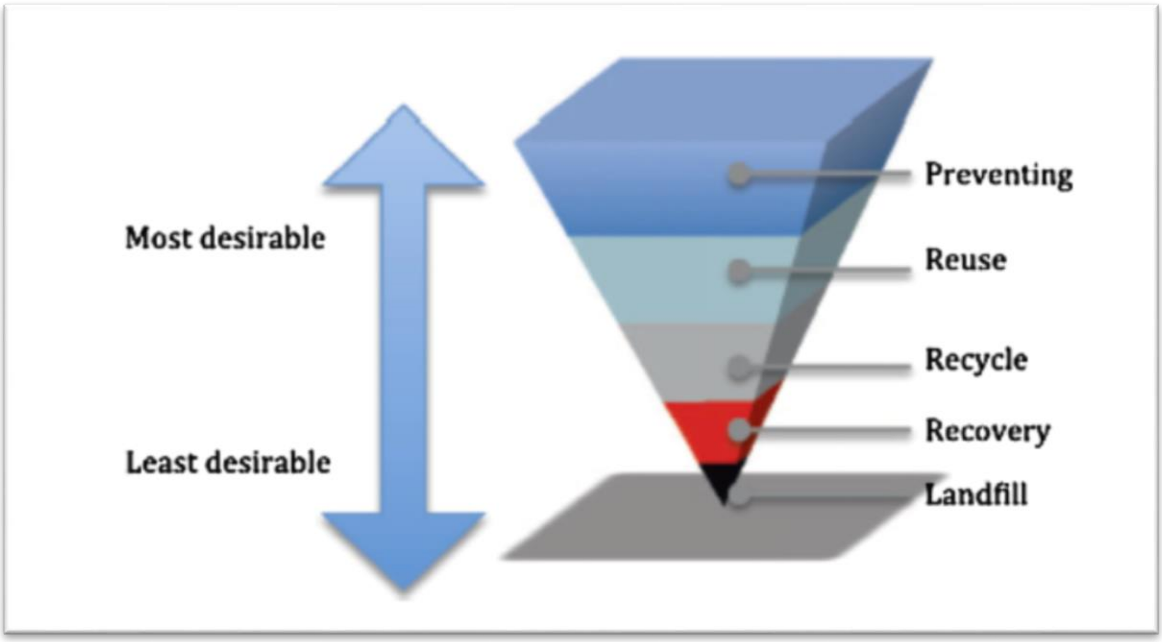

Figure 1. Diagram of the Waste Hierarchy (Kumar & Samadder, 2017)

2.4 Global Waste Composition

Increased economic waste activity world-wide as well the increase in the global population has caused the increase of MSW generation from about 300 000 tonnes of waste in 1900 to 3 000 000 tonnes in the 2000s and this number is estimated to double in 2025 (Pham, Kaushik, Parshetti, Mahmood, & Balasubramanian, 2015).

Waste generation is different between regions, economic activity and development, time and social activities (Pham et al., 2015), and the composition of waste is impacted by sources of material, climate, geographical location and cultural norms (Pham et al., 2015).

In sub-Saharan Africa waste generation was 81 million tonnes of waste per year, but the number is low compared to China which generated 720 million tonnes of waste per year. The Latin America and Caribbean generated 160 million tonnes of waste, while North Africa and the Middle East generated 63 million tonnes of waste (Pham et al., 2015). The OECD nations generated around 572 million tonnes and most of the waste has been generated from commercial and household activities (Pham et al., 2015). Figure 2 shows the waste composition of countries around the world.

Forecasting indicate that by 2030, waste generated globally is expected to increase to 28 billion tonnes of total waste yearly and by 2050 total waste generated is expected to increase to 46 billion tonnes(Allesch & Huber-Humer, 2023).

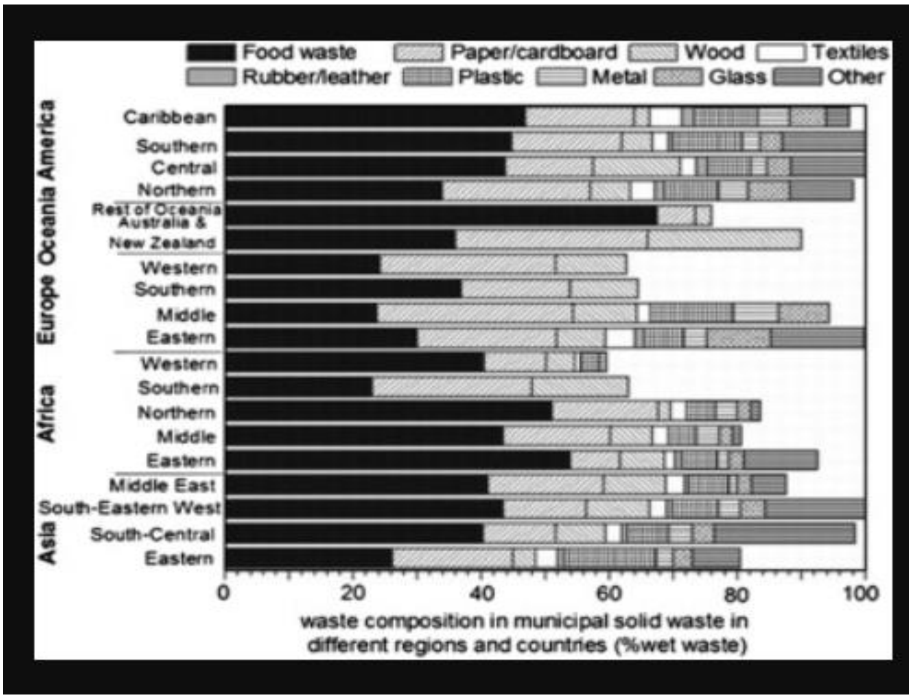

Figure 2 depicts global municipal waste composition (Pham et al., 2015)

2.5 The Evolution of Waste to Energy Patterns: Global, African and South African

2.5.1 The Global Context

In both developing and developed countries there has been an increase in MSW generation and MSW is responsible for pollution air pollution and pollution water bodies to name a few and this has cause a strain in sustainable development.

Developed countries are responsible for the large number of MSW generation, this has been due to increased economic activity, urbanisation and population growth. This has caused infrastructural constraints and therefore a limit in airspace availability (Makarichi et al., 2018).

In Europe to deal with MSW, an integrated approach which includes the waste hierarchy and the life-cycle assessment (which is a cradle to grave analysis technique that assesses environmental impacts associated with all stages of a product's lifecycle) is being implemented (Castillo-Giménez, Montañés, & Picazo-Tadeo, 2019).

There are major differences in the level of specific waste treatment from country to country. The differences are mainly in the amount of waste being treated, consumption patterns, economic development and the organisation and management of municipal waste collection.

Figure 3 gives an overview of 28 European Union (EU) countries and how they treat MSW. The average of each operation is as follows (Castillo-Giménez et al., 2019) –

Landfilling – 25.1%, Incineration – 28.1%, Recycling – 30.1%, Composting and Digestion – 16.7%

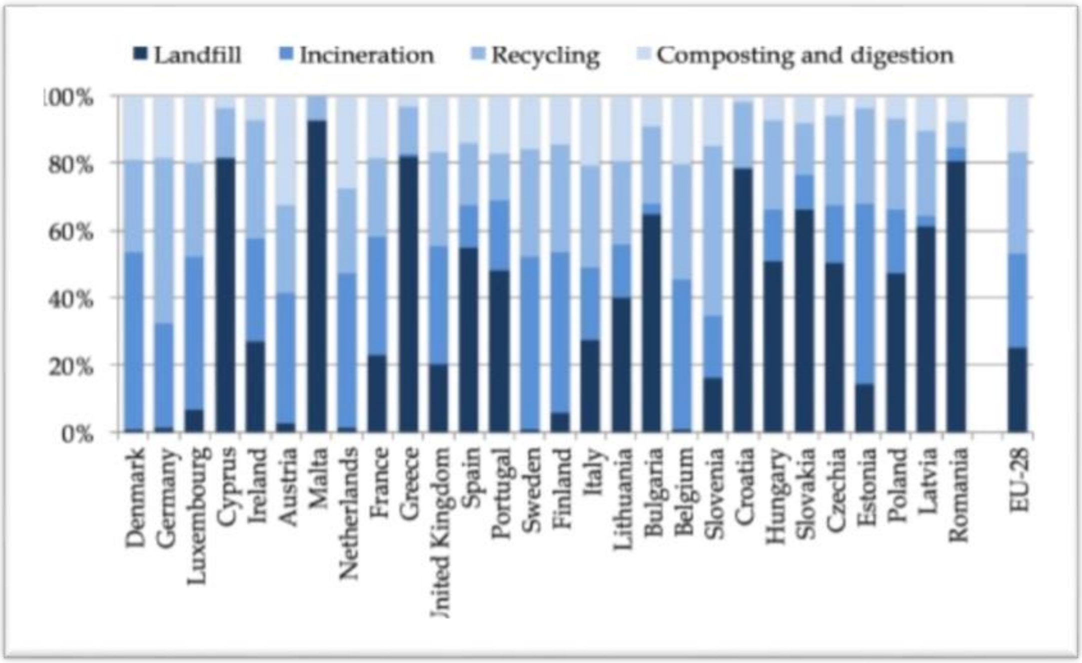

Figure 3 depicts municipal waste treatment by type of operation in the UE-28 member states (Castillo-Giménez et al., 2019)

Sweden and Denmark have shown low landfilling rates and high incineration rates in the EU. The highest landfilling rates with low incinerates rates has been found in countries like Malta, Greece, Cyprus and Romania and this is due to having low numbers of incineration infrastructure and poorly developed collection and recycling facilities.

In the US, 77% of WtE facilities have onsite metal recycling projects. The metal is recovered post combustion from the bottom ash. Other recyclables such as plastic, non-ferrous metals, glass are recovered and ash which can be used in the construction of roads (Castillo-Giménez et al., 2019)

Japan has the most WtE technology units in the world, the number is 1900, while other countries in Asia like India, Malaysia and the Vietnam are only deploying their WtE projects (Awasthi et al., 2019)

2.5.2 The African Context

In Africa, the adoption of WtE technologies has been slow and this is due to challenges in acquiring capital, technical knowledge and skill required to run WtE plants and lack of data on potential feedstock for energy recovery (Makarichi, Kan, Jutidamrongphan, & Techato, 2019).

There has only been a few cases recorded of co-generation in South Africa and Namibia and landfill gas to electricity in Mauritius and South Africa. Cameroon has managed to recover and flare bio-methane from MSW. Ethiopia, Addis Ababa has the first promising MSW incineration plant, which was commissioned in 2018 and has an installed capacity of 20 MW (Makarichi et al., 2019).

2.5.3 The South African Context

The case of South Africa just like many other countries around the world, rapid population growth, migration to urban areas and industrialisation has contributed to an increase in waste generation.

This has put a lot of pressure on municipalities to provide efficient waste services. But the South African waste sector has been flooded with a range of challenges ranging from the lack of financial resources, weak institutional and policy frameworks and a deteriorating waste management infrastructure among others (Dlamini et al., 2019).

The management of waste through WtE technologies has been put forth as one of the alternatives in dealing with waste management while promoting clean cities through the recovery of waste and the generation of energy. But little attention has been put into the research of WtE technologies to advance MSW management in S.A and to benefit from it.

It is suspected that the slow introduction of WtE technologies in SA has been due to the lack of funding, lack of policy, data on waste sources and lack of technical know-how among other challenges (Dlamini et al., 2019).

SA generated 108 million tonnes of waste in 2011 and 59 million tonnes of that waste was MSW, only 10% of that waste was recycled, the rest was diverted to landfill sites and this number is expected to increase (Mabalane, Oboirien, Sadiku, & Masukume, 2021).

There are a few landfill gas to energy extraction plants (LFGE) and biogas plants that are operational in this country.

Durban – Marianhill landfill site and Bisasar road are LFGE plants that have a combined capacity of 7.5 MW (Sangham, 2017).

Cape Town – New Horizon produces biogas (Surroop, Bundhoo, & Raghoo, 2019).

Grabouw – Elgin fruit juices biogas facility produces around 0.5 MW of energy output (Surroop et al., 2019).

Morgan Springs Abattoir – produces biogas with a 0.4 MW capacity (Surroop et al., 2019).

2.5.4 The Gauteng Context

Figure 4 shows a map of the Gauteng province which is divided into three metropolitan municipalities (City of Ekurhuleni (CoE), City of Tshwane and City (CoT) of Johannesburg (CoJ) and two district municipalities (Sedibeng district municipality and West Rand district municipality). The usage of WtE technologies to manage waste has not been fully explored, but there a few LFGE projects that have been implemented in the metropolitan municipalities.

2.5.4.1 The City Of Johannesburg (CoJ)

It is estimated that by the year 2023, municipal landfill airspace in the CoJ would be depleted and the GHG emissions above threshold limits. This has prompted the city to implement LFGE plants to improve environment and public health. In 2016, there were 5 LFGE projects implemented with a total potential energy output of 19 MW. The commissioned projects are Ennerdale, GoudKoppies, Linbro Park, Robinson Deep and Marie Louise. The site operating is Robinson Deep (Mbazima et al., 2022).

The City of Johannesburg (CoJ) conducted a feasibility study in 2017, the report was released proposing an alternative waste treatment solution (City of

Johannesburg, 2017). The solution is to include two metal recovery facilities (MRF) at the Marie Louise landfill site and Robinson Deep landfill site. Waste not recovered from the MRF would be channelled to the 25 MW landfill site at Robinson Deep (City of Johannesburg, 2017). The two landfill sites were chosen to be part of the project because of the availability of waste in the central belt and the potential of the project to grow, the urgent need to divert waste away from the two landfill sites and the fact that there is existing infrastructure and land that could benefit the project (City of Johannesburg, 2017).

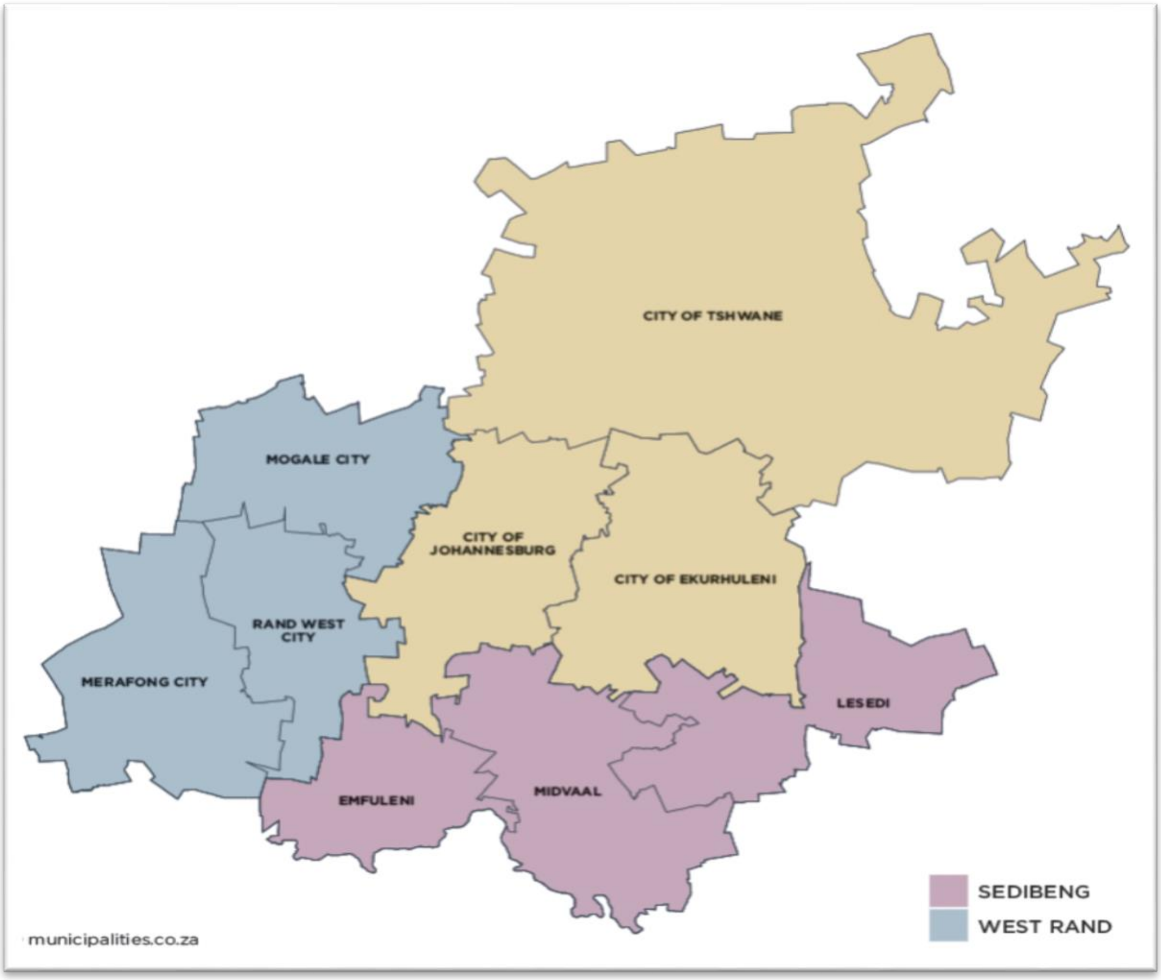

Figure 4 shows a map of the Gauteng Province (Cartography unit, 2019. School of Geography and Environmental Studies)

2.5.4.2 City of Ekurhuleni (CoE)

The CoE identified 4 flagship LFGE projects which are Rietfontein, Rooikraal, Weltevreden and Simmer and Jack(Seshweni, 2021).

The aim of these projects is to produce electricity from landfill gas, this is to reduce the municipality's dependence on Eskom(Seshweni, 2021).

Simmer and Jack is operational, while the 3 other sites are at the implementation phase. The Simmer and Jack LFGE project was commissioned in 2014 with a planned capacity of 1 -2 MW. The project is currently supplying the municipal grid with energy but it's not operational at full capacity (Seshweni, 2021). There is also privately-owned project in the municipality and it generates 1.6 MW of electricity which is fed into the local grid (Mbazima et al., 2022).

2.5.4.3 City of Tshwane (CoT)

The CoT has over the years closed down several landfill sites. The sites include Onderstepoort, Temba, Kwaggasrand and Garstkloof among others (Manyana, 2021). The closure of these sites has caused a rise in illegal dumping. The CoT has been working on a plan to convert waste to energy. Kwaggasrand and Onderstepoort has been identified as sites where landfill gas in the form of methane is extracted to produce energy (Manyana, 2021). The information on the progress of implementation and operations of these projects is scanned.

The Bio2Watt biogas plant in Bronkhorstspruit was commissioned in 2015. The plant has a capacity of 4.6 MW(Surroop, Bundhoo, & Raghoo, 2019). The plant converts manure, abattoir waste, fruits and vegetables, dairy waste and paper waste to biogas using anaerobic digestion (AD) (Surroop et al., 2019). The gas is collected and harvested to drive gas turbines to produce electricity. The distribution of the energy is done by wheeling through the CoT and Eskom.

2.6 TYPES OF WASTE TO ENERGY TECHNOLOGIES THAT ARE AVAILABLE TO DIVERT AWAY FROM LANDFILLING

2.6.1 Waste to Energy Technologies

There are currently challenges with energy security and waste management in SA. Most of the waste is landfilled which has become an unsustainable practice due to the environmental and health challenges as well as the lack of airspace to build more landfill sites.

Alternative waste treatment technologies need to be looked into for the conversion of solid waste into energy. Mass burn incineration has been mainly suggested but there are other technologies to explore.

Below, Figure 5, is a diagram which gives information on the processes of WtE technologies and how electricity is generated in the process.

There are two types of waste to energy technologies for the conversion of solid waste (Khan et al., 2022):

- Thermal conversion – Incineration, gasification, plasma arc gasification and pyrolysis
- Biological conversion– landfill gas extraction and anaerobic digestion

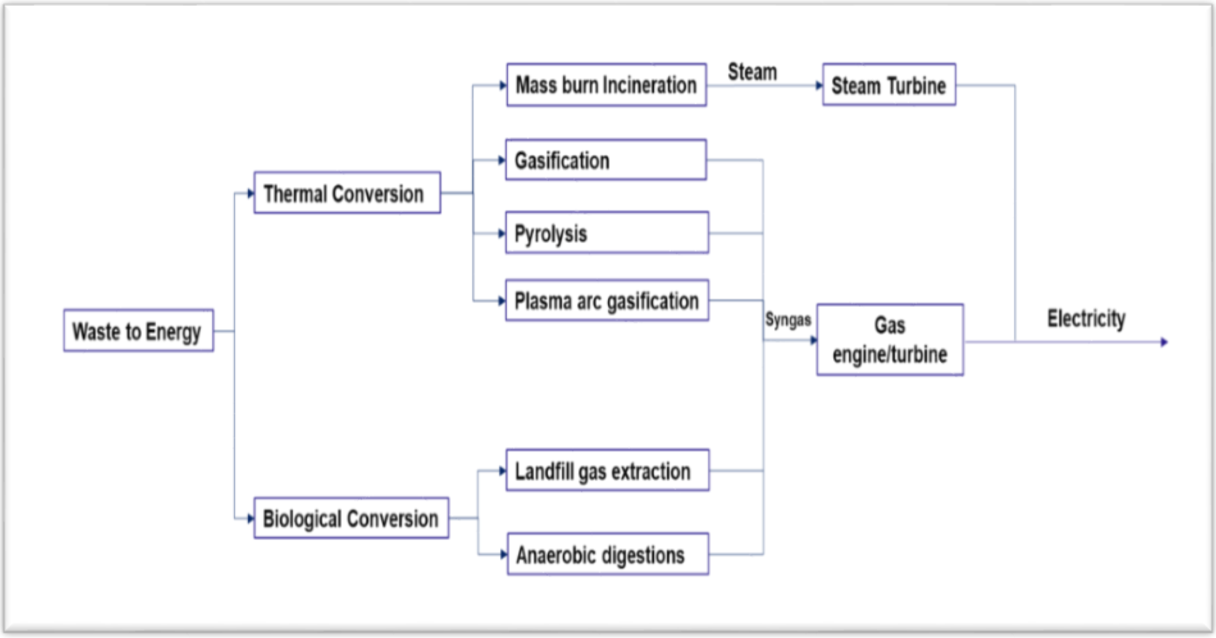

Figure 5 depicts solid waste conversion processes (Young, 2010)

2.6.2 Thermal technologies

2.6.2.1 Mass burn Incineration

It is a combustion process that utilises excess oxygen and/or air to burn MSW (Khan et al., 2022). The burning process only operates with excess oxygen present. Feedstock in the form of suitable MSW is pre-processed to separate recyclables (Young, 2010). The remainder of the waste is fed into the fluid bed boiler that operates at temperature between 1000 and 2200 Fahrenheit (Young, 2010). High pressure steam produced in the fluid bed boiler is sent for gas clean-up and the heat is sent to the power plant for the generation of energy(Khan et al., 2022). The power plants uses steam turbines and saleable excess electricity to produce electricity (Young, 2010). Below Figure 6 shows how electricity is generated through Mass burn incineration.

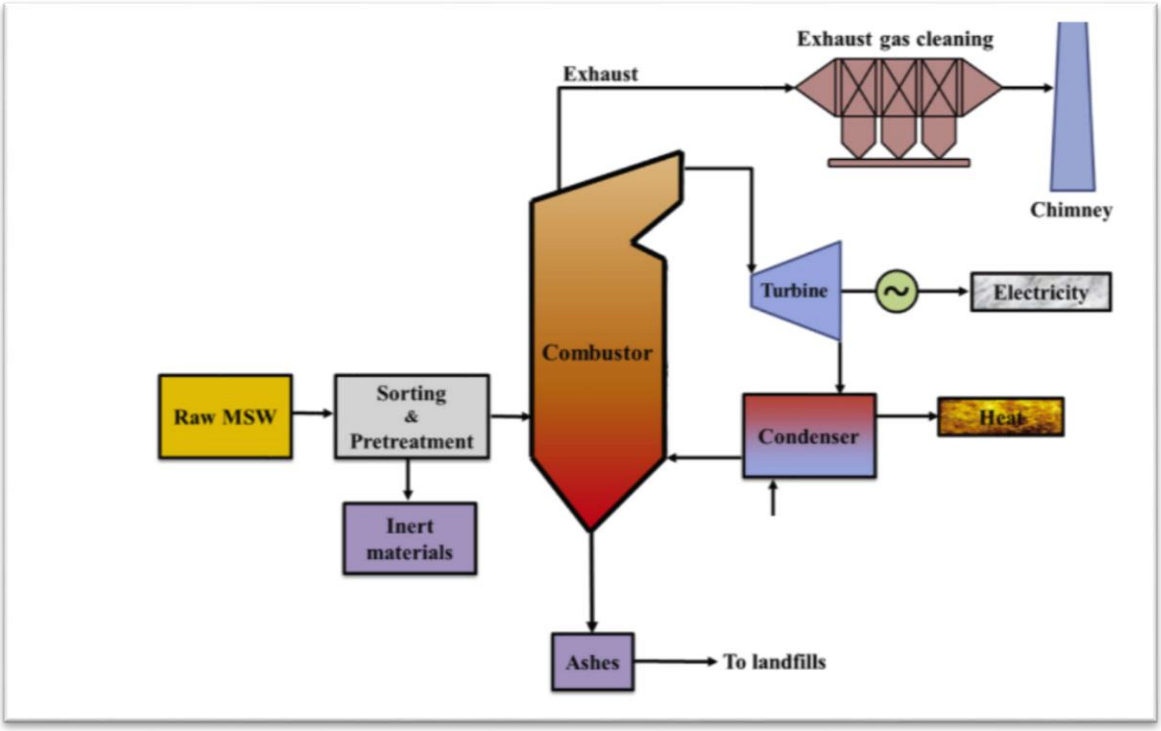

Figure 6, a schematic diagram showing the production of electricity through mass burn incineration (Chand Malav et al., 2020)

2.6.2.2 Gasification

Figure 7 shows how electricity is generated through gasification. It is a thermal process whereby carbon-based material such as MSW is converted to syngas in the presence of air and oxygen (Santos, Assis, Gomes, Nobre, & Brito, 2022). The conditions are around 1450 and 3000 Fahrenheit. Steam is injected into the gas reactor to produce carbon dioxide and hydrogen (Young, 2010). The raw syngas exits the reactor, it is cleaned of ash, metals and slag, it is then sent to a power generation plant to produce energy which is converted to electricity (Kamyab et al., 2022).

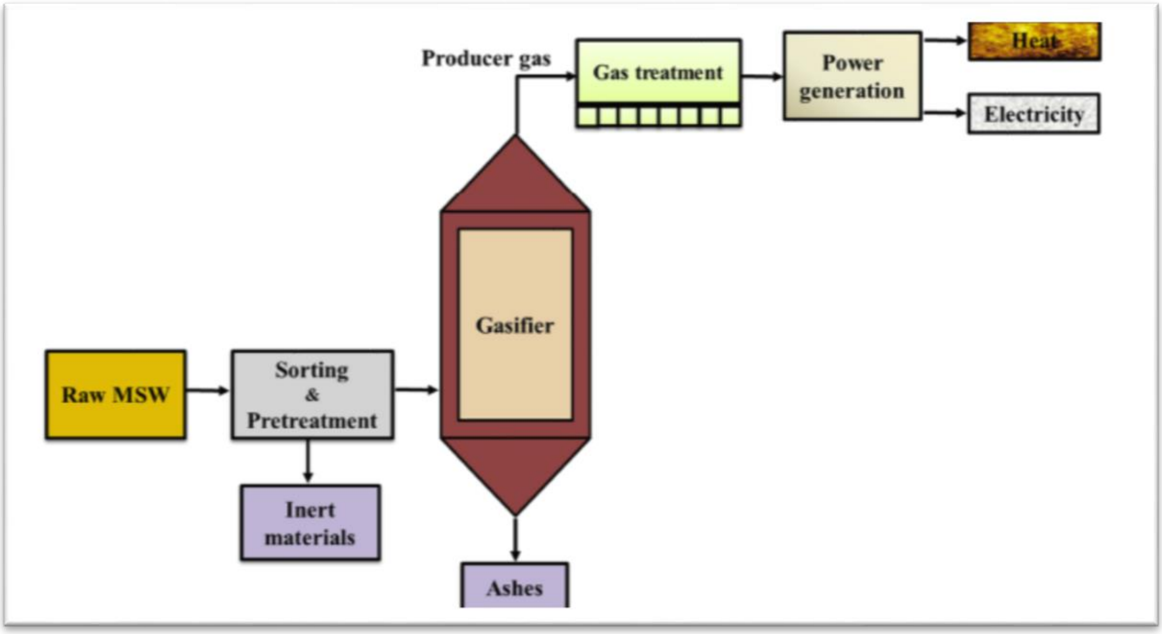

Figure 7, A schematic diagram showing electricity production through gasification (Chand Malav et al., 2020)

2.6.2.3 Pyrolysis

It is a gasification process whereby another reactor is added and extra carbon char/pyrolysis liquid produced from the initial pyrolysis step is further transformed to gas in the presence of air, oxygen and steam(Hasan, Rasul, Khan, Ashwath, & Jahirul, 2021). The combustion reactions are controlled to give sufficient heat to the pyrolysis yielding a temperature between 1400 – 2800 Fahrenheit. The syngas is then transferred to be used for electricity generation(Hasan et al., 2021). Figure 8 shows how electricity is generated through pyrolysis.

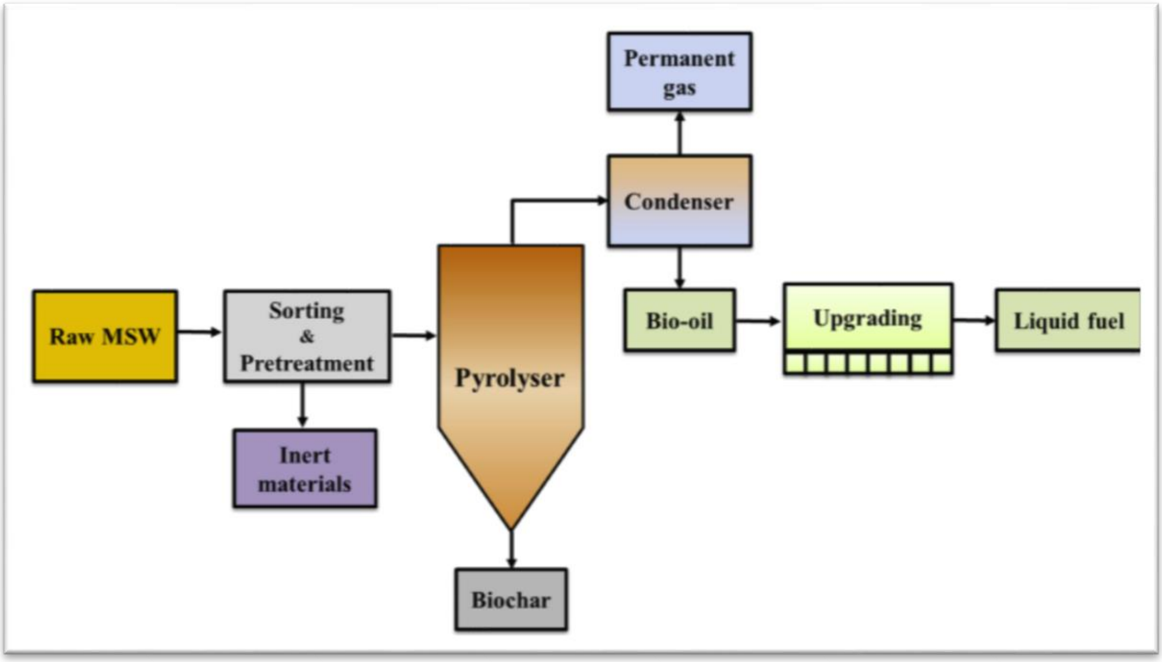

Figure 8 A schematic diagram showing the production of electricity through pyrolysis (Chand Malav et al., 2020)

2.6.2.4 Plasma arc gasification

Figure 9 shows the process of how electricity is produced from plasma arc gasification. This is a high temperature pyrolysis, produced by an electric arc in a torch whereby gas in converted into plasma(Yayalık, Koyun, & Akgün, 2020). Carbon based material is converted to syngas and inorganic material (Young, 2010).

The inorganic material produce a rock-like crystal by-product called vitrified slag. The process is typically operated 7200 – 12,600 Fahrenheit. The syngas produced from the plasma-arc gasification is then cleaned up and sent for power generation of electricity (Yayalık et al., 2020).

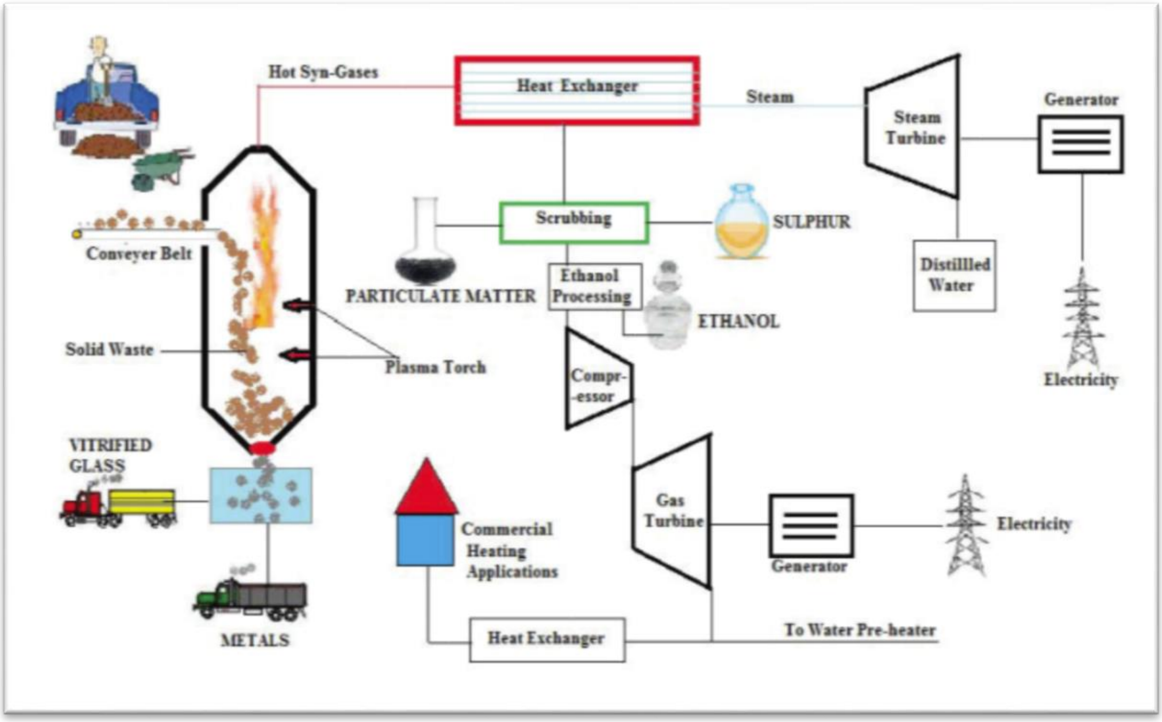

Figure 9 A schematic diagram showing the production of electricity through plasma arc gasification (Ojha et al., 2012)

Figure 10 that shows graph which depicts a study that compares the energy output of each technology. On the graph Plasma arc gasification gives the highest energy output of 816 kW/h from a ton of waste. Followed by Gasification, Pyrolysis then Mass burn incineration which gives the least energy output at 544 kW/h per ton of waste.

The most attractive technology would be one that has proper thermal efficiency, processes variety of different solid wastes, possess minimal pre-treatment/ sorting of solid waste(Young, 2010). The technology needs to be environmentally sound and should not produce a lot of by-product that will require landfilling. Capital as well as operating and maintenance costs should make financial sense for all parties involved.

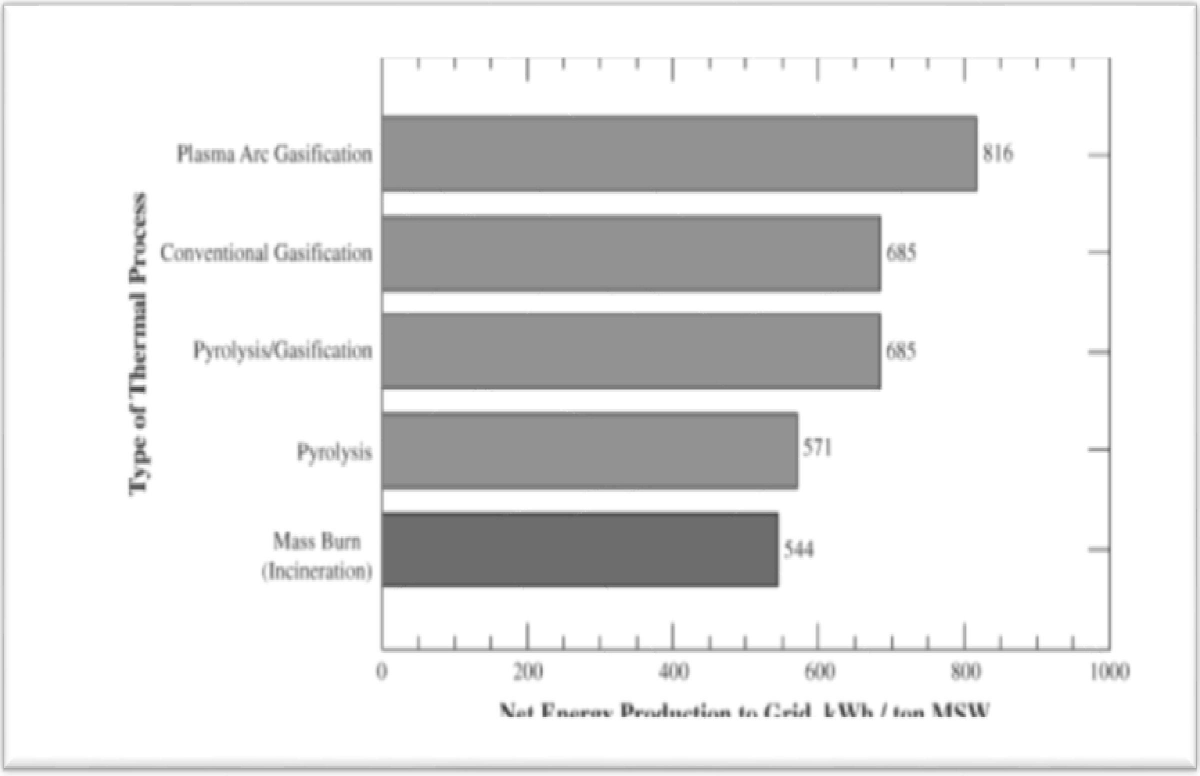

***Figure 10, Graph shows comparison of thermal processes net output of energy from processing MSW (Young, 2010*)

2.6.3 Biological technologies

2.6.3.1 Landfill gas extraction (LFGE)

Landfill gas is extracted from landfills through a series of wells, the gas is produced from the breaking down of organic MSW(Varjani et al., 2022). Landfill gas extraction wells and pipes need to present in the designated landfill cell. The extraction wells can be horizontal or vertical(Varjani et al., 2022).

Gas collected from the MSW, is done so at a central point, where it can be processed and treated. The processing skid has a condensate removal and heat exchanger(Varjani et al., 2022). Further treatment of the gas is required to remove excess moisture, particulates and other impurities. This is dependent on the physical and chemical properties of the gas and type of energy recovery system(Mukherjee, Denney, Mbonimpa, Slagley, & Bhowmik, 2020).

The gas is transferred to pipeline gas which is then transported to different end-user points(Mukherjee et al., 2020) as shown below in Figure 11.

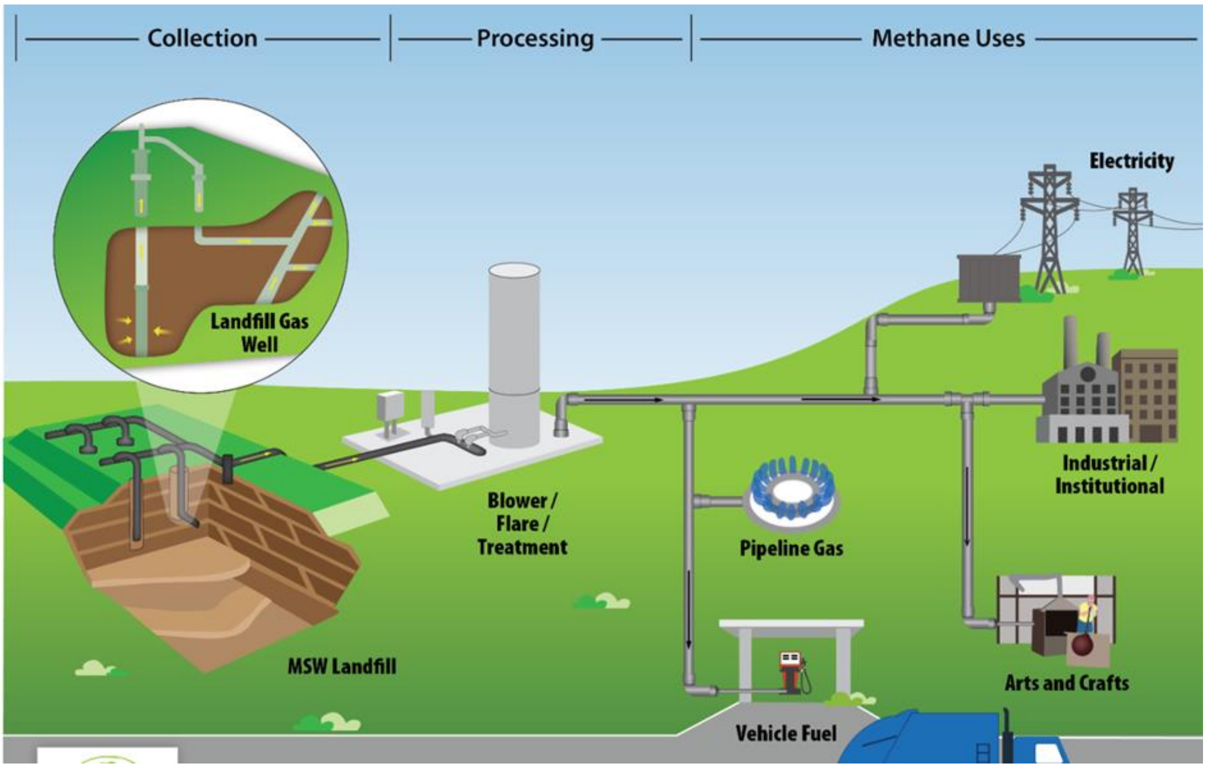

Figure 11, Illustrates the collection, processing and transport of landfill gas to produce methane for use (EPA, 2023)

2.6.3.2 Anaerobic digestion (AD)

Anaerobic digestion at landfill sites produces biogas which is mainly made up of methane, carbon dioxide and trace gases such as nitrogen, oxygen and hydrogen sulphide(Hussain, Mishra, & Vanacore, 2020). These are the gases which mainly escape into the environment. In controlled environments without oxygen, the same process has the potential to convert organic waste into biogas and nutrient rich fertilisers (Ali et al., 2020).

It is reported that 1 cubic metre of biogas from AD is equivalent to 21 MJ of energy, however there are challenges that come with AD, such as the long duration of microbial treatment of the waste, which typically takes 20 – 40 days and the release of free ammonia resulting from the breaking down of protein rich waste (Ali et al., 2020).

The main organic compounds broken down by microbes during AD are lipids, carbohydrates and proteins. There are four main physiologically different microbial groups involved in this process, which hydrolyse complex organic compounds to alcohols, organic acids, and short and long chain fatty acids (Di Maria, Sisani, El-Hoz, & Mersky, 2020).The secondary microbes oxidise the products to hydrogen and carbon dioxide.

Below Figure 12, shows the process of anaerobic digestion, The bio-waste / waste is pre-treated, then broken down by microorganisms in the bio-reactor, biogas is then release which can be used to produce energy as well as digestate(Di Maria et al., 2020).

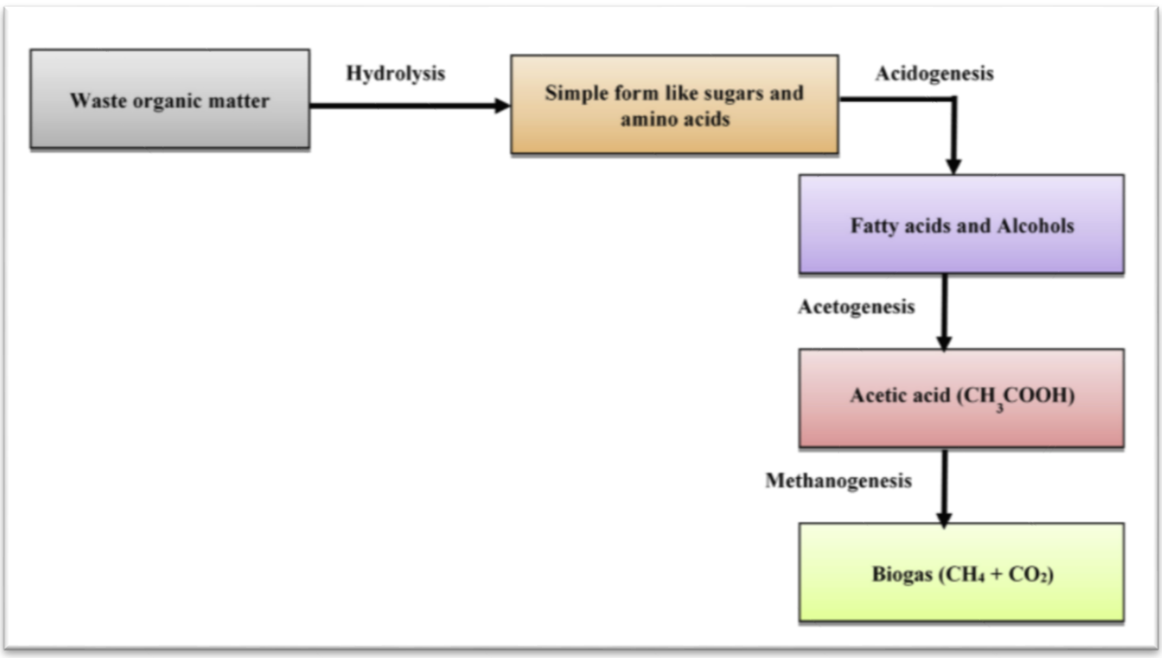

Figure 12, A Diagram of anaerobic digestion (Chand Malav et al., 2020)

2.6.4 Proposition 1

The role of waste managers is to responsibly develop and procure effective and efficient recycling, recovery and disposal of waste methods that meet service standards in accordance to policy, legal compliance and best practice

2.7 CHALLENGES WITH THE ADOPTION OF WtE TECHNOLOGIES

The adoption of WtE technologies is also socially orientated process in which individuals' perception plays a vital role (Kardooni, Yusoff, & Kari, 2016). The perceived usefulness of the technology as well as the ease of use will be mainly determined or influenced by the stakeholders' views on policies, current and previous knowledge on the technology, beliefs, values and interests (Williams et al., 2023).

In an environment where there is an interest to introduce a new technology, it should be noted that different stakeholders involved in the project will have different objectives. This is a challenge that will usually complicate the adoption of new technologies (Lu et al., 2023).

The technology acceptance model (TAM) can be used to determine the degree of user's acceptance of WtE by observing the perceived usefulness and perceived ease of operation. The TAM needs to be used in such a manner that the challenges are identified systematically and comprehensively (Lu et al., 2023)

Challenges refer to the internal characteristics and/or external conditions that have a direct or indirect influence in the adoption of WtE technologies (Lu et al., 2023).

<u>Challenges of perceived usefulness (Lu et al., 2023)</u>

- Environmental secondary pollution
- Imperfect legal and institutional frameworks

- Mismatch between parameter setting and regional planning
- Trust crisis in cooperation between the government, investors and waste managers

<u>Challenges of perceived ease of operation (Lu et al., 2023)</u>

- Insufficient raw material supply
- Little or no investment
- Weak environmental awareness
- Insufficient resources; human resources, financial resources, technical support and experience
- Site availability and selection

<u>Intervention strategies to promote adoption of WtE technologies (Lu et al., 2023)</u>

- Invest in infrastructure, human resources and technical support
- Reducing resistance to the adoption of WtE technologies through supervision, following regulations and having control and preventative measures
- Promote and strengthen environmental awareness
- Waste managers strengthening their own advantages as well as making the effort to bridge gaps in their challenges
- Strengthening legal and institutional frameworks by the government
- Strengthening the relationship between all stakeholders to avoid trust crisis

2.7.1 Proposition 2

Identifying Challenges in the adoption of WtE technologies and finding the solutions, will influence the perceived ease of use as well as perceived usefulness of WtE technologies.

The increase in waste generation has prompted the need to look into the challenges and enablers with regards to the management of waste and energy shortage challenges. Gauteng is faced with waste management issues as well the need to diversify its energy mix. The government and the industry at large needs to look into possible sustainable solutions that can close this gap.

WtE technologies can bridge this gap, but their implementation and adoption is faced with challenges. But where there are challenges, it only offers the opportunity for possible solutions to be looked into where the aim is to implement WtE technologies.

2.8 CHALLENGES AND ENABLERS WITH THE IMPLEMENTATION OF WtE TECHNOLOGIES

2.8.1 Challenges with the implementation of WtE technologies

These challenges include political, environmental, social, technological, economic, legal (PESTEL).

Political challenges include (Kumarasiri & Dissanayake, 2021)–

•Local and private companies lack information regarding potential costs and returns on introducing WtE

•Potential difficulties in getting approvals for WtE technologies

•Potential lack of infrastructure support from the government

•Political interference that might happen in tender processes which could hinder investor interest

Economic challenges include (Kumarasiri & Dissanayake, 2021) –

•High capital costs

•High operational and maintenance costs

•Transparency on the information of true costs

• Lack of knowledge and expertise could run high projects costs as developers could potentially rely on expensive international expertise

Social challenges include (Kumarasiri & Dissanayake, 2021)–

•Negative public opinion

•The public not implementing recycling habits

•Bad odour from waste storage

•Negative people’s attitude and habits ‘not in my backyard’ philosophy

Technical challenges include (Ali et al., 2020) –

•Lack of local and technical and education from experts

•Difficulties in choosing the most suitable WtE technology

•No experience in operating and maintaining these plants

•Challenges with waste composition i.e. low calorific value and high moisture content

•Difficulty in integrating knowledge and co-operation between research institutions, private companies and the government

•The possibility of current available technologies not being suitable to implement at a local scale

Legal challenges include (Ali et al., 2020)–

•Lack of proper legal and institutional frameworks for implementation, operation and maintenance of the plants

•Lengthy permit and licensing requirements or conditions

Environmental challenges include (Kumarasiri & Dissanayake, 2021) –

•Concerns about low air quality around where the plants are

•Possible weak enforcements of environmental standards

•Generation of bottom and fly ash which could cause air pollution

•Generation of leachate which could seep into the ground water

2.8.2 Enablers for WtE implementation

Possible solutions to overcome these barriers are to have tax returns on imported equipment, provide the necessary infrastructure facilities such as water, access to roads etc. Conduct awareness campaign for the public, draft simple and efficient policies for the implementation of WtE technologies and have involvement of all stakeholders when these policies are being developed (Kumarasiri & Dissanayake, 2021). Introduce favourable debt financing loan schemes. It is also going to be important to properly maintain and service these plants to expand their lifespan and involve as much local expertise as possible (Kumarasiri & Dissanayake, 2021). Teach the public about separation at source, have proper storage of waste and implement efficient emission monitoring and controlling systems. Install gas desulphurisation systems and also run secondary projects onsite that will use leftover material from the WtE plants for example in certain instances the ash that is produced from these plants is used to road making projects (Kumarasiri & Dissanayake, 2021).

Coal is abundant and cheap in South Africa which has resulted in the use of coal as an energy very affordable. The electricity tariffs has prevented the introduction of other technologies in the space, therefore encouraging the diversification of the energy mix needs to be explored (Kelly & Geyer, 2018).

The introduction of WtE technologies can allow the introduction of new revenue streams in the sector(Maisiri, Van Dyke, De Kock, & Krueger, 2015). Revenue can be generated through gate fees, energy sales, carbon credits, metal sales (Maisiri et al., 2015). The government could also introduce WtE subsidies which will also attract investors in the space(Maisiri et al., 2015).

To dispose to landfill in Gauteng is cheap and discourages disposal of waste away from landfill. Landfill tax would discourage the development of new landfills and encourage waste to be diverted to WtE facilities (Adeleke, Akinlabi, Jen, & Dunmade, 2021).

In other countries such as the United Kingdom, have looked in circular economy in industries like construction. This is a concept that moves away from the traditional linear economy by promoting the re-use, re-manufacture, repair and recycling of materials and products (AlJaber, Martinez-Vazquez, & Baniotopoulos, 2023).

2.8.3 Proposition 3

The introduction and implementation of alternative waste treatment technologies in developing countries will come with some challenges and all stakeholders including waste managers will need to find measures to mitigate them

2.9 CONSEQUENCES OF NOT INTRODUCING WtE TECHNOLOGIES IN WASTE MANAGEMENT

The country would face health and environmental challenges if WtE technologies are not looked into and considered. There will likely be landfill airspace depletion, which will result in illegal dumping which would cause infectious diseases and environmental degradation. The over-reliance on fossil fuels will also not improve thus further exacerbating the stress on the national grid.

New technologies to manage waste, diversify the energy the energy mix and minimising negative health and environmental impacts associated with landfilling waste need to be considered.

Solid Waste Management

As per the South African constitution, municipalities are mandated to provide waste management services such as waste collection, transportation, treatment and disposal of waste. Rapid urbanisation has made it difficult to efficiently manage waste services (Covary, 2020). Simelane (2007) states that the rapid expansion of uncontrolled and unplanned urbanisation leads to escalated governance challenges, which results in inferior quality service delivery and waste management.

An increase in population and economic activity has caused a rise in MSW generation and this often leads to illegal dumping, thus creating health and environmental hazards (Simelane, 2017), Research also indicates that in the future MSW generation will rise and population growth will also be on the increase, but landfill airspace to manage the waste will be depleted (Dlamini et al., 2019).

Diversifying the Energy mix

In recent times, there has been energy security issues in South Africa, which has led to load shedding, where households are without access to electricity for a couple of hours on a daily basis.

In the CoJ, electricity access levels are at 90% leaving 10% of residents without access to electricity. Most of these people are from townships and informal settlements (Culwick, 2018). Therefore without diversifying the energy mix, residents will suffer due to lack of access to power, the economy will not grow, infrastructure will collapse and a high reliance on fossil fuels will continue, which will further cause stress on the environment i.e. increase the effects of global warming (Culwick, 2018).

Environmental Impact

Greenhouse gases such as carbon dioxide and methane are generated in landfills. Organic waste breaks down, creates gases which are released in the atmosphere thus contributing to global warming (Bedair et al., 2023). How this happens, is that the gases get absorbed, infrared radiation gets emitted by the Earth's surface and acts as a blankets over the surface keeping it warmer than it would normally be. The effects of global warming(Cho, Strezov, & Evans, 2023) are –

•Negative impacts on human and animal health

•Extreme weather events i.e. floods, droughts and wildfires

•Forced human displacements

•Increased hunger and poor nutrition due to people not being able to grow their own food

•Extinction of animal species due to inhabitable environments

Landfilling and illegal dumping of waste are therefore not sustainable waste treatments methods

2.10 Theoretical Foundation

The increase in MSW generation poses a threat to the health of citizens, pollution of the environment and contributes to climate change challenges. Lack of landfill airspace and energy security is also forcing the look into WtE technologies in the efficient treatment of MSW.

The introduction of new technologies in a market can create threats to established business models but can create new opportunities for services (Lai, 2017). A common question asked by researchers and developers is why people accept new technologies, the answers may assist them in better designing the technologies or products (Taherdoost, 2018).

The adoption of new technologies is rather complex it is an inherently social and developmental process which is highly reliant on an individual's construct. But to successfully facilitate the adoption of a new technology, it needs to address cognitive, emotional and contextual concerns (Straub, 2009). This is to avoid huge amounts of money invested in a product, service or technology that may not yield results if it is not adopted by or for the user (Sharma & Mishra, 2014). Consumer needs are not the only deciding factor in products, services or technologies being adopted, in most instances policy, finance, human rights and sustainability issues need to be taken into consideration(Sharma & Mishra, 2014).

The diffusion and adoption of WtE technologies will also depend on their further development and cost cutting through innovation and experience (Neij, 1997).

A number of theories have been used to explain the acceptance of new services, products and technologies in a market (Lai, 2017).

Figure 13 below gives a breakdown of the Adoption Model. A number of models and frameworks have been developed to explain the uptake of new technologies in a market. These models look into factors that will influence consumer acceptance of new technologies or products (Taherdoost, 2018). The models are the Technology Acceptance Model (TAM), Theory of Planned Behaviour (TPB), The Diffusion of Innovation Theory (DIT), Theory of Reasoned Action (TRA), Model of PC utilisation (MPCU), Motivational Model (MM), Unified Theory of Acceptance and Use of Technology (UTAUT) and use of technology and Social Cognitive Theory (SCT) (Taherdoost, 2018). Researchers have used these models to conduct research and more than one approach is needed to do the analysis so that there is clarity and understanding on the issues at hand (Taherdoost, 2018).

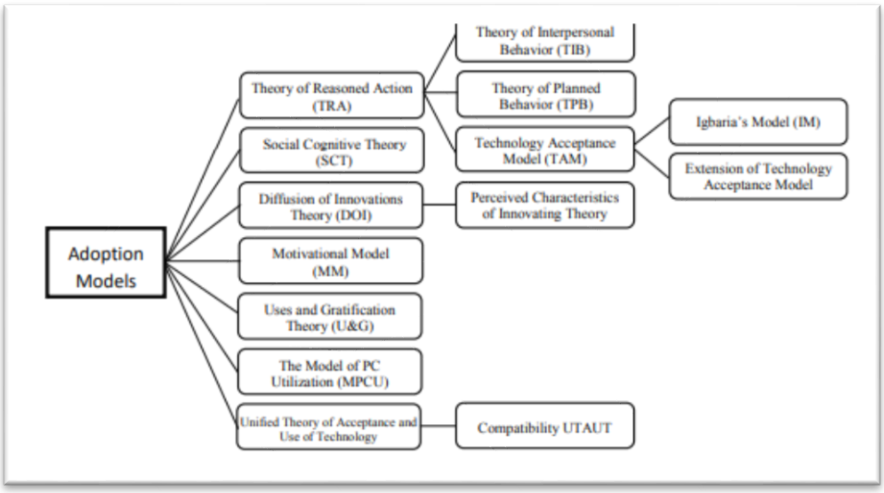

Figure 13 An overview of adoption / acceptance models (Taherdoost, 2018)

The theory which is appropriate for this study is the Theory of Reasoned Action (TRA), it was developed in 1975 by Fishbein and Azjen in their research for sociological and psychological studies (Taherdoost, 2018).

The model is appropriate for this study because it predicts human behaviour through three main cognitive components (Taherdoost, 2018).

- Attitudes
- Social norms and
- Intention

Figure 14 shows the TRA model which gave rise to the Technology Acceptance Model (TAM) it explains the motivation by users to uptake a new technology. TAM looks at three factors (Taherdoost, 2018).

- Perceived usefulness (degree which users believe that the technology can improve their work performance or convenience in life
- Perceived ease of use (degree at which the users believe they are able to master the specific innovative technology)
- Behavioural intention

TAM can be used as a comprehensive framework for the acceptance of WtE technologies studies due to its holistic approach as it allows researchers to understand barriers facing the adoption of WtE technologies (Kardooni, Yusoff, & Kari, 2016).

The limitation that the TAM model has is that it eliminates the social aspect/influence on the adoption of a new technology, therefore it will be challenging to apply it beyond industry or the workplace. Another challenge is that it is not a scientific method (Taherdoost, 2018).

There are external variables that can be considered to the extension of TAM model (ETAM) and these are user training, the design of the technology in this case (WtE technologies), participation in the technology design and involvement in the process to implement the technology (Agustina, 2019). ETAM looks at factors that can improve the adaptability of the TAM model (Agustina, 2019).

The use of ETAM has its limitation in that it does not look at differences in beliefs and attitudes as well as inadequate theoretical and psychometric justifications (Igbaria, 1993).

Igbaria’s model (IM) looks at both intrinsic and extrinsic factors that could influence the uptake or rejection of a technology. IM (Igbaria’s Model) is developed by adding explanation on extrinsic (perceived usefulness) and intrinsic motivators (fun) effecting on the acceptance or rejection of the new technology(Taherdoost, 2018). It is supported by both theoretical development and empirical evidence (Igbaria, 1993).

A study was done in China looking at the acceptance of waste incineration power generation projects. The study investigated the constraints in the uptake of WtE technologies specifically waste incineration power generation plants. The main stakeholders involved in this study were project operators, investors, government and the public (Lu et al., 2023).

The study looked into perceived usefulness and perceived ease of using the waste incinerators using the TAM model and perceived risk was also added as another dimension that could influence the uptake of this technology (Lu et al., 2023).

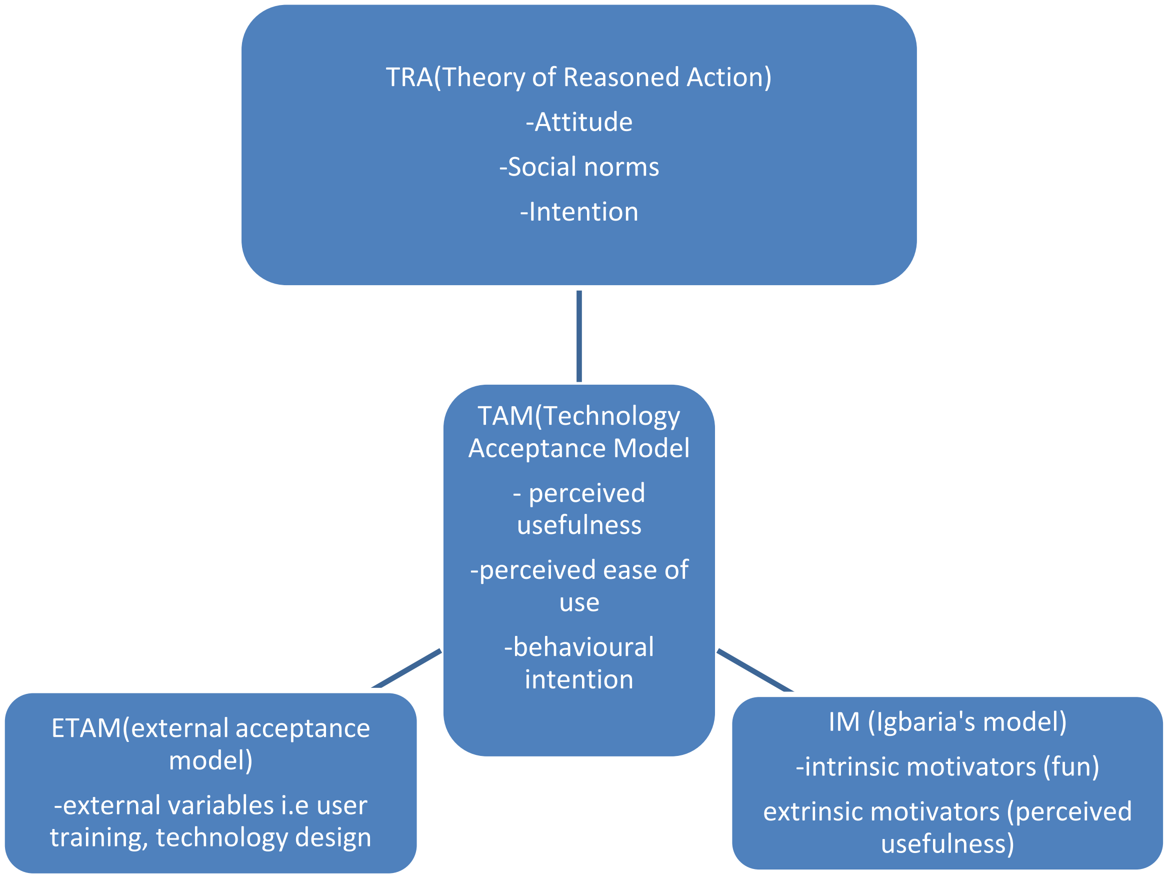

Figure 14 Technology acceptance model

Data was collected through questionnaire surveys, literature survey and case studies (Lu et al., 2023).

In the study it was concluded that challenges which hindered the uptake of waste incinerators were (i) imperfect legal frameworks (ii) poor environmental awareness, insufficient resources (iv) public opposition and (v) the media misleading (Lu et al., 2023).

To overcome these challenges it was suggested through the study that there need to be improved laws, regulation and economic policies, public environmental awareness needs to be cultivated, proper contracts need to be drafted to avoid issues of trust and businesses should also invest in their human resources to develop and improve training frameworks of staff at all levels to enhance the overall human capital (Lu et al., 2023).

South Africa heavily relies on landfilling, but the practice has come with its challenges. There has been strides to combat this practice, due to its landfill challenges, the CoJ has been exploring options for alternate waste treatment methods in line with national waste management strategy and approach to waste management (City of Johannesburg, 2017). The WtE project is said to divert around 80% of MSW away from landfill. This will result in the production of 25MW of energy which could assist in powering 60000 household (City of Johannesburg, 2017). The waste to energy project is said to also create jobs, both full time and part-time.

According to the waste hierarchy, landfilling should be the last resort in managing waste. Waste to energy not only protects human health and the environment but also has the potential to reduce the heavy reliance on fossil fuels thus promoting a wider range of available energy sources in the energy mix (Zhou & Zhang, 2022).

It is important to understand how WtE technology is perceived by all stakeholders in the waste and energy sector as well as the public and to note that each technology available has its own pros and cons and that the selection of technology should be guided by operation costs, labour and skill requirement, waste availability and origin(Zhou & Zhang, 2022).

Technology acceptance models and theories have been applied in many domains to better understand dieting, family planning, voter's behaviour, choice of transport mode and consumer’s purchase behaviour (Taherdoost, 2018). This is for researchers to understand why accept certain technologies and it gives them a window into how to further develop and improve their products (Taherdoost, 2018).

The research on how waste managers perceive WtE technologies in Gauteng is scanned. Research has been mainly focused on public concern. The main areas of concern has been (Maynard & Smethurst, 2009) –

• Health concerns from the emissions of hazardous or toxic pollutants that may be linked to cancers, birth defects, cardio-vascular diseases and respiratory concerns.

• The public does not trust the processes used in determining planning application and operating permits

• Mistrust of expert opinion, this may be based on intuitive feeling or the perception that experts are biased

• Lack of public awareness and understanding of WtE technologies. An example is seen in some of the provinces in China, where there were protests of WtE projects, although the projects had passed assessments (Yuan et al., 2019).

The role and opinion of waste managers in the adoption of WtE technologies is very important as this will likely have a positive or negative outlook for them and this might hinder or promote the uptake of WtE technologies in Gauteng.

2.11 Conclusion of Literature Review

Urbanisation, increased economic activity and an increase in the global population has caused an increase in the generation of waste. Waste generation differs between regions, economic activities and social activities and the waste composition is impacted by sources of material.

By the 19th century formal collection and disposal of waste started to happen. The disposal of waste to landfill has come with its challenges such as landfill airspace depletion which would result in illegal dumping and that will likely cause disease and environmental degradation.

The adoption of WtE technologies would address issues of land availability, diversifying the energy mix, and reduce GHG emissions thus mitigating climate change

WtE technologies for solid waste management can be divided into two types –

- Thermal conversion – incineration, gasification, plasma arc gasification and pyrolysis
- Biological conversion – landfill gas extraction and anaerobic digestion

The introduction of new technologies in a market can create a threat to established business models, but can also create new opportunities for services. It is an inherently social and developmental process. It needs to address cognitive, emotional and contextual concerns. This is to avoid huge expenses being invested in technology that won't be used by the market.

A number of models and frameworks have been developed to explain the uptake and acceptance or lack thereof of new technologies. The adoption model has been developed and can divided into sub-models.

The TAM is used to explain the adoption of new technologies by users and explains the motivation of users by exploring three factors – perceived usefulness, perceived ease of use and behavioural intention.

There are external variables that also need to be considered in the acceptance of a new technology and these are –

- User training
- Design of technology
- Participation of consumers in the design of the technology

TAM can be used as a comprehensive framework due to its holistic approach but its limitation is that it is not a scientific approach and cannot be used outside the bounds of a workplace or industry

Challenges with the adoption of WtE technologies highlighted by TAM are human and financial capital, technological and policy frameworks, environmental pollution, site availability, weak environmental awareness.

Interventions to promote the adoption of WtE technologies would be to invest in infrastructure, human resources, technical support, strengthen environmental awareness, and improve policies and stakeholder relationships.

The implementation of WtE technologies has barriers which include political, economic, social, legal, technical and environmental.

To overcome these barriers you can have tax returns on imported equipment, provide the necessary infrastructure facilities such as water and access to good roads, conduct public awareness, improve and draft simple and efficient policies, introduce favourable debt financing loans, teach the public about separation at source, implement efficient emission monitoring and control systems and run secondary onsite projects.

2.11.1 Proposition 1

The role of waste managers is to responsibly develop and procure effective and efficient recycling, recovery and disposal of waste methods that meet service standards in accordance to policy, legal compliance and best practice

2.11.2 Proposition 2

Identifying Challenges in the adoption of WtE technologies and finding the solutions, will influence the perceived ease of use as well as perceived usefulness of WtE technologies

2.11.3 Proposition 3

The introduction and implementation of alternative waste treatment technologies in developing countries will come with some challenges and all stakeholders including waste managers will need to apply measures to mitigate them

CHAPTER 3. RESEARCH METHODOLOGY

This chapter details the methodology used in the study. It also provides how the data was analysed. The chapter outlines the following; research approach, research designed, data collection method, population and sample, research instrument, procedure for data collection, data analysis and interpretation, limitations of the study, trustworthiness, ethical considerations.

3.1 Research approach

The research is aimed at developing an understanding on how waste managers perceive the adoption or use of waste to energy technologies in Gauteng. The study was highly reliant on the knowledge of the individuals who were be involved in the study. Based on this, the research approach selected to conduct the study was a qualitative approach.

According to (Rutberg & Bouikidis, 2018) a qualitative study examines a research problem using an in-depth holistic approach and a flexible research design that produces a rich narrative that addresses social aspects of a research study. A qualitative study is essentially concerned with understanding human experiences on a subject matter in a humanistic interpretive approach (Jackson, Drummond, & Camara, 2007). It assesses the attitudes, opinions and experiences of the subject matter being researched.

According to Creswell (2003) when conducting a qualitative study, the researcher is the primary tool for the collection of data, therefore it is of importance that the researcher has or learns good interpersonal and communication skills.

The researcher usually uses open-ended questions in the quest of trying to understand a problem that is, not well understood (Rutberg & Bouikidis, 2018), although the research questions need to be formulated in a manner that ultimately answers the research problem comprehensively. The answers given by the participants in the interviews are analysed in an attempt to answer the research question.

It is the responsibility of the researcher to approach each study with objectivity, ethical diligence and rigor (Jackson et al., 2007)

A qualitative study is an appropriate research methodology to use because the meanings and processes are not measured, rather insights are discovered and interpreted (Noor, 2008).

3.2 Research design

A qualitative research can be described as perspective based research method, it includes a range of methodological approaches (Kemparaj & Chavan, 2013). Creswell et al., (2007) describe these methodological approaches as case study, participatory action research, narrative research, phenomenology and grounded theory (Creswell, Hanson, Clark Plano, & Morales, 2007). The aim of these approaches is to gain an in-depth understanding of the social world i.e. people's social and material experiences, past experiences, their view on the subject and history (Creswell et al., 2007).

The methodical approach for this research is qualitative phenomenology study, it identifies a phenomena through the perspective of an individual, based on personal knowledge, experience and it is subjective (Lester, 1999). It is an essential tool when a researcher is trying to gain insight into a person's motivation and action (Lester, 1999).

It is a qualitative research design because the researcher gives in-depth descriptive questions which has the ability to provide insight into the research topic.

This research design is appropriate for the study because it focuses on the insights and perceptions of the participants.

The study focuses on an issue with i.e. individuals or group of people selected to provide their insight on a topic (Creswell et al., 2007).

However there are advantages and disadvantages in using this methodology to collect information for the research. The advantage is that you can gain more in-sight by raising more issues through broad and open-ended questions (Choy, 2014). The disadvantages are that it is time consuming, requires knowledgeable and skill interviewers, it is difficult to verify results because the participants have more control over the content (Choy, 2014).

3.3 Data collection methods

Data collection is a crucial step in a qualitative research study, the data is meant to contribute to a better understanding of the research theoretical framework (Etikan, Musa, & Alkassim, 2016). It is therefore crucial to ensure that data collection is done with sound judgement because no amount of analysis can make up for data that is poorly collected (Etikan et al., 2016). In a qualitative research design, there are restrictions on how data can be collected as well as the analysis method (Tetnowski, 2015). Data can be collected flexibly and this helps avoids prior knowledge bias (Tetnowski, 2015).

The researcher is the key instrument in data collection and the researched needs to have the ability to construct appropriate questions suited to answer the research question and be able to analyse the data (Tetnowski, 2015).

There are 3 main methods of collecting data in a qualitative research; focus groups, observations and interviews.

In this research study, interviews were conducted to collect data. The reason interviews seem appropriate as a mode of collecting data because it is a direct and straight forward approach in acquiring rich and detailed data (Barrett & Twycross, 2018).

The research questions guided the type of interview that will be conducted to collect data (Barrett & Twycross, 2018).

The type of interview questions can be structured into 3 categories; open or unstructured, semi-structured and structured (Barrett & Twycross, 2018).

In this study, semi-structured interviews were held, this was to ensure that interview questions are controlled to answer the core questions of the study, while allowing participants to be expressive on the topic

Interviews were carried out face to face and on Microsoft Teams.

Barrett (2018) points out the challenges in conducting interviews being the research questions likely being bias and leading as well as the analysis of the data being time consuming.

3.4 Population and sample

This section covers the population and sample of this research study. It includes the experience, position and role of each participant.

3.4.1 *Population*

The population of the research study is based on employees who work in waste industry; mainly in the private and public sector at provincial level. The participants have senior roles in waste management and energy and they also had knowledge in administration and finance knowledge as well as legislation applied in these sectors.

3.4.2 *Sample and sampling method*

The sampling method to be used, is purposive sampling. This method allows the researcher to decide what needs to be known and their goal is to find participants who are willing to share information based on their knowledge and experience (Etikan et al., 2016).

The sample chosen were participants at managerial and technical and sales level in the waste and energy industry and the participants were chosen based on being proficient and well informed on the research topic. The individuals were also selected on their availability as well as their willingness to share and communicate on the research topic. The study looks into waste managers in Gauteng. 4 participants were from the CoJ, 3 participant from CoT and 6 participants were from the CoE. The sample was chosen on the basis on who as available to be interviewed, the time it would take to conduct the interviews and the variety in the interviewees to ensure that quality data was collected.

The sample that was used in the research study is indicated in the table below

Table 2: Indicating the description and number of participants

Description of participant	Number of Participants
Senior Engineer (Waste)	**1**
Executive Associate (Waste and Energy)	**1**
Project Consultant (Waste)	**1**
Process Operations Director (Energy)	**1**
Technical Director (Waste)	**1**

Operations Director (Waste)	**1**
Commercial Director (Waste)	**1**
Commercial Manager (Waste)	**1**
Commercial Manager (Energy)	**1**
Technical Manager (Waste)	**1**
Project Manager (Energy)	**1**
Senior Engineer (Waste and Energy)	**2**
Total number of Participants	**13**

3.5 The research instrument

The research instrument used to conduct the research study.

The interviews were one-one sessions in person and on Microsoft Teams with the selected participants. The interview questionnaire was based on the research questions in Chapter 1 and the propositions in Chapter 2. Follow up questions were also asked to gain further insight on the information that the participants were giving

The research instrument is attached as Appendix C

A semi-structured interview, is a type of interview where core elements of the research are being explicitly asked by the interviewer to the interviewee, while allowing the interviewee to bring their own perspective into the discussion (Barrett & Twycross, 2018). There are four factors that would encourage a semi-structured interview, firstly it would be the intention of the study, it needs to be exploratory and open-ended interview questions are recommended. The other three factors are the participant's prior knowledge on the research question, their availability and degree of flexibility between the interviewer and interviewee (Jackson et al., 2007).

3.6 Procedure for data collection

The preferred data collection procedure is face-to-face semi-structured interviews, but in cases whereby face-to-face interviews were not possible virtual platform Microsoft Teams was used

Direct permission from the participants was requested. The code of ethics was upheld. Participants were granted confidentiality and anonymity.

3.7 Data analysis and interpretation.

In this study to analyse and interpret the research findings, thematic analysis will was conducted. It entails searching research data to identify, analyse and report data (Kiger & Varpio, 2020). Data acquired from the semi-structured interviews was transcribed. Codes, categories and themes were then formulated according to how thematic analysis is done.

This method is suitable to use when analysing data seeking to understand experiences, thoughts or behaviours of research participants (Kiger & Varpio, 2020)

The diagram below Figure 15, gives a step by step explanation on how the thematic analysis will be done.

i) Familiarise yourself with the data – this will done by going through and understanding data from interviews

ii) Generate initial codes – this will done through a systematic analysis of the data

iii) Search for themes through categorising various codes into potential themes

iv) Review potential themes by mapping to determine the correlation among themes

v) Define and name the themes

vi) Produce the report once data analysis is concluded

Figure 15 A diagram showing thematic analysis

3.8 Limitations of the study

Possible study limitations will be that all stakeholders in the waste management industry will not be included

The data collected is dependent on an individual's perspective

Study is limited to participants who are the waste and energy industries

3.9 Trustworthiness

The trustworthiness of a qualitative research study is usually defined and proven of the terms transferability, credibility, dependability and confirmability (Elo et al., 2014).

The aim of trustworthiness in a qualitative study is to support the validity of the research results (Elo et al., 2014). To enhance the validity, transferability and reliability of the study, data source triangulation was deployed with the semi-structured open-ended questions. Triangulation involves multiple data sources to establish integrity and enhancement of the findings (Given, 2008).

3.9.1 *Transferability*

Relies on the reasoning that the findings on the research study can be generalised to another group (Elo et al., 2014). In this research study, participants were chosen based on their role and expertise in the waste and energy industry. The study will give the opportunity to apply it in various contexts, scenarios and areas.

The reader will have the ability to implement the same participant selection criteria and principles employed in their own study.

3.9.2 *Credibility*

Refers to the researcher's ability in ensuring that the participants of the research study are identified and described accurately (Elo et al., 2014). The study will ensure credibility by triangulation.

This can be further enhanced by the participants' involvement in critiquing and questioning or agreeing to the study's findings. Triangulation will be used to enhance the quality and validity of the study (Given, 2008).

3.9.3 *Dependability*

Refers to the stability of the data over time and the ability of another researcher to easily replicate the research study used by the initial researcher (Elo et al., 2014).

The research study aims to be dependable and this is reliant on how the study is undertaken. The research study aims to clearly outline how the data was collected and used in the analysis. This should give another researcher a trail should they need to conduct the same research.

3.9.4 *Confirmability*

Refers to the objectivity between two or more independent people about the data's accuracy, relevance or meaning and that the data has not been invented by the researcher (Elo et al., 2014). To ensure confirmability the research study will allow participant contribution in the study findings. This will ensure that the information provided and analysed is not just an invention created by the study but presents inputs provided by the participants.

To ensure that there is transferability, credibility, dependability and confirmability in the research study to be conducted; the preparation, organisation and reporting of the results is very important.

3.10 Ethical considerations

The study will ensure ethical practices by following the guidelines of the University of the Witwatersrand. Ethics clearance from the ethics committee will be obtained before the research study.

Participants will also need to provide consent before they can participate in the research study and their details will not disclosed

a) They will need to provide consent to participate

b) They will be informed so that they understand what the study is about

c) Their participation will voluntary, and they can withdraw if they see it necessary

d) Their details will not be disclosed

CHAPTER 4. PRESENTATION OF FINDINGS

4.1 INTRODUCTION

This chapter presents information or findings from the data collected in the semi-structured interviews with experts from the waste and energy industry, based on the purposive sampling approach.

The structure of this chapter includes how data was analysed using thematic analysis, demographic of participants and proposition findings.

4.2 DATA ANALYSIS METHODOLOGY

The data audio-recorded from participants was analysed using thematic analysis as explained by Braun et al (2012). It is a six-phase approach and involves –

- Familiarisation of data
- Generation of initial codes
- Categorisation of various codes into themes
- Reviewing potential themes
- Defining and Naming themes
- Producing a report

4.3 PROPOSITION 1 FINDINGS

One theme emerged from proposition 1(theme1), which is the prioritisation of the waste hierarchy and four categories a) improved waste management practices b) less environment challenges c) new revenue streams d) waste manager is a researcher, collaborator and educator. Figure 16 below shows thematic analysis on proposition 1

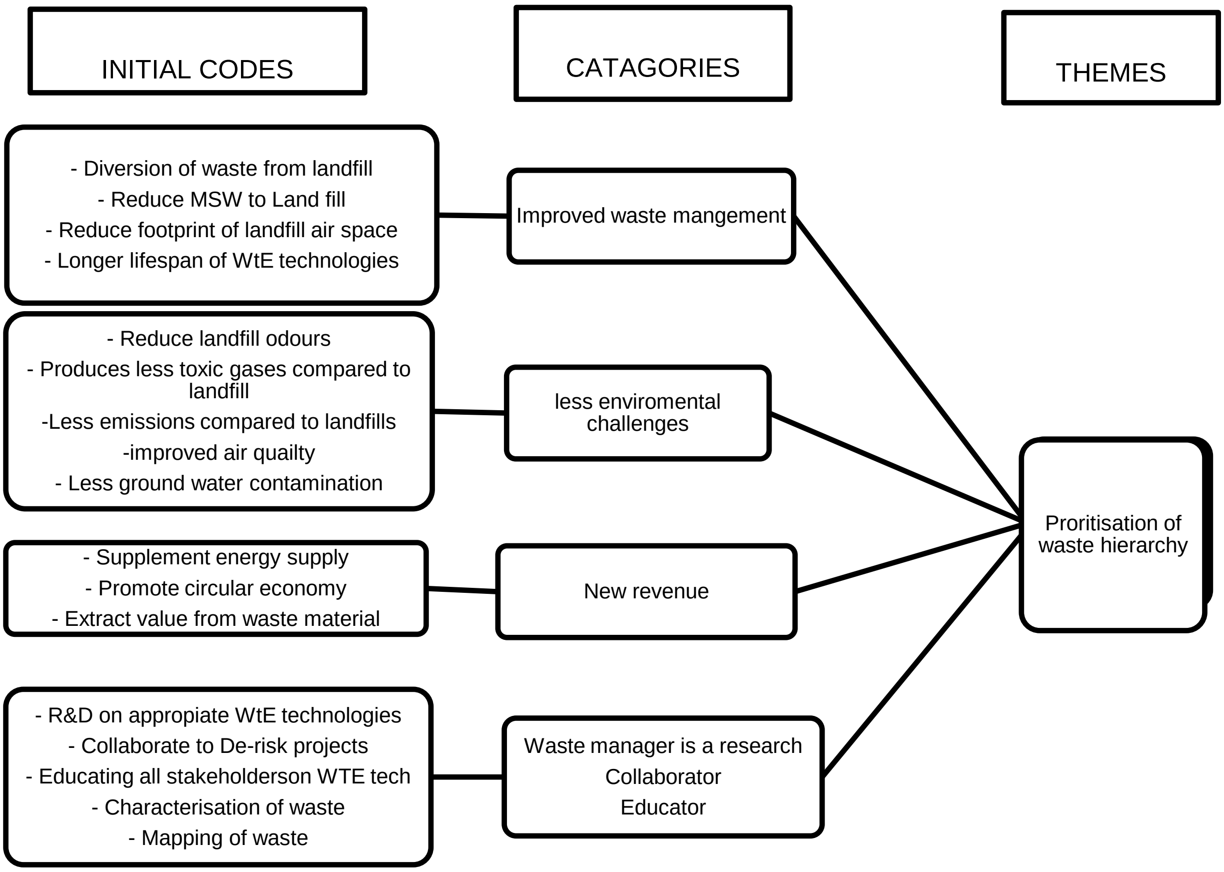

Figure 16: Thematic analysis findings on proposition 1 from the semi-qualitative interviews

4.3.1: Prioritisation of the waste hierarchy

a) **Improved waste management practices**

All the research participants indicated the importance of having WtE technologies in the waste sector. They mentioned the diversion of waste away from landfill, reduce MSW to landfill, dwindling landfill airspace and a longer lifespan of WtE technologies compared to landfills.

Participant 6 said

"WtE technologies are not an energy solution but a waste solution and municipalities are running out of landfill airspace''

Participant 12 mentioned

Land availability is a challenge and WtE technologies will reduce challenges with landfill airspace depletion and some of these technologies have a longer lifespan than landfills

Participant 7

"WtE technologies can be used to assist in the management of problematic waste streams, recyclers can't deal with all the waste and strategically placing these technologies might help reduce transport cost for waste generators"

Participant 2

WtE technologies should be considered after the consideration of re-using and recycling of waste according to the waste hierarchy

b) Less environmental challenges

All the participants agreed that WtE technologies will alleviate environmental issues associated with the disposal of waste to landfill. These challenges include the reduction of landfill odours, less toxic gas emissions, improved air quality and less groundwater contamination.

Participants 13 mentioned that

"Methane gas generated in landfill is more toxic than the carbon dioxide from WtE technologies"

Participant 7 added

''The scrubbers in the incinerators need to be fitted with scrubbers that can efficiently reduce carbon dioxide emissions"

Participant 4

"I trust that WtE technologies will reduce the contamination of groundwater in the landfills"

c) New revenue stream

The participants observed that the bio products produced from WtE technologies can used to create a new revenue stream and this will assist in promoting the circular economy. This can be done in the form of supplementing and re-selling the energy, promoting recycling, selling fertiliser from AD plants, extract value from waste material.

Participant 1

"There is a lot of potential is creating other forms of income from these technologies, heat and steam can be used to generate electricity and that can be sold into the grid"

Participant 4

"In our plant, we also generate manure or fertiliser which we sell to the surrounding communities"

d) Waste Managers are researchers, collaborators and educators

All the participants view the importance of procuring more technologies in the space. Waste mangers play a role in giving clients a holistic view in the management of waste and this includes the mapping and characterisation of the waste.

Participant 7 said that

"Waste managers are vital in educating all stakeholders, this includes investors, communities, and the public and private sector"

Participant 6 emphasised that

"WtE technologies or plants are expensive therefore partnerships to raise funds to invest in these projects as well as securing the volumes needed as feedstock to run the plants, this is to de-risk the projects"

Participant 2

"Research and Development for appropriate technologies that fit the local space need to be done"

Participant 8

“Clients are needing zero to waste solutions, waste managers are now forced to think out of the box, therefore constant research and collaboration by waste managers with universities and research institutions is important”

Participant 6 also mentioned that

“*Waste will need to be view as a feedstock, therefore understanding the quality, quantity and consistency of receiving the waste is crucial”*

4.4 PROPOSITION 2 FINDINGS

Five themes emerged from proposition 2, themes (2 – 6) which are 2. Affordability and Feasibility of WtE technologies 3. Access to finance and viability of the projects 4. Availability of technical skills 5. Employment opportunities 6. Supplement energy supply. Figure 17 below shows thematic analysis on proposition 2

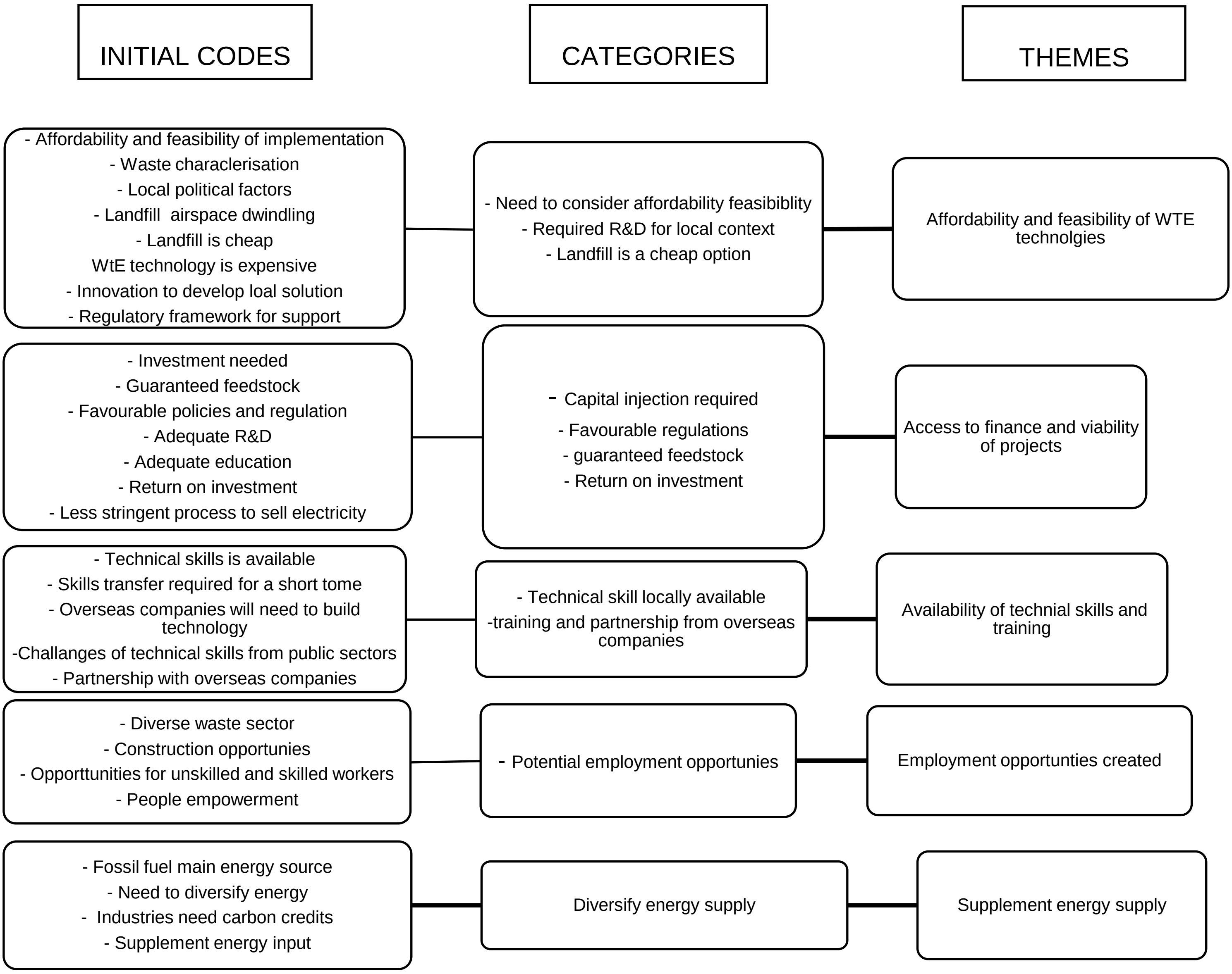

Figure 17: Thematic analysis findings on proposition 2 from the semi-qualitative interviews

4.4.1 *Affordability and Feasibility of WtE technologies*

a) Need to consider affordability and feasibility of these projects

All the participants indicated the need to diversify the waste sector due to landfill space constraints among other issues, but had concerns with regards to the affordability of these technologies.

Participant 12 said

"High gate fees to access these WtE facilities will be challenging due to high costs of operating and maintaining these plants. The first five years or so will be expensive but over a 20 year lifespan, some of these technologies might start seeing a decline in these costs and hopefully this will be the turning point of start seeing profits"

b) Require R&D for the local context

All the participants regarded R&D as an important part on the adoption of WtE technologies and how they fit in the local context as crucial. This will improve and ensure that the technologies that are introduced in the sector bring about the positive changes into the space that are intended for them to do without having a negative disruption to the industry .

Participant 2 confirmed

"Yes, there is R&D and innovation happening in the sector to develop opportunities, although we might need to look at it on a small to medium scale as we are a developing country"

c) Landfill is still a cheap option

The participants agreed that landfill is still a cheap option in waste management compared to alternatives which might hinder the speed at which WtE technologies are adopted

Participant 7 was concerned and shared that

‘’Disposal to landfill sites in Gauteng is cheap and there is a perception that it is under-priced. There is no landfill tax and the gate fees are low. The other issue is that land is no longer available and there is also land competition with housing, schools and businesses’’

Participant 7 went on to say

“There is a need to characterise the true value of waste and at the current moment the true value of disposing to landfill is not entirely understood”

And Participant 6 mentioned that

“Issues with landfill airspace have created the need to look into other technologies, otherwise we are going to end up having to build very far in the outskirts and this will increase transport cost”

4.4.2 *Access to finance and viability of projects*

a) Capital injection is required

All the participants gave heed that capital is needed to finance these projects. Funding for the infrastructure is required which is usually high as well as high operating and maintenance costs.

Participant 5

“Waste managers cannot do this alone, partnerships with the government, private investors and grants will be needed to fund and implement these projects”

b) Favourable regulations and policies

The participants reiterated the importance of having adequate policies and regulations in place to ensure that the sector is well managed and regulated.

Participant 7 alluded to

“There are decent regulations in the waste sector, but implementation has been a challenge”

Participant 1

“To attract investment in the waste sector, having good regulations and policies and implementing them. This will give assurance to investors to invest”

c) Guaranteed feedstock

All the participants observed the need to guarantees with regards to feedstock. WtE technologies need feedstock to operate, it is therefore importance to characterise the chemical and physical properties of the waste in Gauteng, the available tonnages, the source of the waste and where they are currently being disposed. Mapping and characterising the waste would ensure that the appropriate technology and scale of the technology is chosen.

Participant 2

"Waste is feedstock, therefore the characterisation is important, behavioural change is also important. WtE technologies are not the only solution but part of the solution"

Participant 3 added that

"WtE plants are expensive, to set up a plant you need to ensure that you have secured the volumes required to operate these plants"

d) Return on Investment (ROI) guarantees

The participants acknowledged that investment in the sector or projects is needed. Investment are required for the financial viability of the projects and the importance of ensuring that that investors make profits on the projects.

Participant 1 said

"Anyone who makes an investment in a projects before doing so there are going to assess their ROI"

4.4.3 Availability of Technical Skills and Training

a) Technical skills locally available

All the participants were comfortable with the fact we are not short of technically ability to operate these technologies.

Participant 6 said

"The country has worked on many complicated plants and technologies, looks at the likes of Sasol and Eskom"

Participant 8

"Our Universities produce highly skilled engineers which will be beneficial but due to brain drain and poor governance we might lose them to other countries"

Participants 7 warned

"There is potential to get this right in the private sector, whereas in the public sector there might be a low technical barrier to entry"

Participant 11

"To *build the technology and systems, we are going to require overseas companies, because you need to get it right there is no room of getting the mechanism wrong, but in terms of operating these systems local engineers and scientists are more than capable*"

b) Training and skills transfer from overseas manufacturers required

The participants mentioned that there will be a need for a training and skills transfer from the overseas manufacturers but for a short period

Participant 1

“We are going to need a temporary skills transfer from manufacturers on the specifics on how the particular technology is operated”

Participant 4

“For some of these technologies, the skills are there, but for some we are going to require education and skills transfer”

4.4.4 Employment Opportunities created

a) Potential Employment Opportunities

The participants agreed that sustainable employment across the waste and energy sector value chains would be created but they could not quantify the scale of these employment opportunities.

Participant 5

“Having a waste sector that has a diverse ways of managing waste is more ideal for job creation”

Participant 6

“*Construction opportunities and operating the plants, from skilled to unskilled workers will be created*”

Participant 8 said

“Different employment opportunities will be created from the skilled to unskilled. But this might create at landfills due to the waste being diverted”

Participant 4 commented

"Diversifying the types of technologies and looking into a more circular economy, employment opportunities would be created"

4.4.5 Supplement Energy Supply

a) Increase energy supply

All the participants mentioned the fact that our main source of energy supply are fossil fuels and they do not see the usage slowing down. The country is on the road to introduce other energy sources such as solar and wind and energy from WtE can be used to increase the supply of energy.

Participant 9

"*The energy will supplement and reduce reliance on fossil fuels but won't stop the usage"*

Participant 4

"Fossil fuels are currently more reliable and cheap, it won't substitute but can add on"

Participant 10

"*Industries that use a lot of coal to run plants can purchase the energy generated from these plants to reduce their carbon footprint"*

4.5 PROPOSITION 3 FINDINGS

Five themes emerged from proposition 2, themes (7 – 11) which are 7. Lack of education and stakeholder collaboration 8. Political interference 9. Lack of access to capital 10. WtE enablers 11. Investor interest. Figure 18 below shows thematic analysis on proposition 3.

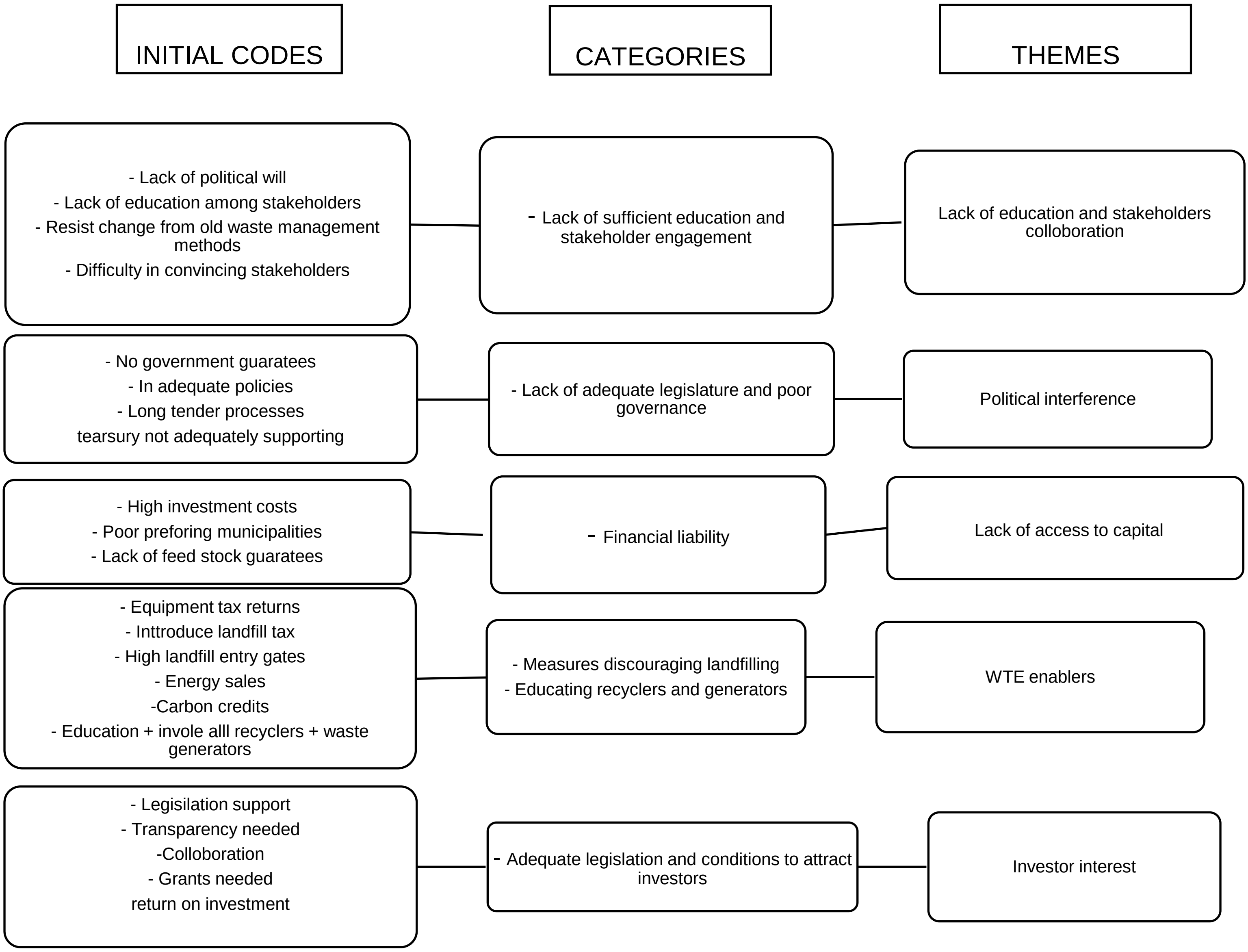

Figure 18: Thematic analysis findings on proposition 3 from the semi-qualitative interviews

The participants all agree that political, social, economic and legal factors will greatly affect the adoption of WtE technologies and great deal of work will need to be done to overcome these barriers.

4.5.1 *Lack of education and stakeholder collaboration*

a) Lack of education and insufficient stakeholder engagement

All the participants noted that, there is a lack of education or awareness among stakeholders and this is mainly with the politicians who ideally need to play a significant in the adoption of WtE technologies.

Participant 12 stated

"The level of expertise in the municipalities in writing proper contracts and the tender contracts might be stumbling block and there is little or no education among the politicians, council. The waste generators also need to be included in the education of WtE technologies"

Participant 13 also said

"The public also needs to be educated on these technologies, in European countries, these plants are placed in the cities, the technologies have become so advanced that noise and air pollution is minimal"

According to Participant 8

"We can learn a lot from Europe. Educating the communities and politicians will be a factor. It is about managing perception, pollution and cost. The government can assist in incentivising the uptake of WtE technologies

4.5.2 *Political Interference*

The participants noted the importance of politicians being involved in the adoption of WtE technologies, but the current political environment is not proving to be favourable and the current legislation does not fully include the use of WtE technologies.

a) Poor governance

All the participants were concerned about politics of the country interfering with the uptake of WtE technologies

Participant 7 noted

"Poor governance and corruption are one of the threats that could hinder the uptake of WtE technologies"

Participant 2 said that

"Political interference is the biggest challenge to overcome but we also need to look into technical applicability as well as social and political acceptance"

b) Lack of adequate legislature

The participants agreed that the current legislature does not fully support the adoption of WtE technologies and that the government and treasury do not fully back these projects.

Participant 1 mentioned that

"The regulations need to be abit relaxed and inclusive of the technologies, the current model which we have is command and control which need relaxing"

Participant 8

"*Our policies are not far off, but the challenge is in the implementation and maintaining what is in the regulations"*

Participant 1 repeated

"*There is a lot of red tape in the projects getting approval, the process is long and drawn out"*

4.5.3 ***Lack of access to capital***

a) Financial Liability

The general consensus among the participants is the lack of access to capital and that this prohibits the adoption of WtE technologies. There is worry about poor performing municipalities and lack of feedstock guarantees.

Participant 10

"The current legislature does not give investors the security in making investment in the sector"

Participant 6 emphasised the need for partnership

"Partnerships with relevant stakeholders will create the safety net and return of investment as there is a need to diversify the waste sector"

Participant 3

"*WtE technologies are expensive to set up and run, you need to ensure that you have secured the required feedstock volumes to operate the plants*"

Participant 9

"It is important to de-risk projects, so that investors are attracted into making investments"

4.5.4 WtE enablers

a) Measures discouraging landfilling and educating waste generators and recyclers

All the participants agreed that certain measurers such as WTE technology, applying landfill tax and high landfill entry gates might be useful in trying to discourage disposal to landfill.

Participant 8 expressed that

"There is a need for enablers, but we need to be aware that they will come at a cost"

Participant 6 and Participant 12 cautioned against increasing landfill entry gates

Participant 6

"As a developing country, there is still a place for landfill, increasing landfill entry gates for businesses and citizens in a country that is struggling economically might come with issues"

Participant 12

"It is unavoidable to diversify the energy and waste sector. The South African dynamic is different in that the affordability to the masses will be increased which might lead to illegal dumping"

Participant 7 also said

"We need to understand the true cost of managing waste and properly implement the regulations that are already in place"

Participating 1

"Educating and involving waste generators and recyclers is necessary, each have an important role to play in the adoption of the technologies. Incentives for recyclers would also prove worthwhile"

4.5.5 *Investor Interest*

a) Adequate legislation and conditions to attract investors and collaborators

The participants were all of the same opinion that capital injection in the waste sector is a need, but were worried that due to poor governance in the country, it might be difficult to attract investors in the sector.

Participant 3

"There is a risk with government projects due to the current political landscape being unpredictable and funding from the government has been previously mis-used"

Participant 1

"Investors need guarantees of profits on their investments"

Participant 7

"Cost is not the only factor that investors look into before making the investments. Value proposition will need to be well communicated and documented effectively if there is a possibility on getting an investment"

Participant 2 and Participant 13 mentioned the need to diversify the type of collaborators required in the adoption of WtE technologies

Participant 2

"Local and international funding is available on projects that will yield results. Grants is a solution, but with investors who are looking into getting profits, they might be hesitant"

Participant 13

“To get these projects off the ground, you will need to get grant funding and soft loans will need to come into place. Grant funding from overseas organisations who don’t expect to gain monetary profits from these projects, but support such initiatives with soft loans the loan conditions attract less interest”

Participant 4 added that

“We probably need to look into small to medium scale technologies that might not need large CAPEX and OPEX amounts”

4.6 DATA TRIANGULATION

Data triangulation is a method using multiple sources to verify the integrity of the findings. Triangulation is a technique used to establish credibility or validation of a study (Given, 2008).

In this study triangulation was done using the government legislature and organisational studies.

Table 2 below shows data triangulation comparing it with information obtained from semi-structured interviews

Table 2 Data Triangulation

RSA Government Document (source)	Document Description	Issue	Comparison to Interviews

4.7 SUMMARY OF FINDINGS

Eleven themes came out of three propositions from the semi-qualitative interviews. The themes mainly focused on the perceptions of waste managers regarding factors that would influence the uptake of WtE technologies.

The themes that emerged from the semi-qualitative focused on the need to prioritise the waste hierarchy. The adoption of WtE technologies is regarded as one of the interventions needed to move up the waste hierarchy. According to the participants introducing WtE technologies would assist in improving waste management practices and reduce environmental challenges. New revenue streams were also mentioned as a result of adopting WtE technologies. The participants also highlighted the integral role that waste managers needed to play in the adoption of WtE technologies. Waste managers are regarded as researchers, educators and collaborators and are seen as the link that would bring all the stakeholders in the industry together.

According to the participants, factors that would influence the perceived ease of use and usefulness of WtE technologies is the affordability and feasibility of the projects, R&D in the local context, the need for capital, having guaranteed feedstock and the availability of technical skills and training. Mitigating these factors would eliminate some of the challenges that come with the introduction of a new technology in any industry, a lot of factors need to be looked into hence ensuring the feasibility exercises are done before adoption.

Political, economic, social, technological, environmental and legal challenges would also pose challenges with the implementation of WtE technologies and according to the participants these challenges were lack of education and stakeholder collaboration, lack of adequate legislature and poor governance and financial liability. Another factor is that landfill is still a cheap option in the province and to encourage the uptake of WtE technologies WtE enablers would need to be introduced, these included introducing equipment tax returns, landfill tax, high landfill entry gates, carbon credits, and energy sales as well as educate recyclers and waste generators.

Another major factor in the uptake of WtE technologies is the need for capital. In a developing country capital injection in the sector is a challenge. It is therefore important to create an environment that would attract investors. The participants noted these conditions as having adequate legislature support, contract transparency, collaborations, guarantee on investments and access to grants.

CHAPTER 5: DISCUSSION OF THE FINDINGS

5.1 INTRODUCTION

This chapter discusses the findings of qualitative study giving context of the literature review conducted in Chapter 2. The three propositions of the study are discussed per section concerning the findings from semi-structured interviews.

5.2 PROPOSITION 1 DISCUSSION

This section discusses the findings from proposition 1 **(**The role of waste managers is to responsibly develop and procure effective and efficient recycling, recovery and disposal of waste methods that meet service standards in accordance to policy, legal compliance and best practice) the question in relation to the proposition is (What is the level of awareness on WtE technologies in waste management in Gauteng?).

The results from the findings indicated adequate level of understanding that is required from Waste managers regarding WtE technologies. They indicated the benefits of adopting WtE technologies in Gauteng which were improved waste management practices, less environmental challenges and the introduction of new revenue streams. (Pilusa & Muzenda, 2014) concluded in their study that using fuels obtained from WtE technologies processes will positively affect the environment while boosting the circular economy.

The improved waste management practices include diversion of waste from landfill, reduce footprint to landfill, WtE technologies have a longer lifespan compared to landfills which would reduce landfill odours, toxic gases produced from landfill, improved air quality and less ground water contamination. The benefits of WtE technologies is supported by a study done by (Portugal-Pereira & Lee, 2016) which looks into the economic and environmental benefits of WtE technologies.

The results indicated the importance of the waste hierarchy which is prevention, re-use, recycling, recovery and disposal in waste management and the importance of diversify technologies in the waste sector in Gauteng. This is supported by (Kumar & Samadder, 2017) who outline the importance of the waste hierarchy.

The semi-qualitative interviews also showed the participants understood how WtE technologies would introduce new revenue streams into the sector which is supplementing the energy supply, promote the circular economy and to extract value from waste material. (Pilusa & Muzenda, 2014) in their research of .

The findings also strongly support the role of waste managers being major players in the role as collaborators which will assist in the de-risking of WtE projects, researching and developing appropriate WtE technologies for the local context, educating all stakeholders in the waste sector as well as the mapping and characterisation of waste to ensure that there is enough feedstock to operate the WtE technologies. The findings are in alignment with (Kaza & Bhada-Tata, 2018) and the paper discusses the role and the kind of decisions waste managers should make in the adoption of WtE technologies.

5.3 PROPOSITION 2 DISCUSSION

This section discusses the findings from proposition 2 **(**Identifying Challenges in the adoption of WtE technologies and finding the solutions, will influence the perceived ease of use as well as perceived usefulness of WtE technologies) the question in relation to the proposition 2 is (What are waste manager's opinions on the ease of operating WtE technologies and the perceived usefulness if WtE technologies were to be adopted?)

The results from the semi-qualitative interviews showed the participants understood the need to check the affordability and feasibility of adopting WtE technologies. For a project to be a success or fail from a financial and operations point of view, a feasibility and affordability study needs to be done. This is to manage stakeholder expectations about the cost and length of the project, logistics, finances and market challenges of a project. This is to make sure that time and money spent on the project is spent wisely and to enable enough resources and timeframe is put towards the project. They also discussed the importance of researching and developing methods that are suitable for the local context and how the fact that landfill is still a cheap option which might hinder the need and speed for the adoption of WtE technologies. (Kobayakawa & Kandpal, 2014) have done a study on renewable energy sources and the feasibility thereof which shows the importance of these studies.

Access to finance and the viability of the project has been factors that the participants agreed will be a major factor in the adoption of WtE technologies. The factors include the capital injection required for these projects, favourable regulations and policies, having guaranteed feedstocks and the need to have a return on investment for investors. These are some of the factors that the participants brought to light and these factors will influence the perceived ease and usefulness of the technologies. (Lu et al., 2023) also discussed these challenges that will affect the perceived ease and usefulness of adopting these technologies.

The other main factor that could affect the perceived ease of use and usefulness on the adoption of WtE technologies is the availability of technical skills locally. The participants did note that technical skills were available locally and that more technically complicated projects and plants in the likes of Sasol and Eskom have been previously worked on. The also mentioned that there are good universities in the country that are producing engineers and scientists that will offer the kind of technical ability required. The participants also discussed the need to have a skills and training transfer for a short period and installation from the overseas companies that produce the technologies. Having the technical skills available for the adoption of WtE technologies will positively influence the perceived ease and usefulness of adopting WtE technologies.(Lu et al., 2023) also discussed this under ease of operation.

Other indirect factors that were discussed by the participants that could affect the uptake of WtE technologies are the possible employment opportunities.

The participants said that unskilled and unskilled employment opportunities would be created across the whole value chain and some preferred diversifying technologies used in the waste sector instead of eradicating landfilling. Another major positive factor that could affect the adoption of WtE technologies is that it could supplement the shortages in the energy supply.

5.4 PROPOSITION 3 DISCUSSION

This section discusses the findings from proposition 3 (The introduction and implementation of alternative waste treatment technologies in developing countries will come with some challenges and all stakeholders including waste managers will need to find measures to mitigate them) the question in relation to the proposition 3 is (What do waste managers think the challenges and enablers would be, with regards to the implementation of WtE technologies in Gauteng?)

The results from the semi-qualitative interviews discussed some important points regarding the challenges, some of the points were the ones discussed by (Kumarasiri & Dissanayake, 2021) who discuss the barriers to implementing WtE technologies.

The participants mentioned the lack of political will, lack of education among stakeholders, resist to change from known waste management methods.

The lack of adequate legislature and poor governance were also discussed and these included no government guarantees, inadequate policies, long tender processes and treasury not adequately supporting the implementation of WtE technologies.

Lack of access to capital was discussed as a factor that majorly influences the implementation of WtE technologies. According to the participants high investment costs, poor performing municipalities and lack of feedstock guarantees made these projects a financial liability which would lead to the lack of access to capital injection.

To attract investor interest, the participants mentioned the need for adequate legislation and better investment conditions. Legislation support, contract transparency, stakeholder collaborations, grants and the guarantee that these projects are viable enough to give return on investment are some of the conditions needed to attract investors in the space.

To overcome the challenges that hinder the implementation of WtE challenges, this can be done by creating an enabling environment. The participants mentioned the introduction of technology tax subsidies, landfill taxes and high landfill taxes which were seen as controversial due to the fact that the cost will be passed onto the citizens who are already struggling in the low performing economy. Energy sales, carbon credits as well as educating and involving all stakeholders would assist in the uptake of WtE technologies.

(Kumarasiri & Dissanayake, 2021) discussed in their paper the introduction of tax returns on bought equipment, conduct awareness campaigns, draft simple policies for efficient implementation, involve all stakeholders in the drafting of policies, have favourable loan schemes and teach the public about separation at source.

According to (Maisiri et al., 2015) the introduction of WtE technologies would introduce new revenue streams which can be generated through gate fees, energy sales, carbon credits and the sales of metals.

5.5 CONCLUSION

The findings from the semi-qualitative interviews and literature review were aligned with regards to the role of waste managers' play in the procuring of waste to energy technologies as well as the benefits on the introduction of WtE technologies, which are improved waste management practices, less environmental challenges and the introduction of new revenue streams. Waste managers are also viewed as researchers, collaborators and educators.

Factors that would influence the perceived ease of use as well as perceived usefulness of WtE technologies that were discussed in the semi-qualitative is in line with that in literature. The factors according to the study participants include the feasibility and affordability of these technologies, access to finance, the availability of technical, training and skills transfer, potential employment opportunities and the need to diversify the energy supply.

The challenges and enablers on implementing WtE technologies that would have an impact on the implementation of WtE technologies in the semi-qualitative interviews corresponded to what is in literature. The challenges observed by the participants were the lack of stakeholder engagement and sufficient education, lack of adequate legislature and poor governance, lack of access to capital. The enablers were noted as equipment tax returns, introduce landfill tax, high landfill entry gates, energy sales, carbon credits as well as educating and involving all waste generators and recyclers.

To attract investors, the participants in the semi-qualitative interviews mentioned the need for transparency on contracts, having relevant collaborations, the need for grants and assurance on return on investment.

CHAPTER 6. CONCLUSIONS AND RECOMMENDATIONS

6.1 Introduction

This chapter summarises the findings of the propositions of the original research questions in Chapter 1, secondly, the chapter suggests recommendations for Chapter 1 under the significance of the study

6.2 Research question 1 conclusion

The first question of the research study investigates the level of awareness that waste managers have regarding WtE technologies in Gauteng. Based on the semi-qualitative interviews, waste managers are knowledgeable on WtE technologies. There is adequate understanding on the impact of WtE technologies in the waste sector. The participants understood that the use of WtE technologies will be prioritising the need to go up the waste hierarchy in Gauteng and this is through improved waste management practices, less environmental challenges and the introduction of new revenue streams.

Waste managers also understand the important role they need to play in the adoption of WtE technologies in the sector. They view themselves as researchers i.e. research and develop methods that are appropriate in the local context, characterise the type of waste generated in the province as well as map the waste, where it is from, who transports it, and where it is going? As a collaborator, they understand the need to have the type of partnerships that will encourage the adoption of WtE technologies, create an environment that is conducive for the uptake of WtE technologies and financially de-risking WtE technologies.

Waste managers also understand that they need to be an educator to all stakeholders in the waste sector to ensure that everyone is knowledgeable on WtE technologies and the role that they need to play.

6.3 Research Question 2 conclusion

The second question of the research study investigates waste managers' opinion on the ease of operating WtE technologies and the usefulness of these technologies. In the semi-qualitative interviews, the findings indicated the factors that would influence the ease of operating and usefulness of WtE technologies. WtE technologies are regarded as expensive as compared to disposing waste to landfill, therefore the feasibility and affordability of taking on these project will influence their uptake. Ensuring that the adopted technologies fit the local context will influence consumer uptake, relatability and adaptability and positive impact of these technologies.

The findings also indicated the need to ensure the viability of these projects in the local context. Having suitable guaranteed amounts of waste as feedstock will influence the choice of technology and its usefulness thus ensuring the viability of the project.

Having technical ability and scientific knowledge to operate WtE technologies is regarded as a factor that would influence the ease of operating the technologies. In the findings, technical ability and scientific knowledge are skills that as a province and country we do not have shortage of although training and skills transfer would be needed in the short term.

Due to employment and energy challenges that we face in the province and country. Adopting new technologies and their need to be seen as useful addressing some of these challenges would give advantage to the technology being adopted. WtE technologies can be regarded as useful in that skilled and unskilled employment opportunities would be created, energy supply will be supplemented and that the circular economy will be improved.

6.4 Research Question 3 Conclusion

The third question of the research study investigates what waste managers' think are challenges and enablers with regards to the implementation of WtE technologies in Gauteng. In the semi-qualitative interviews the findings indicated the challenges that would need to be overcome to before the uptake of WtE technologies as well as the suggested enablers that would make the uptake of WtE technologies possible.

Lack of sufficient education and stakeholder engagement is one of the challenges noted in the findings. Lack of political will, no or little education among stakeholders, resisting change from old waste management methods to embrace new waste methods. Without the buy in from all stakeholders the uptake of WtE technologies will be difficult or not even happen in the province. It is important that all stakeholders from the provincial government, researchers, waste managers, waste generators, the society and investors to buy into the idea of implementing WtE technologies.

Poor governance and inadequate legislature were also indicated as challenges that would impede the uptake of WtE technologies.

Current waste management policies in the province are not fully inclusive on how to legislate WtE technologies, long tender processes and lack of government and treasury backing investments in WtE technologies is also a hurdle that needs to be overcome to facilitate the uptake of WtE technologies.

Inadequate access to capital is a major challenge. High CAPEX and OPEX amounts are needed to construct WtE facilities, which waste managers in the province are struggling to attract. Poor performing municipalities and the lack of feedstock guarantees also make it difficult to attract investment in the sector.

In the findings, measures that were suggested to attract investment in the sector were proper legislation support, efficient and quick tender processes, transparent and simple contracts, guarantees on return of investment, getting grants and collaboration among all stakeholders.

The suggested enablers in the findings, to overcome challenges in the implementation of WtE technologies were having tax returns on equipment, introducing landfill tax and high landfill entry gates to discourage waste being taken to landfill for disposal. Energy sales, access to carbon credits for industries that use energy from the WtE technologies are also seen as measures to encourage the uptake of WtE technologies. Educating and including the stakeholders in all processes is seen an enabler that would make the adoption of WtE technologies possible.

6.5 Recommendations

This section looks at the recommendations of the research based on the significance of the study, Section 1.6 (Chapter 1). The study intended to understand the perceptions of waste managers on WtE technologies in Gauteng and sets to contribute in the knowledge of understanding how waste managers perceive WtE technologies and their understanding of them. Understanding the views of waste managers on WtE technologies will likely influence the adoption or non-adoption of WtE technologies.

The study assessed the level of awareness or knowledge waste managers have on WtE technologies, their opinions on the ease of operating and perceived usefulness of WtE technologies as well as the challenges and enablers with regards to the implementation of WtE technologies in Gauteng. From the knowledge that waste managers gave to light about WtE technologies, the following recommendations can be made to –

a) Gauteng government and policymakers

The findings in the study indicated the need for regulations to support the uptake of WtE technologies and the need for easier tender process and transparency. The provincial government and policy makers can look into strategies to align the regulations with regards to WtE technologies and to make processes to acquire funding more streamlined and transparent

b) Energy sector (IPPs)

The need to diversify the energy sector in the province gives IPPs the opportunity to look into WtE technologies. They would also have the knowledge to assist the municipalities in the province to develop the sector into viable business

c) Investors

The findings in the study identified the challenges and enablers of adopting WtE technologies. The information will assist investors to make informed decisions with regards to making decisions on whether to make investments in the sector or not

d) Public

The study will educate and inform the public about WtE technologies, this will allow them to understand WtE technologies and further inform their perceptions (whether positive or negative) on the adoption of WtE technologies

e) Waste generators

The study will educate waste generators on the adoption of WtE technologies. For waste generators it gives them the ability choose a waste management practice that is suitable for them in terms of cost, sustainability and their carbon footprint impact

f) Universities and research institutions

The study showed some of the challenges that are hindering the uptake of WtE technologies. Universities and research institutions can further study the challenges and come up with possible solutions to overcome the challenges

g) Urban planners

Space is an issue in the Gauteng province, there is competition for land for example schools, hospitals, commercial and housing space. The uptake of WtE technologies would allow urban planners to identify locations where these technologies can be constructed

6.6 Suggestions for further research

The study is limited to the Gauteng province to understand how waste managers perceive WtE technologies. The same study can be repeated in other provinces of South Africa.

There are different types of WtE technologies, this study did not focus on a specific WtE technology. A suggested research idea is to choose a specific WtE technology and study on how that particular technology is perceived by waste managers.

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APPENDIX A – CONSENT FORM

Research Title: Understanding how professionals employed in the waste industry perceive the adoption or use of waste to energy (WtE) technologies in Gauteng

Student Name: Ingrid Mokgolobotho

I ______________________ **(optional)** agree to participate in the research project named above. The study has been explained to me and I have understood what is expected of me. My questions prior to the interview have been answered to my satisfaction. I understand that I am free to request further information at any time during the interview

I agree that:

1. My participation in the study is voluntary
2. My personal information will be kept confidential
3. I am free to withdraw from participating from the study at any time
4. The interview may be audio-recorded
5. I will not be remunerated for participating in the study
6. By signing this document, I agree to participate in the study

Signature of participant: ______________________

Name of participant (Optional): ______________________________

Date: ____________________

APPENDIX B – PARTICIPANT INFORMATION SHEET

Dear Sir/Madam,

My name is Ingrid Mokgolobotho I am a Masters of Management in Energy Leadership candidate at the University of the Witwatersrand in Parktown, Johannesburg. For my Masters, I need to complete a research project as required for the programme under the supervision of Professor Lwazi Ngubevana, I am conducting a research on the perception on the adoption or use of waste to energy technologies in Gauteng by waste managers. The aim of this study is to understand how professionals in the waste sector perceive the adoption of waste to energy technologies in the sector

I would like to invite you to participate in an interview as part of my research project. The questionnaire will consist of 13 questions.

If you engage in this survey, no personal expenses would be incurred. Additionally, there are no compensations or reward benefits attached to this interview. If it does not please you to engage, there are no consequences, and you have the option to withdraw or not respond. The interview will be entirely confidential and they will be kept anonymous, no personal information such as your name or address and contact number will be required. Any information you provide to me will be kept private and will not be shared with someone else it will be for the sole purpose of this study. In my final report, I will use a false identity to reflect your involvement.

Please feel free to email me at any time before or after the interview if you have any concerns. My contact information is listed below. On the university library's website, this study will be published as a research paper. If you would like a summary of the paper, please let me know and I will gladly give it to you. The information gathered for this study will be saved in my external hard drive and Google Drive for a period of two years. For any concerns relating to the ethical procedures of this study, kindly contact the Human Research Ethics Committee

(Non-Medical), telephone +27(0) 11 717 1408, email hrec-medical.researchoffice@wits.ac.za

Yours Sincerely,

Ingrid Mokgolobotho.

Researcher: Ingrid Mokgolobotho,

Supervisor: Prof. Lwazi Ngubevana,

APPENDIX C – RESEARCH INSTRUMENT

Proposition 1

The role of waste managers is to responsibly develop and procure effective and efficient recycling, recovery and disposal of waste methods that meet service standards in accordance to policy, legal compliance and best practice

Questions 1

1.1 How would WtE technologies assist in the management of waste?

1.2 What role do waste managers can play in the procuring of new technologies in waste management?

Proposition 2

Identifying Challenges in the adoption of WtE technologies and finding the solutions, will influence the perceived ease of use as well as perceived usefulness of WtE technologies. The technology acceptance model (TAM) looks at perceived usefulness of a new technology as well as the ease of operating the new technology(Taherdoost, 2018)

Questions 2

2.1 If WtE technologies were to be available, would and explain

2.1.1 the technologies be easily accessible?

2.1.2Waste managers be willing to try out the new technologies?

2.1.3The needs of waste managers be met?

2.1.4How would the waste sector attract the technical skills needed to operate the technologies?

2.2 Do you think the availability of WtE technologies would

2.2.1Improve the management of waste and why?

2.2.2Provide employment opportunities in the sector without the loss of talent and how can that be achieved?

2.2.3 Reduce the consumption of fossil fuels?

Proposition 3

The introduction and implementation of alternative waste treatment technologies in developing countries will come with some challenges and all stakeholders including waste managers will need to find measures to mitigate them

Questions 3

Challenges with the implementation of WtE technologies include political, environmental, social, technological, economic, legal (PESTEL) barriers (Kumarasiri & Dissanayake, 2021).

3.1 At what extent and how would think PESTEL barriers would impede the adoption of WtE technologies?

Some of the proposed enablers that may enhance the introduction WtE technologies are WtE technologies subsidisation, applying landfill tax to discourage the construction of new landfills, high landfill entry gate fees, introduce new revenue streams such as energy sales and diversify the energy mix

3.2 Would these enablers increase the chances on the implementation of WtE technologies and why?

3.3 In your view, would WtE be attractive to investors and banks and why?

APPENDIX D – ETHICS CLEARANCE CERTIFICATE

Graduate School of Business Administration
University of the Witwatersrand, Johannesburg

Wits Business School Ethics Committee
Constituted under the University Human Research Ethics Committee (Non-Medical)

Ethics Clearance Certificate

Ethics protocol number: WBS/EL0301195V/257
This certificate is only valid with a legitimate ethics protocol number and signed by the Researcher (below).

Project title	Perceptions on the adoption or use of waste-to-energy technologies among waste managers in Gauteng
Investigator / Researcher	Ms Ingrid Mokgolobotho
Nature of Project	MM (Energy Leadership)
Decision of the Committee	Approved, provided stakeholders and participants are guaranteed confidentialty.
Issue Date of Certificate	2023/10/30
Expiry date	Date of submission of the project / research report
Chairperson	Dr Pius Oba ☎ +27 11 717 3976 +27 82 733 6587 pius.oba@wits.ac.za

Declaration by Researcher

One copy must be signed by the Researcher and returned to the Chairperson of the Wits Business School Ethics Committee.

I fully understand the conditions under which I am authorized to carry out the abovementioned research and I guarantee to ensure compliance with these conditions. Should any departure to be contemplated from the research procedure as approved I undertake to resubmit the protocol to the Committee.

Signature

30 - 10 - 2023
Date: