Thermal conversion of waste-to-energy by incineration in Johannesburg

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ABSTRACT

The City of Johannesburg's population growth and economic activity have resulted in increased amounts of generated municipal solid waste (MSW); concerns developed about landfill airspace depletion. Environmental concerns subsist as a landfilling activity often create greenhouse gases, air pollution and water contamination, therefore, contributing to climate change. Conversely, the City requires electricity to keep its economic activity functional, while providing its citizens with electricity. This case study examined the opportunities and impediments of waste-to-energy (WtE) implementation in the City of Johannesburg. Focus was on thermal conversion by mass-burn incineration, identifying the function of decision-making frameworks in supporting the integrated solid waste management leading to development and WtE implementation. The study established that WtE will stimulate the circular economy in the City of Johannesburg, therefore, contributing to environmental preservation, waste minimisation, and additional electricity capacity for the City. To align with the legislated decision framework, the waste hierarchy, the WtE facility should incorporate the material recovery facility (MRF). The waste hierarchy and other legislated processes, such as the Municipal Finance Management Act (MFMA) and the public-private partnership (PPP) Framework, are inadequate to support WtE development. The research recommends developing a local government-based decision-making framework by the City of Johannesburg—service delivery focused; this would complement existing legislation. A multi-criteria decision making (MCDM) model is suggested. The increase in grid tariffs, cost-reflective gate fees, and introducing landfill tax could contribute to the commercial viability of WtE. The identified barriers are a lack of education and awareness, and improper stakeholder engagement with WtE. Findings indicate a lack of expedited legislation processes tailor-made for projects, such as WtE and five-year political terms, hampering service delivery plans. Findings also identified access to waste by independent power producers

(IPPs) and the City of Johannesburg's financial viability as barriers. These should be focused on to realise WtE implementation.

KEY WORDS – City of Johannesburg, waste-to-energy, municipal solid waste, landfill, circular economy, decision-making frameworks

DECLARATION

I, Nkumbulo Sithole

, 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 the Field of 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: Nkumbulo Sithole Signature:

Signed at Johannesburg

On the …3rd……. Day of …August…….…… 2022

DEDICATION

I dedicate this research to my late grandmother, WIN Sithole, and my mother, TG Sithole.

My wife, Nosisa Sithole, and my children, Owethu and Thando Sithole.

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I thank my supervisor, Dr Mohlala, for guiding me throughout this research; when things were tough, you inspired me to continue.

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AD	anaerobic digestion
AHP	analytical hierarchy process
ANP	analytic network process
APES	Academic and Professional Editing Services
AWTT	alternative waste treatment
CoGTA	Cooperative Governance and Traditional Affairs
DEMATEL	decision-making trial and evaluation laboratory
DFI	Development Financial Institution
DMRE	Department of Mineral Resources and Energy
DPE	Department of Public Enterprises
EIA	environmental impact assessment
EISD	Environment and Infrastructure Services Department
EPR	extended producer responsibility
ESI	electricity supply industry
GCRO	Gauteng City Region Observatory
GHG	greenhouse gases

IDP	Integrated Development Plan
IMCDM	integrated multi-criteria decision-making model
IPP	independent power producers
IRP	integrated resources plan
ITSO	independent transmission system operator
LCA	life cycle assessment
LCC	life cycle costing
LFGTE	landfill gas extraction to energy
MCDM	multi-criteria decision-making
MFMA	Municipal Finance Management Act
MOE	municipal-owned entities
MRF	material recovery facility
MSA	Municipal Systems Act
MSW	municipal solid waste
MSWM	municipal solid waste management
O&M	operations, and maintenance
PPA	power purchase agreements
PPP	public-private partnership

QLFS	Quarterly Labour Force Survey
REIPPPP	Renewable Energy Independent Power Producer Procurement Programme
RFP	request for proposals
SADC	Southern Africa Development Community
SALGA	South African Local Government Association
SAW	simple additive weighting
SDG	Sustainable Development Goal
WEC	World Energy Council
WtE	waste-to-energy

CHAPTER 1. INTRODUCTION

1.1 Introduction

This chapter outlines the study purpose while providing orientation on the topic. This is achieved by discussing the study purpose, the context of the study, the research problem, the research questions, the significance of the study, the delimitations, and assumptions.

1.2 Study purpose

This research was based on a case study examining the opportunities and impediments to WtE implementation in the City of Johannesburg (the City). The focus was on thermal conversion by mass-burn incineration and how decision-making frameworks play a significant role in supporting integrated solid waste management, leading to WtE development and implementation.

1.3 Context of the study

As per the Constitution of South Africa, municipalities are mandated to provide basic services (Covary, 2020), including electricity and municipal solid waste (MSW) management. The City of Johannesburg provides these services through its municipal-owned entities (MOEs), such as City Power and Pikitup, responsible for electricity services and MSW management, respectively. The South African state-owned utility Eskom, provides electricity to parts of the City (Abrahams & Everatt, 2019).

South Africa encountered electricity security supply problems since the capacity shortages begun in late 2007 and early 2008, leading to rotational load shedding to avoid total grid collapse (Covary, 2020; Kelly, 2016). This study is crucial as it tackles both the electricity security problems and challenges relating to landfill airspace, which, according to Dlamini et al. (2019), is expected to be depleted by 2023. This is compounded by that the City of Johannesburg has the highest population growth in South Africa and is at the centre of South Africa's economy (Dlamini et al., 2019).

It was clear from the studies that the City of Johannesburg needs to approach two critical issues, electricity security and MSW disposal. Ironically MSW, is a proven source of energy in several parts of the world (Moya, Aldás, López, & Kaparaju, 2017). The City has indicated interest in exploring WtE by undertaking activities, including feasibility studies, scrutinising, and enabling by-laws and industry engagements both locally and abroad (City of Johannesbug, 2017). Despite all these efforts, the City is struggling to implement WtE as one of the optimal solutions to curb the waste problem. While there seems to be a challenge on thermal conversion implementation, it is worth noting that on the landfill gas extraction to energy (LFGTE) projects with a combined capacity of 19 MW were awarded in the Renewable Energy Independent Power Producer Procurement Programme (REIPPPP).

This case study indicated that WtE is one of the critical components addressing the MSW management problem, while reducing the need for new landfill sites. WtE also contributes to curbing emissions emanating from landfill sites while adding to electricity capacity and, therefore, contributing to catalysing the circular economy.

1.4 Research problem

According to Dlamini et al. (2019), the City of Johannesburg's landfill airspace would be depleted by 2023. The City already encounters high transportation costs as the landfills in the northern regions, running out of airspace, therefore, needed to transport MSW to the southern regions-based landfills. No approval for the new landfill site development exists; however, the City earmarked two land parcels for new landfill sites. This provides an environmental challenge as landfills are known for their ecological degradation through water contamination, as reasoned by Nevondo et al. (2019). There are still problems with air pollution (CO_2, CH_4 and N_2O) and other hazards, therefore, contributing to the climate change problem (Scheutz, Kjeldsen, & Gentil, 2009).

Besides its waste management problems, the City encountered electricity security of supply emanating from the Eskom load shedding since 2007 and 2008 and capacity shortages, resulting in electrification backlogs (Nxumalo, 2018). This is further exacerbated by theft and illegal connections. In 2020, Eskom initiated load reduction programmes in areas affected by high loading emanating from illegal connections (Eskom, 2021). These activities lead the City to exceed its notified maximum demand during peak hours and encounter associated penalties.

To address these challenges, the City of Johannesburg undertook several studies assisted by appointed experts called "transaction advisors". According to the City of Johannesburg (2017), the first study was conducted in 2008; the second in 2010; the third in 2015; and lastly, in 2017. These studies identified MRF and WtE as alternative waste treatment (AWTT) to landfilling, addressing electricity security concerns and climate change mitigation.

Despite all these efforts, the City did not implement thermal conversion WtE for more than a decade since the inception of its AWTT programme. In 2020, the City of Johannesburg issued a request for proposals (RFP) for AWTT, which included two MRF at Robinson Deep and Marie Louise Landfill sites and WtE at Robinson deep. The scope of work is for the environmental impact assessment (EIA) and PPP procurement process; the project is expected to reach a financial close in 2023.

More than a decade after the inception of its AWTT programme, the City is yet to implement the programme. In the process appointing several transaction advisers and obtaining funding from development financial institutions (DFIs). The study indicated that barriers derailing the progress still apply to the ongoing work the City is undertaking.

Studies indicated that by 2023 the City would run out of landfill airspace if the AWTT programme is not implemented, so the City should implement its programme before this eventuality. The problem that the study evaluated was to explore and investigate decision-making frameworks the City employs and actions they should undertake for successful WtE implementation.

1.5 Research questions

By sanctioning several studies to determine the feasibility of WtE implementation technologies, the City of Johannesburg only advanced and implemented LFGTE in the REIPPPP. The City has not yet implemented thermal conversion technologies despite their proven success in reducing MSW by electricity generation from the global perspective. This study contends this is because of the lack and non-implementation of decision-making frameworks in the City. For example, the City must conform to the Waste Act of 2008, prescribing the waste

hierarchy as a framework for MSW management. The City is not aligned with the waste hierarchy, with the waste disposal still dominating at 80%. For this research, therefore, the questions were:

a) What are the potential benefits of WtE implementation for the City?
b) What decision-making frameworks and actions are needed to implement WtE?
c) What would be the consequences of WtE non-implementation in the City?
d) Is WtE a commercial proposition?
e) What are barriers to WtE implementation through thermal conversion?

1.6 Significance of the study

This research attempted to contribute to the literature undertaken in WtE, focusing on the City of Johannesburg, South Africa. The area of contribution is on the impediments or barriers to WtE implementation and opportunities. Whereas there was WtE implementation in the developed countries, minimal implementation in Africa was established, particularly with thermal conversion technology (Makarichi et al., 2019).

This study observed decision-making frameworks and why they were not implemented or adopted, identifying amendments required which may help WtE implementation; for example, the integrated multi-criteria decision-making (IMCDM) model developed by Wang et al. (2018) and the energy justice criteria and alternatives as described by Fetanat et al. (2019). These decision-making frameworks are suitable in WtE as they follow similar approaches to the waste management hierarchy prescribed in the Waste Act of 2008.

Additional research was reviewed; for example, Dlamini et al. (2019) contend that implementing thermal conversion WtE technologies could lead to 93% diversion of waste from landfills and extend landfill airspace to 2030 instead of depletion by 2023 as forecasted. They have not indicated explicitly in their studies why it has not been implemented even though it could present such benefits. This study, therefore, identified the barriers to implementation while analysing the decision-making frameworks by the City and WtE operators across the globe. Emissions emanating from the WtE plant, and its commercial viability, were also assessed.

According to Stafford (2019), the increase in MSW generation results from rapid urbanisation in Africa. This is supported by Dlamini (2019), contending that urbanisation in the City of Johannesburg resulted in increased waste quantities. This urbanisation cause growth in electricity demand within cities. Stafford (2019) asserts that MSW treatment with WtE technologies addresses both challenges at once, indicating the disposal of waste and associated environmental pollution and energy demand and security.

From similar studies, it is concluded that Johannesburg implemented LFGTE projects under the REIPPPP (Baker & Letsoela, 2016). Second, WtE thermal conversion technologies have not been implemented yet in Johannesburg despite their successful deployment in other cities abroad.

The expected beneficiaries of the study include:

f) The City of Johannesburg and its entities on developing, adopting, and amending decision-making frameworks in alignment with the country's Constitution.
g) Government policymakers and administrators across the country.

h) The private sector, in particular IPPs, which attempt to enter power purchase agreements (PPAs) with municipalities to generate electricity from WtE technologies.
i) The academic research fraternity concerning the barriers and opportunities of WtE in metropolitan municipalities in Africa.

1.7 Delimitations of the study

According to Young (2010), the methods of treating MSW to Energy are primarily:

a) A thermal conversion includes mass-burn combustion, often called incineration, gasification, pyrolysis, and plasma arc gasification
b) A biological conversion includes anaerobic digestion (AD) and landfill gas extraction.

The City implemented LFGTE technology and conducted several studies on the feasibility of thermal conversion technologies without success. The study was limited to the City of Johannesburg Metropolitan Municipality to ascertain barriers to WtE implementation by thermal conversion technologies in the City. The study undertook that the information provided by the participants is correct and a true reflection based on their expertise and experience.

1.8 Definition of terms

Incineration: also called mass-burn incineration, is combustion of waste in the presence of oxygen or air (Young, 2010).

Municipal solid waste: waste “garbage generated from households, commercial business and schools” (Young, 2010, p. 2).

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

Thermal conversion: waste treatment by combustion processes to produce heat, fuel, or gas (Kumar & Samadder, 2017).

Waste-to-energy: generation of energy from MSW conversion by either biological or thermal technologies (Awasthi et al., 2019; Kumar & Samadder, 2017; Young, 2010).

1.9 Assumptions

The assumptions of this research were as follows:

a) There is a willingness by the City to implement WtE based on several feasibility studies conducted, yet there are known and unknown impediments.
b) The City's MSW characteristic content is suitable for WtE generation and sufficient as indicated by feasibility studies.
c) The answers provided by the selected participants generate the answers this research pursued.

1.10 Structure of the report

This research report comprises the following six chapters:

1. CHAPTER 1: This chapter serves as an outline of the purpose of this study while providing orientation to the reader on 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 important terms for this study are circular economy, decision-making frameworks, consequences of non-implementation, commercial viability, and impediments to WtE implementation. At the end of the literature, review, propositions are stated as possible answers to the research questions posed in Chapter 1.
3. 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.
4. 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 extracted from transcripts. This is followed by categorisation of codes in various themes and lastly mapping the correlation among themes, defining and naming themes.
5. CHAPTER 5: 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.
6. **Error! Reference source not found.**: 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

This research was based on a case study, examining the opportunities and impediments of WtE implementation in the City of Johannesburg, focusing on thermal conversion by mass-burn incineration. How decision-making frameworks support the integrated solid waste management leading to WtE development and implementation was evaluated.

This chapter analyses the literature on the subject, attending to the divergences within the literature. First, the background of energy and waste management evolution is investigated and presented and how this led to implementing first waste treatment technologies and how later energy was recovered from the same technologies. Second, the review of WtE implementation technologies explores the global perspective, South African context, and the City of Johannesburg. The drivers leading to implementation and understanding of the constraints are analysed and demonstrated through theoretical frameworks. This is followed by:

a) Identifying positive contributions, including opportunities for WtE implementation
b) Consequences of inaction
c) The required decision-making frameworks and actions to implement WtE
d) The commercial viability of WtE
e) Identifying the barriers to implementation

The research contends that the City encounters the electricity security challenges and associated rising costs. MSW generation and disposal challenges could

contribute to resolving the electricity problem and climate change mitigation by energy recovery from MSW.

2.2 Energy and waste management evolution

This section focuses on energy and waste management evolution and the WtE technology implementation and advancement globally. The information collected demonstrates that the WtE technology is worldwide well advanced.

Since the industrial revolution in the 1760s, energy has played an integral role in transformation, economic growth, and the transition of human development from one phase to the next. Wrigley (2013) contends that before the industrial revolution, humanity and communities relied on the annual cycle of plant photosynthesis for their energy needs—wood and water were the choices of energy sources. According to Zou et al. (2016), after this age of wood, coal took over as the main primary energy source, followed by oil and gas. It could be deduced that the primary energy sources evolved with new resource discoveries and innovative technologies which derive value from fossil fuels and conversion into valuable energy.

According to Ritchie et al. (2017), fossil fuel-based primary energy sources of coal, oil, and gas have maintained a high share in the energy systems globally as of 2017. Fossil fuel-based energy sources were the major influencer and impetus in the technological, socio-economic, and development progress during the industrial revolution. Fossil fuel-based energy sources are a major cause of greenhouse gas (GHG) emissions leading to climate change. To curb the climate change problem globally, the energy sector is undergoing an unprecedented transition from centralised carbon-intensive fossil fuel-based systems to

decentralised low carbon systems. This transition is led by renewable and clean energy sources and technologies with energy efficient and storage systems.

While the newly discovered energy sources and related technologies actualised high paced industrialisation and modern cities. People flocked to the cities, pursuing jobs and business opportunities to improve their livelihood. This urbanisation generated large MSW quantities (Dlamini, 2019; Qazi, Abushammala, & Younes, 2018; Rasmeni & Madyira, 2019). This rapid increase of population and economic activity often leads to illegal dumping of MSW, as contended by Dlamini (2019), lacking sufficient infrastructure creating environmental and health problems in cities.

According to Young (2010), systematic burning of waste began in Nottingham, England, during the 1870s. The first waste incinerator was commissioned in New York, the United States, in 1885. These initiatives were to approach waste problems as urbanisation increased and the space for dumping was already decreasing. Young (2010) continues that Washington DC experienced a lack of space for waste during 1889. In 1898, the first recycling occurred in New York.

In recent years, waste disposal challenges and its environmental and health problems led to adopting solid waste management systems supported by implementing the waste hierarchy. This study considers that energy recovery from waste is second from the bottom of the waste hierarchy, as demonstrated in Figure 1. Studies revealed that countries embracing and implementing recycling enjoy significant waste reduction. They also hold successful WtE energy operation regimes (Kumar & Samadder, 2017).

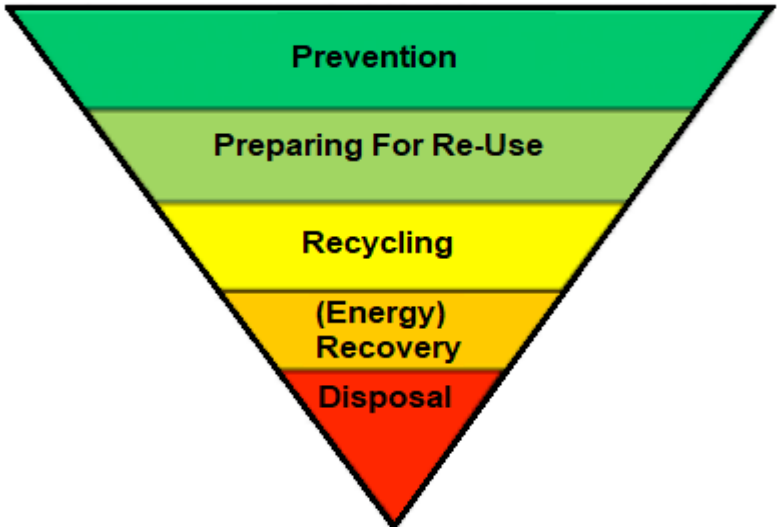


Figure 1: Waste hierarchy (AlQattan et al., 2018)

According to Godfrey and Oelofse (2017), South Africa remains behind the developed countries in waste management, with 90% of MSW being landfilled. A huge opportunity remains for South Africa to benefit from MSW availability to resolve electricity shortages, environmental and health problems, and landfill airspace depletion.

According to Young (2010), the methods of treating MSW to Energy are primarily:

a) Thermal conversion, including mass-burn combustion, is often called incineration and gasification, pyrolysis, and plasma arc gasification
b) Biological conversion, including AD and landfill gas extraction

The two treatment technologies are demonstrated as schematic in Figure 2 below.

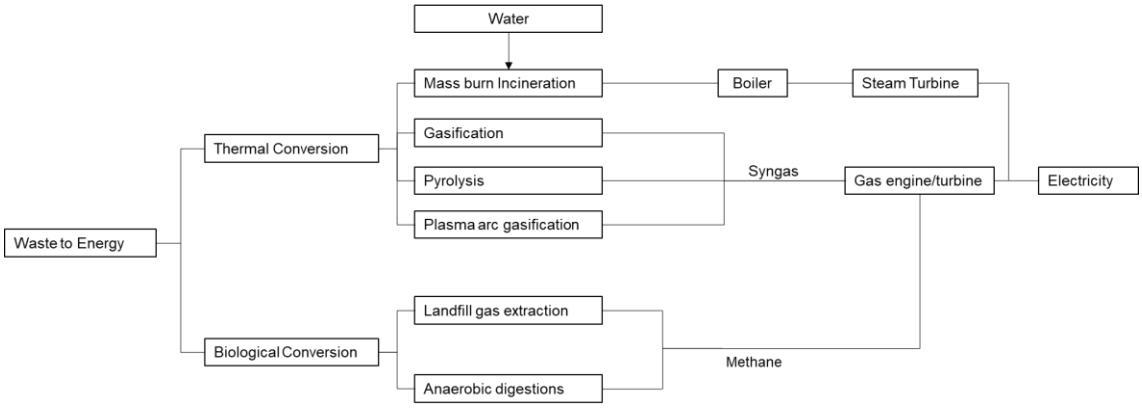


Figure 2: Waste conversion processes adopted from (Young, 2010)

2.2.1 *Global context*

Globally, based on the urbanisation trends, MSW daily generation is projected to grow to 6 million tonnes in 2025 (Makarichi, Jutidamrongphan, & Techato, 2018; Qazi et al., 2018). With this rapid urbanisation and population growth come infrastructural constraints about landfill airspace availability (Dlamini, 2019). This implies that as waste generation quantities continue to grow, it will lead to inadequate landfills to accommodate MSW. As contended by Qazi et al. (2018), cities should adopt and implement waste management according to the priorities of the waste hierarchy. The waste hierarchy regard landfilling as the last option after exhausting all other levels, indicating prevent, reduce, reuse, recycle, and recovery (WtE).

For the period 2015 to 2017, European Union 28 countries (EU-28) generated MSW—98.1%, treated in this manner:

a) Composed and digested: 16.7%
b) Recycled: 30.1%
c) Incinerated (WtE): 28.1%
d) Landfilled: 25.1% (Castillo-Giménez, Montañés, & Picazo-Tadeo, 2019)

This translates to 75% average of landfill airspace saved. Denmark and Sweden, where waste landfilling for all combustible material was banned, achieved a landfill rate of 1% and 0.6%, respectively. Defined and implemented legislation and policy, therefore, influence the outcomes. Figure 3 comprises the graph of the EU-28 concerning their MSW management. The total number of plants in Europe is 420 (Awasthi et al., 2019).

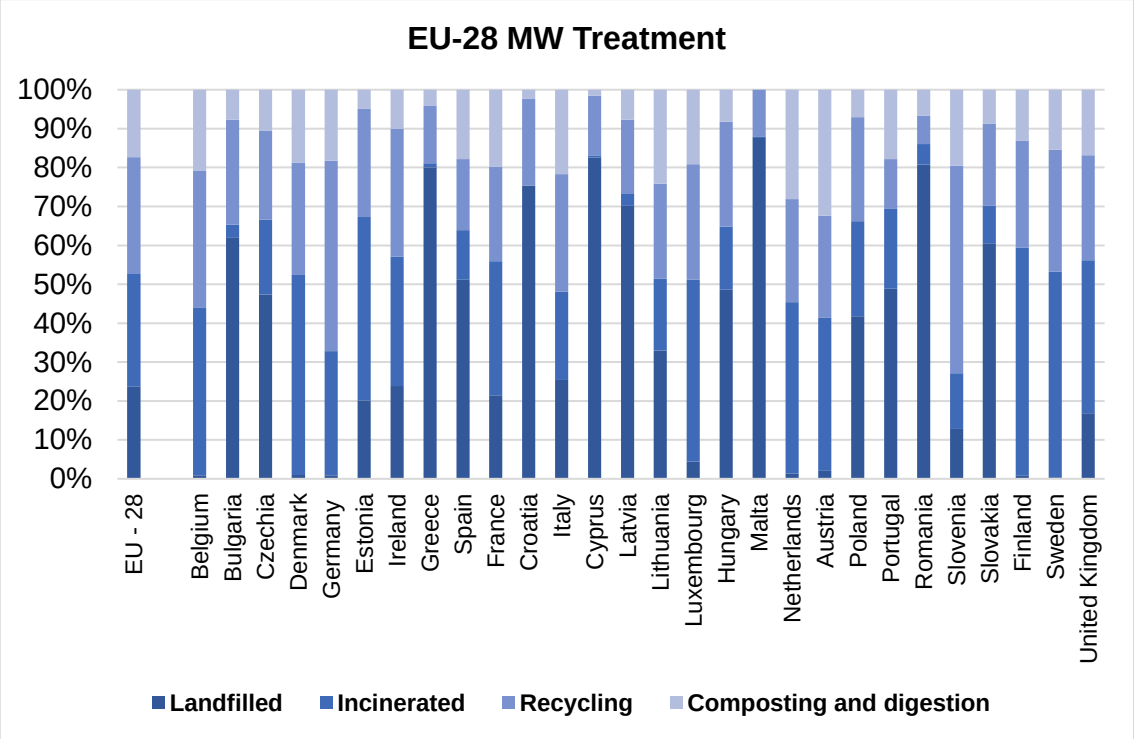


Figure 3: EU-28 MSW Treatment 2015 to 17 (Castillo-Giménez et al., 2019)

Japan is the world leader in WtE conversion by incineration with 1900 WtE units, whereas China has 434 WtE units (Awasthi et al., 2019). Japan, as of 2015 generates about 41 million tonnes and incinerates about 32,9 million tonnes of MSW (Japan Industrial Waste Information Center, 2018). Several Asian countries implement WtE technologies and MSWM. According to Kumar et al. (2017), Singapore recycles 44% of its waste. Other countries, such as India, Malaysia, and Vietnam, are deploying their WtE projects.

Sub-Saharan Africa still has the lowest waste generation compared to other regions (Awasthi et al., 2019). Ethiopia has one WtE incineration plant in Sub-Saharan Africa (Makarichi, Kan, Jutidamrongphan, & Techato, 2019); this plant was commissioned in 2018 with an installed capacity of 20MW. Other countries, such as South Africa and Mauritius, have LFGTE plants (Makarichi et al., 2019).

2.2.2 *South African context*

In 2011, South Africa generated 108 million tonnes of waste, of which 59 million tonnes is MSW (Dlamini, 2019; Mabalane, Oboirien, Sadiku, & Masukume, 2020). According to Mabalane et al. (2020), 10% of this MSW is recycled, and 53 million tonnes are disposed in landfill sites. With increased population growth and urbanisation, it is expected to continue to grow.

WtE has made little progress in South Africa's electricity supply industry (ESI), which is heavily reliant on coal as its primary energy source. According to Ratshomo and Nembahe (2019), coal contributes 69% of primary energy sources, with renewables contributing 11%. This high coal dependence is a huge contributor to CO_2 emissions in South Africa—2020 electricity generation contributed 212 Mt CO_2 e (Eskom, 2020).

Despite the potential presented by MSW for energy conversion, South Africa lacks WtE thermal conversion plants by incineration. Some plants are LFGTE based, commissioned in South Africa. Additional biogas plants exist, as illustrated in Table 1 below.

Table 1: Waste-to-energy plants in South Africa (Source: as indicated per row)

Location	Plant description
Johannesburg	Combined installed capacity of 19 MW from five landfill sites of the City (Baker & Letsoela, 2016)
Durban	eThekwini Metro projects: Marianhill (1MW) and Bisasar Road (6.5 MW) – LFGTE projects commissioned in 2006 and 2008, respectively (Sangham, 2017)
Cape town	New Horizons WtE plant - 560 tpd of MSW to produce biogas (Surroop, Bundhoo, & Raghoo, 2019)
Bronkhorstspruit,	Bio2Watt's biogas plant – a biogas to energy plant (4.6 MW) (Surroop et al., 2019)
Grabouw	Elgin Fruit Juices biogas facility - 5 tpd of waste fruit (0.5 MW) (Surroop et al., 2019)

2.2.3 *Johannesburg context*

MSW management services in the City of Johannesburg is mandated to Pikitup, the MOE wholly owned by the City. The City generates 1.5 million of solid waste annually (Rasmeni & Madyira, 2019). This spans the City's geographical area of 1 646km² (Dlamini, 2019) and a population of 5.4 million in 2017 (Abrahams et al., 2018). The City's geographic area is indicated in Figure 4 as in 2017, the City operated four landfill sites, and the two new sites were proposed (City of Johannesbug, 2017). The other two new sites have not been approved yet.

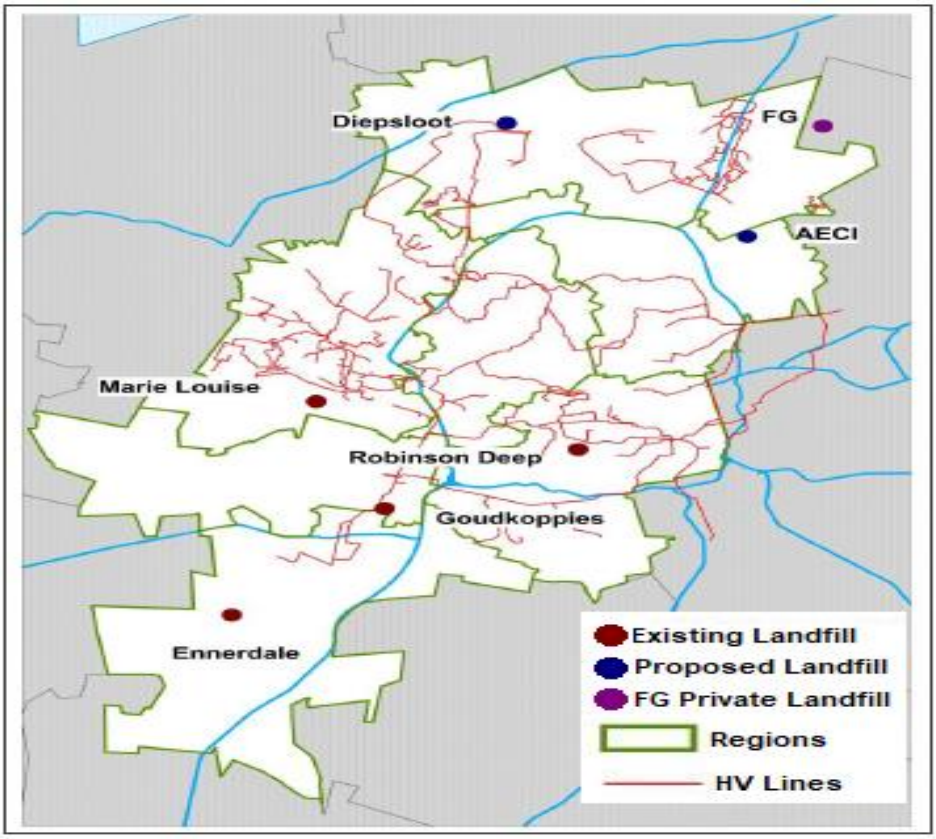


Figure 4: The City geographic area (City of Johannesbug, 2017)

In 2015, under the REIPPPP, five landfill sites in of the City of Johannesburg were awarded for landfill gas to energy extraction (LFGTE); with a combined capacity of 19 MW, this capacity can supply electricity to 12500 middle-income households (Baker & Letsoela, 2016). The City lacks WtE incineration projects despite several feasibility studies. In 2017, the City released a feasibility report, proposing an AWTT solution.

According to the City of Johannesburg (2017), this solution would entail two MRFs at Robinson Deep and Marie Louise landfill sites. Waste not recovered from the MRF would be channelled to the proposed 25 MW WtE site at Robinson

Deep. The WtE plant would treat 335 000 tonnes annually by deploying incineration, moving grate combustion technology (City of Johannesbug, 2017). The proposed project has not yet begun with construction. In June 2020, the City issued the RFP to appoint the service provider, overseeing the EIA and the procurement according to the PPP framework. It is expected that the financial close would be reached in 2023, when construction may begin.

2.3 Theoretical foundation

Municipal solid waste management involves various stakeholders (Wang et al., 2018). There are several treatment technologies commercially viable today. The most prominent technologies include landfill gas extraction, AD, incineration, gasification, pyrolysis, and plasma arc gasification (Young, 2010). Based on these options, it is often a complex process to select MSW treatment technology. This section analyses theoretical frameworks supporting WtE implementation. Wang et al. (2018) contend there are often conflicts among stakeholders in WtE technology selection and implementation; therefore, decision frameworks are critical as they handle these conflicts.

Soltani et al. (2016) developed a decision framework for selecting the most mutually agreed sustainable solution and technology options for conflicting stakeholders. The conflicting priorities for stakeholders are environmental, economic, and social aspects.

The components of the decision framework by Soltani et al. (2016) include sustainability assessment frameworks, life cycle assessment (LCA), and life cycle costing (LCC) of competing for technology options to determine both environmental affects and costs over a lifetime. An MCDM analysis was performed to rank and select suitable options by weighing the components of the

selected criteria and technology options comparison. For optimal use of the MCDM framework, the stakeholders should agree on the criteria beforehand.

Several MCDM frameworks can be employed, Soltani et al. (2016) selected the analytical hierarchy process (AHP). The AHP is the most widely deployed decision-making framework, popular for MSW management and energy planning (Yap & Nixon, 2015). Finally, to complete their decision framework, Soltani et al. (2016) use game theory to capture and model the engagement among stakeholders, such as municipalities and cement industrial companies in Metro Vancouver, Canada.

Fetanat et al. (2019) conducted a case study for the city of Behbahan, Iran. They proposed a decision-making framework for waste treatment technologies to implement WtE based on the energy justice criteria, alternatives, and integrated multi-criteria decision-making model (IMCDM).

According to Fetanat et al. (2019), WtE strategies should be developed considering the energy trilemma context. According to the World Energy Council WEC (2019), the three critical components of the energy trilemma are energy security, energy affordability, and environmental sustainability. Energy justice emerges to balance the components of the trilemma. The challenge of the trilemma is to balance the three elements because progress towards meeting any two of these goals creates problems concerning meeting the third. WtE implementation contributes to the balance of two and possibly all elements of the trilemma by:

a) Contributing towards meeting energy security and additional energy access can be achieved, particular in developing countries with energy poverty.
b) Reducing GHG emissions by preventing methane formation in landfill sites or extracting methane to generate energy

c) Energy affordability depends mainly on technology maturity in a country and political and socio-economic aspect.

Decision prioritisation could be based on the energy trilemma to achieve energy justice. Fetanat et al. (2019) contend that various alternative technologies for WtE treatment exist; however, these would be influenced by various factors, such as waste content and type, geographical location, availability of expertise and skills. The technology choice would be influenced by environmental considerations, socio-economic aspects, and technology maturity and acceptance.

The IMCDM framework developed by Fetanat et al. (2019) is based on a Wang et al. (2018) developed fuzzy decision-making trial and evaluation laboratory (DEMATEL) method, which could avert conflict among various stakeholders. The model ranks the WtE technologies in order prioritisation (Fetanat et al., 2019). The fuzzy DEMATEL method was employed with the analytic network process (ANP) to weigh the ten energy justice criteria components and the simple additive weighting (SAW) approach, selecting the most suitable technology options.

Decision-making frameworks could assist and fast track decision-making processes in developing countries, particularly Africa, where there is minimal progress in WtE implementation projects.

2.4 Positive contributions of implementing waste-to-energy

According to Malinauskaite and Jouhara (2019), the three critical areas of WtE in policy are waste management, energy, and climate change. These three policy components are essential in establishing a circular economy (Malinauskaite & Jouhara, 2019). This aligns with Pan et al. (2015), contending that WtE could be the sustainable way to implement the circular economy, simultaneously resolving

the predicament of energy shortages, waste management challenges, and climate change.

Hahladakis, Lacovidou, and Gerassimidou (2020, p. 8) define a circular economy as “a system that can restore, retain and redistribute materials, components and products back into the system in an optimised manner and for as long as it is environmentally, technically, socially and economically feasible”. Based on the above definition, it can be deduced that the circular economy system is aligned, promoting the waste hierarchy in waste management prioritisation. Malinauskaite et al. (2019) contend that in the circular economy environment, waste is circulated to the system as useful raw material, contributing to energy generation while reducing GHG emissions. Waste is no longer observed as ‘waste’ but as a useful resource, resolving the landfill airspace problems.

2.4.1 *Catalysing and implementing the circular economy*

This section maintains that WtE implementation would benefit by contributing to the catalysation and implementing the circular economy. It would contribute to three critical areas of concern in Johannesburg, indicating waste management, energy demand, and climate change.

Circular economy supports the reuse, retaining, and redistribution of material within the system in a substantial sustainable period (Hahladakis et al., 2020). According to Pan et al. (2015), circular economy provides a positive platform to accommodate a prosperous economy and sustainable environment. Figure 5 indicates WtE participation and contribution in a circular economy.

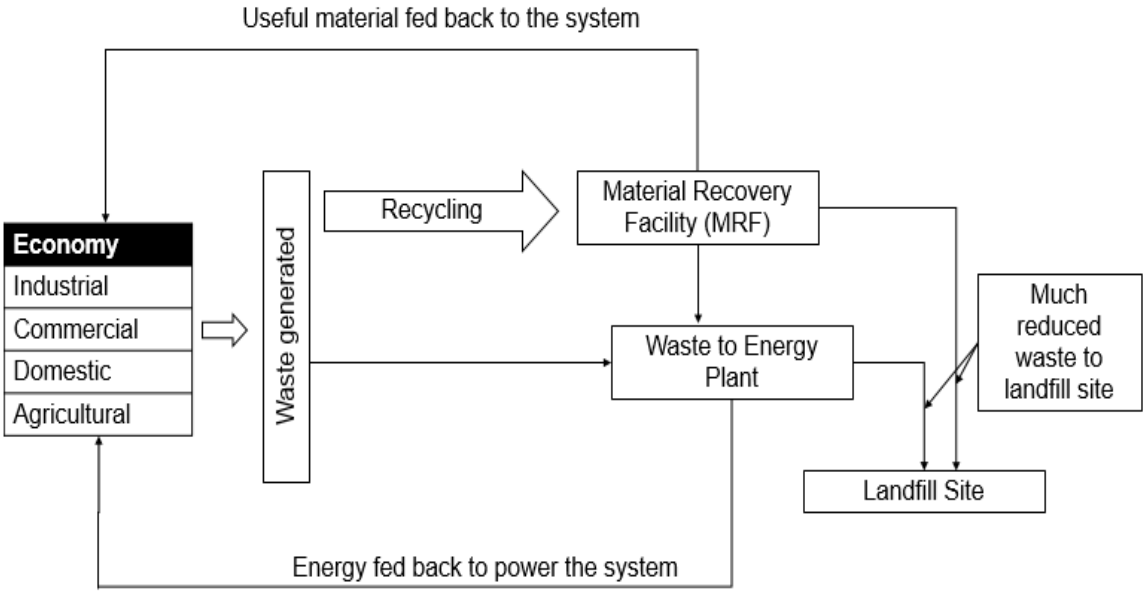


Figure 5: Waste-to-energy participation in a circular economy (Van Caneghem, Van Acker, De Greef, Wauters, & Vandecasteele, 2019)

As depicted in Figure 5, the waste generated in the economy is fed back to the system through recycling; second, the remnants are supplied to the WtE plant as a second priority after recycling. The energy (electricity and heat) generated from the WtE plant supplies the economy, generating waste. Landfilling is the last resort according to the waste hierarchy; the limited waste disposed of improves land availability and reduce GHG resulting from landfill sites.

WtE will, therefore, contribute to improved energy access by reducing energy deprivation to the citizens of the City, while addressing landfill airspace depletion problems and, finally, reducing GHG and other environmental hazards associated with landfilling. These WtE aspects lead to the circular economy catalysation.

2.4.2 *Proposition 1*

WtE implementation would contribute to catalysing the circular economy in the City of Johannesburg.

2.5 Decision-making frameworks and actions to implement waste-to-energy

The decision-making frameworks proposed in this study are supported by the waste hierarchy framework and the energy justice-based decision-making frameworks for WtE technologies, such as those described by Fetanat et al. (2019) as they:

a) Align with WEC energy trilemma, which attempts to balance three challenges: energy security, energy affordability, and environmental preservation. These three challenges must be weighed and balanced to arrive at an investment decision.
b) They are also aligning with the Waste Act of 2008, which prescribes adopting waste hierarchy as a framework for solid waste management.
c) Align with the Constitution of South Africa, focusing on the right to a clean environment, emissions reduction, and justifiable economic and social development.

In several developed countries, WtE implementation, the main drivers are increasing volumes of waste generated because of rapid urbanisation, climate change mitigation, and energy security. Several countries introduced incentive schemes to support WtE implementation owing to the high capital investment costs in WtE development. These countries adopted the waste hierarchy to

enforce effective integrated solid waste management systems. The waste hierarchy prioritises prevention, reuse, and recycling before energy recovery.

According to Kumar and Samadder (2017), countries embracing and implementing recycling have effective WtE projects. This is supported by Malinauskaite et al. (2019), contending that Europe leading with WtE facilities holding effective recycling. These countries include Denmark, the Netherlands, and Sweden. From these arguments, it could be deduced that following a waste management system according to the waste hierarchy leads to WtE implementation and, therefore, this is a policy and legislation driven action.

These countries aligned with the energy trilemma as described by the WEC by considering in their decisions energy security, affordability with incentives and subsidies as well as environmental preservation, deploying WtE as a renewable source and prevention of landfilling. A clear alignment with the MCDM ranks the WtE technologies in order of prioritisation, particularly by adopting the waste hierarchy, which prioritises prevention, reuse, recycles recovery, and disposal.

Farooq et al. (2021) developed a decision-making framework for sustainable MSW management systems. The framework includes these inputs:

a) Environmental considerations
b) Waste composition
c) Capital and operational costs
d) Technology efficiency and complexity
e) Expertise and suitable locality for the WtE plant

The framework by Farooq et al.(2021) considers developed and developing worlds, as indicated below in Figure 6.

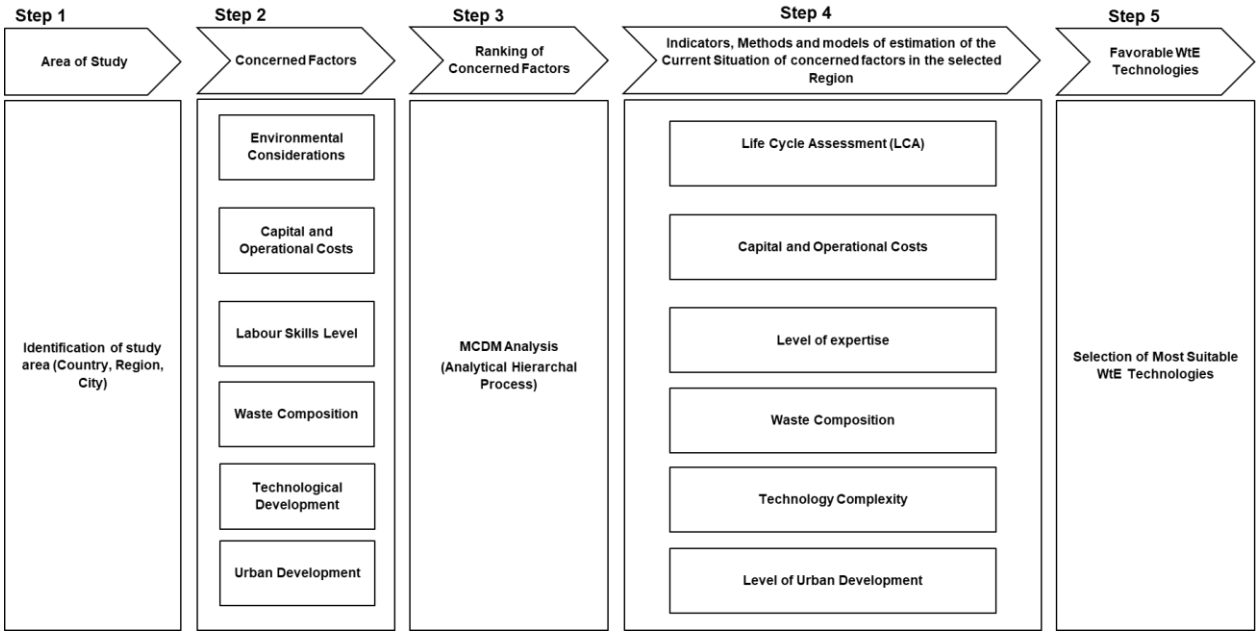


Figure 6: General framework for waste-to-energy suitable technology (Farooq et al., 2021)

2.5.1 *Energy policy and legislation in South Africa*

In South Africa, new generation capacity is developed and implemented based on the IRP. The inaugural IRP 2010 was published in 2011 and recently updated 2019 (DMRE, 2019). The IRP is the electricity plan for the country, determining the future path, requiring new capacities, decommissioning, and infrastructure upgrades of the South African ESI (Mqadi, Musango, & Brent, 2018). The IRP is the living document, updated regularly, especially with the fast-changing energy transition. Although the IRP does not explicitly mention WtE, it falls under the category of “other”; therefore, municipalities could pursue this option, requiring no ministerial determination.

In 2019, the Department of Public Enterprises (DPE) published a roadmap for Eskom in a reformed ESI to divide Eskom into three entities:

a) Generation
b) Transmission
c) Distribution

This enables the creation of the independent transmission system operator (ITSO) (Department of Public Enterprises, 2019). The formation of the ITSO would advance the removal of the monopoly of Eskom, sometimes observed as the impediment to implementing renewable energy sources. This was perceived when Eskom refused to endorse the PPAs for REIPPPP round four, delaying the implementation of renewables in South Africa. In 2020, the Department of Mineral Resources and Energy (DMRE) issued draft amendments to the Electricity Regulations Act on new generation capacity enabling the municipalities in good financial standing to procure electricity directly from IPPs. This would enhance the opportunity for implementing other sources of energy, such as WtE, to curb electricity shortage crises and landfill airspace depletion.

2.5.2 *Proposition 2*

Adoption and implementation of decision-making frameworks would lead to WtE implementation.

2.6 The consequences of waste-to-energy non-implementation

This section identifies the consequences to the City if WtE were not implemented. The study explored three critical service delivery areas of the City:

a) Solid waste management
b) Electricity delivery
c) Environmental impact

2.6.1 *Solid waste management in Johannesburg*

The Constitution of the Republic of South Africa mandates municipalities to provide waste management services, such as waste collection, transportation, treatment, and disposal (Covary, 2020; Malope, 2020). The City of Johannesburg provides its waste management services through its MOE Pikitup. The City experiences challenges in MSW management, resulting from people flocking the City from all corners of South Africa and recently from Africa, particularly from SADC neighbouring countries. The rapid increase of the population in the City complicates matters for Pikitup to follow its MSW management mandate. According to Simelane (2017), the rapid expansion of uncontrolled and unplanned urbanisation leads to escalated governance challenges. This fast and unplanned urbanisation, therefore, leads to inferior quality service delivery and solid waste management.

According to Kubanza and Simatele (2020), solid waste mismanagement is one of the major causes of environmental degradation problems and can lead to challenges related to poor health and economic and social concerns. According to Quantec, as quoted by Abrahams et al. (2018), the population of Johannesburg was estimated to be 5.4 million in 2017; this is the highest of any city in South Africa. This population growth compounded the social problems in the City, leading to the increase of illegal informal settlements (Lekalakala, 2019). Solid waste management problems, therefore, increased in the City, leading Pikitup to struggle to fulfil its mandate.

An increase in population translates to a rise in MSW generation (Dlamini, 2019; Qazi et al., 2018; Rasmeni & Madyira, 2019). According to Dlamini (2019), this rapid population and economic activity increase often lead to illegal dumping of MSW with insufficient infrastructure, creating environmental problems in cities. The forecast indicates that at this rate of MSW generation and population growth, the landfill airspace in the City would be depleted by 2023 (Dlamini et al., 2019). They further contend that if WtE energy were implemented in the City, this landfill airspace lifeline would be extended to 2030.

2.6.2 *Electricity delivery*

Electricity provision in the City is mandated to City Power, an MOE wholly owned by the City. City Power is accountable for purchasing, distribution and selling electricity in the areas under the jurisdiction of the City, apart from areas in Soweto and Sandton supplied by the national utility Eskom (City Power, 2018). The City receives the bulk of its electricity supply from Eskom and the rest through its PPA with the Kelvin Power Station (City Power, 2018).

According to Culwick (2018), electricity access levels in the City of Johannesburg are at 90%, therefore, leaving 10% of citizens of the City without electricity access. Most of these are from townships and informal settlements on the rise in the City. The problem of non-access is exacerbated because Eskom struggles to meet the demand in the country, often resorting to load shedding since 2007. The City of Johannesburg stressed its desire to reduce reliance on Eskom, attempting to engage with IPPs as an alternative to the Eskom unreliable supply.

2.6.3 *Environmental impact*

According to Kearns (2019), greenhouse gases (GHG), such as carbon dioxide (CO_2) and methane (CH_4), are generated in landfills and dumps. The waste decomposes and is released into the atmosphere, causing significant harm to the environment. Kearns (2019) continues that landfilling and dumping are, therefore, unsustainable methods. According to Mohee and Simelane, as quoted by Dlamini (2019), 90% of MSW is disposed of in landfills in Johannesburg. This is supported by Rasmeni and Madyira (2019), indicating several studies confirm that 90% of MSW reaches open dumps and landfill sites.

The City generates 1.5 million tonnes of solid waste annually (Rasmeni & Madyira, 2019). This number is expected to continue to increase significantly as the population of the City grows. WtE technology deployment, therefore, can curb the generation of these GHG emissions with reduced MSW creation. The City's LFGTE project is expected to reduce 60 to 70% of GHG emissions emanating from landfill sites during its life span (Baker & Letsoela, 2016).

In 2021 the City of Johannesburg devised a recycling program that includes a separate recycling fee to be levied on residences located in the City's suburban districts to slow the growth in MSW generation and disposal (City of Johannesburg, 2021). However, following the public participation processes the City shelved the proposed levy. Even though not yet implemented the proposed levy on affluent households is an indication that the City is prioritising recycling in alignment with the waste hierarchy.

2.6.4 *Proposition 3*

The City would encounter these consequences if WtE is not implemented. Landfill airspace depletion, illegal dumping resulting in induced infectious diseases leading to poor health and environmental degradation and over-reliance on the national grid for electricity would not be curbed, and energy access would not be improved.

2.7 Waste-to-energy commercial viability

This research considered alternatives to determine the commercial viability of WtE in the City, including grid electricity tariffs and other renewables, such as solar photovoltaics (PV) and Wind, landfill gate fees, and landfill tax. The revenue streams generated by the WtE plants were analysed as described by Maisiri, Van Dyke, De Kock, and Krueger (2015). These include energy sales, gate fees, metals sales, and carbon credits. Finally, the capital costs of WtE technologies were analysed and incentives adopted by the countries that successfully implemented WtE over the years.

2.7.1 *Grid electricity tariffs*

According to Kelly and Geyer (2018), before a democratic government, Eskom supplied affordable electricity, though most citizens lacked electricity. This cheap electricity legacy prevented other technologies to compete with the coal dominated grid. Figure 7 depicts the historical trend of grid electricity average tariffs. When South Africa embarked on its generation capacity new build programme, the prices increased by 460% from 2007 to 2020 (Figure 7).

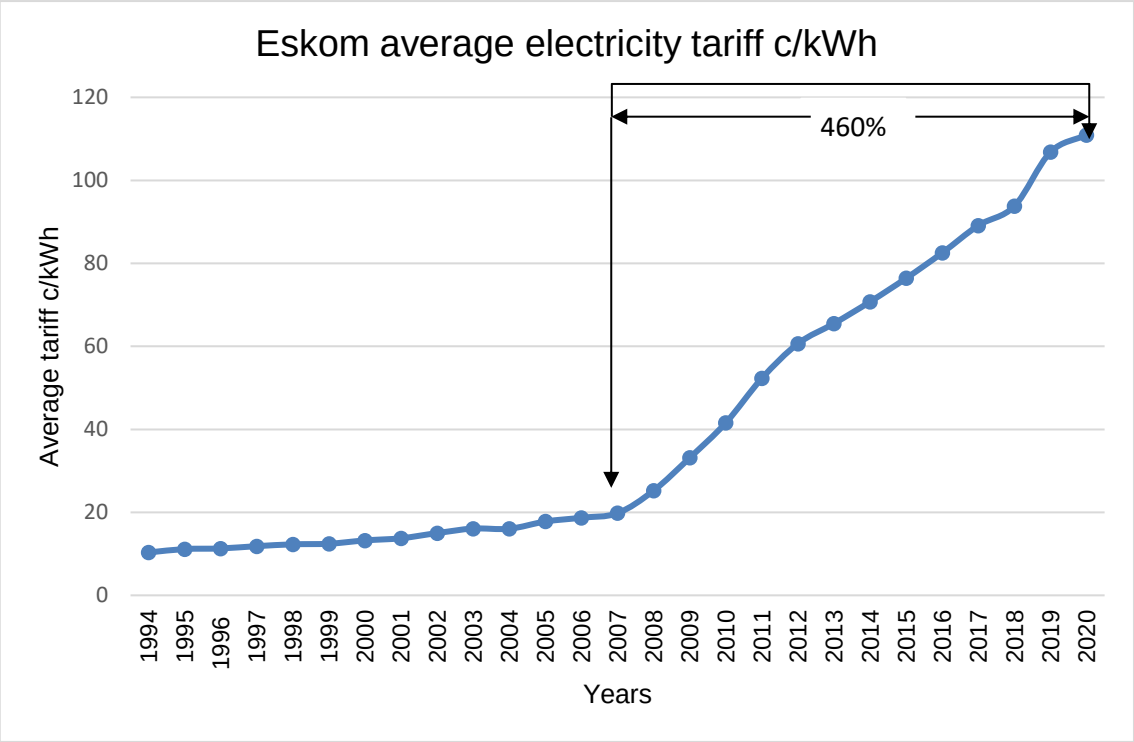


Figure 7: Eskom average electricity tariff (nominal)c/kWh (Eskom, 2021,May 11)

According to Amsterdam and Thopil (2017), even though in the last decade grid electricity tariffs increased considerably, they were still cheaper compared to WtE (LFGTE) tariffs in 2017. The LFGTE tariffs bid in REIPPPP in 2015 were 94c/kWh compared to the grid electricity average price of 70,10c/kWh in the same year. The REIPPPP tariffs are government-guaranteed if a default by Eskom occurs, catalysing the energy investment from IPPs in South Africa. According to Young (2010), mass-burn incineration has the highest capital, operations, and maintenance (O&M) costs. These elevated capital investments and O&M costs for incineration could cause high tariffs that may not easily compete with other technologies and discourage its development.

2.7.2 *Landfill gate fees and landfill tax*

The landfill gate fees in South Africa are cheap and, therefore, discourage the diversion of waste from landfills (Adeleke, Akinlabi, Jen, & Dunmade, 2021). According to Amsterdam et al. (2017), the range of landfill gate fees in South Africa is R100 to R150/tonne with the highest fees at around R450/tonne, whereas in Europe, the range is 80 to 140 Euro/tonne besides the landfill tax. For the City of Johannesburg, the gate fee is R180/tonne.

The gate fees could be crucial in a WtE plant as they can offset costs, contributing to the high tariff. The landfill tax would discourage the developing of new landfill sites, while most of the waste would be redirected as feedstock to the WtE facilities.

2.7.3 *Waste-to-energy revenue stream*

Revenue streams that could be derived from the WtE plant include gate fees, energy sales, carbon credits, and metal sales (Maisiri et al., 2015). All energy generating plants WtE derive most of its revenues from the actual sale of electricity through PPAs. According to Maisiri et al. (2015), the revenues through energy sales could cover 80% of all O&M and capital loan repayments. Gate fees otherwise directed at landfill sites are critical contributors to the revenue streams of the WtE plant. Other contributors are by-products metals of value sold to the markets.

2.7.4 *Waste-to-energy subsidies*

Amsterdam et al. (2017) contend that subsidisation could be an enabler of WtE in South Africa if it is introduced. They also emphasise the lack of subsidies in

the WtE industry as a hindrance to its implementation. Maisiri et al.(2015) contend that with subsidisation, WtE becomes more attractive to investors. This aligns with the observations of Amsterdam et al. (2017), asserting that in the early stages of WtE development, the government should intervene with subsidies, as this is necessary in the WtE sector. In several developed countries, subsidies played a significant role; without subsidies, the projects do not make a financial standing.

2.7.5 *Proposition 4*

Capital and O&M costs for WtE by incineration are expensive, leading to high tariffs; for WtE to be commercially viable, decision-makers should consider subsidisation, landfill tax, and high landfill gate fees, discouraging landfilling and supporting WtE deployment.

2.8 Barriers to waste-to-energy implementation

According to (Coelho, 2020), WtE opportunities can be two-fold. First, contributing to GHG emission prevention by displacing fossil fuel-based energy generation. Second, contributing to energy provisions, simultaneously diversifying the energy mix. Growing populations and urbanised waste generation continue to increase, providing sufficient quantities for WtE. Despite increased volumes, landfill airspace limitations, environmental and health hazards related to waste disposal, many African countries and cities have not yet used the energy potential of waste. This section attempts to establish the barriers to WtE implementation by incineration from the government's perspective (local and national), investors (IPPs and banks), and residents.

Dlamini et al. (2019) contend that despite successful global WtE deployment, challenges to implementation remain, such as operating financial implications, stakeholder perceptions and acceptance, legislations, and institutional frameworks. Coelho (2020) and Pan et al. (2015) assert that the barriers to WtE implementation include:

a) Financial risks and barriers
b) Technology barriers
c) Institutional barriers
d) Market failures

2.8.1 *Financial barriers*

Historically, the South African state-owned utility, Eskom, under apartheid laws, was mandated to provide reliable electricity to the country at the cheapest possible tariffs (Kelly & Geyer, 2018). With the electricity crises of 2007 and 2008 resulting in load shedding, South Africa attempted to introduce IPPs to relieve the situation. The problem was that the Eskom tariff was too cheap for IPPs—the reason is that previous investors were uninterested in investing in South African ESI. The City of Johannesburg embarked on its WtE feasibility in 2008 (City of Johannesbug, 2017). During 2008, the Eskom tariffs had risen as Eskom embarked on its massive new build programme. The Eskom tariffs were still way too low to compete with, indicating that any new WtE must be subsidised. The City receives 90% of its electricity through Eskom, for cheaper than WtE.

Coelho (2020) contends that WtE technologies capital investment and operations and maintenance regimes are expensive. The required expertise is lacking and could lead to expensive labour. Considering WtE, developers must convince local

authorities that the transportation costs, landfilling, and carbon emissions penalties exceed the costly tariffs.

Dlamini et al. (2019) contend that in addition to a lack of institutional and policy framework, WtE also lacks finance. But to finance renewables, the South African government established a green fund in 2011 that is headquartered at DBSA ((Bhandari, 2014). The case for WtE's finance mechanisms should be supported by the green fund and commercial financing institutions.

2.8.2 *Technology barriers*

According to Coelho (2020), where WtE energy technologies were globally successfully deployed, the main challenge is that the waste contents differ. The technologies deployed elsewhere may not perform at their optimal levels in another region. This means that waste characterisation must ascertain its contents (calorific value and moisture) and establish the technology parameters suitable for this waste. It is perceived that WtE technologies are enormous emitters of GHG, leading to a ‘not in my back-yard’ attitude by the residents threatened by the WtE plants.

Waste-to-energy technologies involves thermal conversion technologies incineration, gasification, pyrolysis, and plasma arc gasification or biological treatment (AD or landfill gas extraction). Incineration is the most advanced as it was first deployed just to burn waste without energy recovery and later deployed for WtE recovery (Kumar & Samadder, 2017). The other technologies, such as gasification, pyrolysis, and plasma arc gasification, require a homogenous waste type. These technologies are more expensive than mass-burn incineration but more efficient and emit lesser.

The biological treatment is based on biodegradable organic waste material, resulting from the waste separation process at source or MRF. The product of this process is biogas, which could be used in a gas engine to produce electricity. Methane is extracted from landfill sites; this is not preferred as this study advocates for waste hierarchy implementation and, therefore, observes waste disposal as the last option.

2.8.3 *Institutional barriers*

According to Sustainable Energy Africa (2017), WtE includes waste management and electricity delivery and, therefore, would involve various municipal entities or departments with their own separate budgets, human resources, skills, and reporting lines. Conflicts may evolve based on the priorities of these entities. While the electrical department is interested in electricity production and meeting the demand, the waste department is interested in improving waste minimisation—the feedstock for energy generation.

Sustainable Energy Africa (2017) contends there must be clear roles and accountability regarding feedstock management and supply. This would limit conflicts, as both aim to complement each other sustainably. They approach GHG emission reduction to prevent health hazards while stimulating the economy by creating jobs and generating new revenues streams for the municipality.

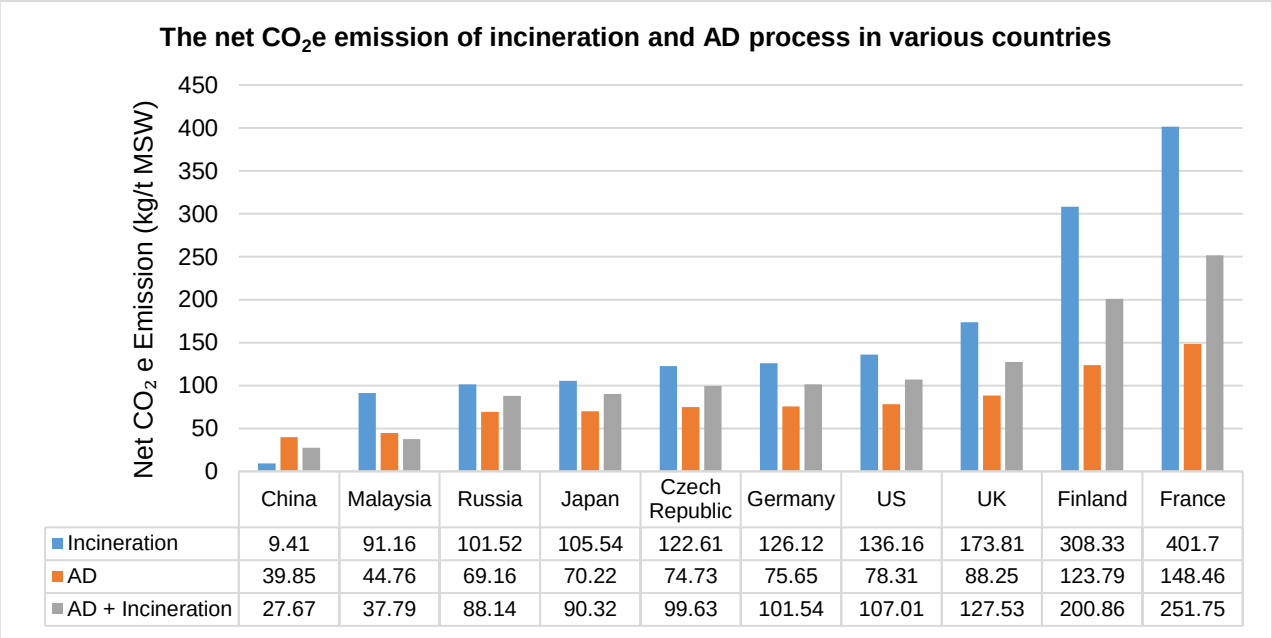
Government bodies, including NERSA, DMRE, DFFE and the city council, regulate electricity generation, legislating and regulating waste treatment (City of Johannesbug, 2017). The processes of approval, therefore, could be time-consuming because of multiple government bodies involved. According to Sustainable Energy Africa (2017), approval for WtE projects could take three to eight years.

2.8.4 *Environmental barriers*

According to Liu (2020), WtE encounters opposition from several residents, observing this as an unwanted facility in their localities. This stigma emanates from the perceived negative environmental impact of WtE facilities. Adeleke et al. (2021) support this observation, confirming a consensus that WtE facilities should be far from the neighbourhood because of the visible pollution from the plants, in particular incinerators. This resulted in the ‘not in my backyard’ phenomenon, where residents can enjoy electricity benefits from WtE if it is not in their area of residence.

Although WtE has benefits, such as minimising MSW volumes and electricity generation, it contributes to flue gas emission, which could be harmful to the environment if not well handled (Cudjoe & Acquah, 2021). According to Wilson et al. (2013), incineration of MSW, such as fossil fuel combustion, produces carbon dioxide, nitrogen, sulphur oxides, and other gas phases of organic and inorganic air emissions.

When selecting WtE technologies typically, AD is preferred, compared to the thermal conversion methods, because of its high efficiency and low emissions. The chart in Figure 8 below by Van Fana et al. (2019) illustrates emissions from incineration and AD in various countries—mostly sampled countries, where incineration has higher net CO_2 e emissions.



	China	Malaysia	Russia	Japan	Czech Republic	Germany	US	UK	Finland	France
Incineration	9.41	91.16	101.52	105.54	122.61	126.12	136.16	173.81	308.33	401.7
AD	39.85	44.76	69.16	70.22	74.73	75.65	78.31	88.25	123.79	148.46
AD + Incineration	27.67	37.79	88.14	90.32	99.63	101.54	107.01	127.53	200.86	251.75

Figure 8: The net CO2e emission of incineration and AD process in various countries (Van Fana et al., 2019)

Even though AD is preferred over incineration, it is difficult to deploy as the biodegradable material must be separated first. In countries lacking advanced waste management systems, there is no separation at source and, therefore, MSW is mixed, causing selection of incineration. Incineration is preferred to LFGTE as landfilling proved to be more detrimental to the environment.

2.8.5 *Proposition 5*

Barriers to implementation include:

a) Financial
b) Technological
c) Institutional
d) Environmental

2.9 Conclusion of literature review

Waste-to-energy implementation occurs through thermal conversion technologies, incineration, gasification, pyrolysis, and plasma arc gasification or biological conversion (LFGTE and AD). Among these technologies, incineration is the most advanced as it was first deployed to mass-burn waste without energy recovery, later deployed for energy recovery. The biological treatment is based on biodegradable organic waste material, resulting from the waste separation process at source or MRF. The product of this process is biogas, which could be used in a gas engine to produce electricity. Methane is extracted from landfill sites. This is not preferred, as this study advocates for implementing the waste hierarchy and, therefore, observes waste disposal as the last option.

WtE technologies were implemented in the 1920s but were not used fully despite being technologically proven and improving. The incineration technology was proven for over a century and succeeded deployed in Europe, Asia, and Americas. Barriers to implementation remain, including:

a) Financial
b) Technological
c) Institutional
d) Environmental

To overcome such barriers, developing countries and Johannesburg in particular should take lessons from countries implementing WtE for over a century. This can be conducted by adopting theoretical decision-making frameworks, such as energy justice, alternative technologies, and MCDM. This research attempted to prove that WtE implementation benefits outweigh these barriers.

Waste quantities would increase while disposal space is depleted by rapid urbanisation and population growth. Concerning the City, landfill airspace would be depleted by 2023. If WtE was implemented, it could save 90% of airspace, extending the life cycle of landfills to 2030. The landfill sites in the northern parts of the City are closed, forcing the City to use private landfills and to transport waste to the southern regions of the City for disposal.

WtE implementation would address issues about land availability, while attending to energy demand and complement electricity the City receives from Eskom. This would partially address the load shedding challenges, load reductions and capacity exceedance charges. WtE contributes significantly to reducing GHG emissions, mitigating against climate change, environmental degradation, and health hazards.

WtE is pivotal in the stimulation of the circular economy phenomenon. The circular economy creates opportunities for environmental preservation and job creation by ensuring that materials perceived as waste are observed as commodities and are reused, redistributed, and reinvested in the economic system for an extended period.

WtE is capital intensive, resulting in high tariffs compared to other technologies. For WtE to be commercially viable, decision-makers should consider subsidisation, landfill tax, and high landfill gate fees, discouraging landfilling and supporting WtE deployment.

2.9.1 *Proposition 1*

WtE implementation would contribute to catalysing the circular economy in the City of Johannesburg.

2.9.2 *Proposition 2*

Adoption and implementation of decision-making frameworks would lead to WtE implementation.

2.9.3 *Proposition 3*

The City would encounter these consequences if WtE is not implemented; landfill airspace depletion, illegal dumping resulting in induced infectious diseases leading to poor health and environmental degradation and over-reliance on the national grid for electricity would not be curbed, and energy access would not be improved.

2.9.4 *Proposition 4*

Capital and O&M costs for WtE by incineration are expensive, leading to high tariffs. For WtE to be commercially viable, decision-makers should consider subsidisation, landfill tax, and high landfill gate fees, discouraging landfilling while supporting WtE deployment.

2.9.5 *Proposition 5*

Barriers to implementation include:

a) Financial
b) Technological
c) Institutional
d) Environmental

CHAPTER 3. RESEARCH METHODOLOGY

This chapter outlines the methodology followed in this study, describing the approach where the study's research questions were addressed and how the data were analysed. The areas covered include the research approach, the research design, the data collection method, population and sample, the research instrument, the data collection procedure, data analysis and interpretation, limitations of the study, and ethical considerations.

3.1 Research approach

This case study followed a qualitative research approach. This research approach was informed by Creswell (2009), remarking that qualitative research bases are to explore a social or human problem. This research asserts that waste collection, handling and disposal challenges are societal problems and cause human issues, such as health hazards and environmental pollution. WtE would address energy poverty issues should it be implemented.

The study also considered the quantitative approach described by Creswell (2009) to explore the connection among variables to test objective theories. The quantitative approach was inappropriate for this study as WtE implementation in Johannesburg by thermal conversion lacks, meaning a limited research base for the quantitative approach. This aligns with Gill et al. (2008), contending that qualitative studies are preferable to quantitative studies, lacking insight and understating of a specific subject.

According to Alharahsheh and Pius (2020), for a researcher to attain valuable insights and observations from a particular social perspective, based on experience, the interpretivism paradigm should be deployed. This differs from the

positivist paradigm, which, according to Creswell (2009), is more aligned and relevant for quantitative studies than qualitative; it is based more on theory verification and of a reductionist approach testing various distinct variables of a particular hypothesis.

An interpretive approach was preferred as it pursues subjective interpretations of a social context from the participants' viewpoint involved in this qualitative case study. The positivist paradigm provides more statistical-based belief and generalisation (Alharahsheh & Pius, 2020). The intention of the qualitative study is not to generalise outside boundaries of the study area (Creswell, 2009). This case study, therefore, integrated the subjective versions of various expert participants based on the interpretive paradigm approach.

This approach was preferred as it provided first-hand information based on the field experiences and viewpoints from various experts in energy development and waste management. Observations were obtained from policy experts and officials or departments directly mandated and responsible for WtE implementation related projects.

3.2 Research design

According to Creswell (2009), five approaches exist in qualitative research, including case study, ethnography, phenomenology, narrative research, and grounded theory. The research design employed was a qualitative case study. It is a more suitable design in this study, as WtE implementation by thermal conversion has not advanced in Africa. According to Makarichi et al. (2019), there is only one operational plant in Ethiopia; there is none in Johannesburg. According to Opoku, Ayarkwa, and Agyekum (2019), the semi-structured open-ended questions provide the lacking information, while contributing to the

formulation of future research questions upon which the study area would be built. This agrees with Gill, Stewart, Treasure, and Chadwick (2008), contending that qualitative interviews are suitable, where the study phenomenon has limited insights.

Creswell (2009) remarks that the nature of qualitative research is exploratory and, therefore, means there is little written on the subject or population and it should establish an understanding based on interactions. The qualitative case study of the City of Johannesburg was suitable to establish such understanding concerning WtE implementation by thermal conversion.

Disadvantages of qualitative case study open-ended interviews are that they entail collecting massive data based on personal views, perceptions, and experiences of various participants. Collecting such data is time-consuming, as the findings cannot be easily presented in graphic formats. The findings are more word descriptive as opposed to the statistical or numerical nature of quantitative data. A general challenge and perception exist for a qualitative case study to justify rigour (Baskarada, 2014). It is also challenging to replicate.

3.3 Data collection methods

Barrett and Twycross (2018) identify the three main qualitative data collection methods as focus groups, observations, and interviews. The interviews are further divided into semi-structured, open-ended, and structured questions (Barrett & Twycross, 2018). The data collection of this study was based on semi-structured interviews with open-ended questions with officials from the City of Johannesburg, national and provincial government officials. Private sector participants, such as lenders, DFIs, consulting firms and IPPs, were also engaged.

Barrett et al. (2018) contend that a well-designed semi-structured interview encourages participants' flexibility by allowing their perspective and personal experience, while ensuring that all required critical data are captured. This study, therefore, allowed for this flexibility and participation; therefore, ensuring participants reflect beyond the pre-planned questions, enabling the discussion to explore additional areas of research based on the participant's encounters.

The semi-structured interviews with open-ended questions were conducted with identified experts. The experts were identified based on their experience in electricity, waste and environmental management, policy, project finance, IPPs and WtE. The critical criteria were at least 10 years' experience in the field, and the average work experience was 20 years for all participants combined.

According to Creswell (2009), the disadvantages of interviews indicate the participants' perceptions, which may be filtered, and the interviewer could create bias. Finally, the observations of participants may be inaccurate owing to the inability of some to articulate.

3.4 Population and sample

This section outlines the population and sample of the study; it includes the positions, roles, experience, and departments.

3.4.1 *Population*

The population of this study was based on the management and leadership participants with responsibility and influence on waste management, energy provisions, climate change and related policy and the legislation at municipal,

provincial, and national levels, the private sector, and investors. The City of Johannesburg was selected as the case for the study.

The selection was based on that the City has, for several years, since 2008, pursued an alternative waste treatment technology programme (AWTT) where WtE plays a pivotal role; the project has not yet been implemented fully. The City is the most populous in South Africa and still growing at a rapid rate, creating problems of waste management, energy poverty and environmental degradation. Johannesburg's 2021 population is estimated at 5 926 668 (World Population Review, 2020). According to Stats SA (2021), 42,9% are employed as of quarter four of 2020.

The City has a total staff complement of 32 316, including MOEs (City of Johannesburg, 2020). The Environment and Infrastructure Services Department (EISD), which has an oversight mandate over City Power and Pikitup, with 97 employees as of 2019 (City of Johannesbug, 2019). There are 20 senior management positions; seven are section heads reporting to the departmental chair. The EISD handles WtE implementation as it is the custodian of waste, energy, and environmental management. Experts from the department were sampled for the City of Johannesburg.

3.4.2 *Sample and sampling method*

City officials at director levels were sampled and interviewed as participants. Provincial and national department officials at director levels were also identified and interviewed. Finally, the private sector participants responsible for the development and operations of WtE plants were also sampled and interviewed; this included lenders, DFIs, consulting firms and IPPs.

The sampling method employed in this study was purposive sampling. Campbell et al. (2020) state that purposive sampling, as used in a qualitative study, may select a sample to establish understanding; therefore, in purposive sampling, participants are chosen with expectations they would contribute useful information. Creswell (2009, p. 199) contends that “In qualitative data collection, purposeful sampling is used so that individuals are selected because they have experienced the central phenomenon”. In this study, therefore, the purposive sample was based on the participants with expert knowledge on issues on waste management, energy, and environment. They provided an in-depth insight and understanding upon which future study interest would be developed. There are several studies that has suggested that to reach data saturation, qualitative research need a minimum sample size of at least 12 (Vasileiou, Barnett, Thorpe, & Young, 2018). Therefore, based on this, for this study a sample of 12 was deemed appropriate.

The sample used in this study is illustrated in Table 2 below.

Table 2: Profile of participants

Description of participant	**Number to be sampled**
Director, Energy	1
Director, Waste Management	1
Project Manager, Finance	1
Vice President, Engineering	1
Head of Strategy and Growth	1
Senior Engineer, Planning	1
Senior Manager, Environmental Management	1
Specialist, Project Preparation	1
Senior Specialist, Energy Projects	1
Financial Adviser, Mergers and Acquisitions	1
Specialist, Waste Management	1
Director, Pollution and Waste management	1
TOTAL number of participants	**12**

3.5 The research instrument

The research instrument employed in the study was based on semi-structured interviews with open-ended questions. The interviews involved one-one sessions with the selected officials and experts. First, the interview questionnaire was developed based on semi-structured questions per each proposition identified in Chapter 2, then followed by open-ended questions where applicable; the aim was an understanding from participants by follow-up questions based on the discussions and insights of each participant. This allowed for flexibility in the discussions, as contended by Barrett et al. (2018). The research instrument is attached in Appendix C.

3.6 Procedure for data collection

The preferred data collection method was face-to-face interviews in a natural setting of the participant, as described by Creswell (2009). Owing to the COVID-19 pandemic, various health concerns were present; most participants (9) were more comfortable using virtual platforms, such as Microsoft Teams and Zoom. Face-to-face interviews engaged only three participants. For member reflection, the participants were involved by email to present their reviews of the study findings. The participants of the City of Johannesburg were approached through the EISD department responsible for environmental and waste management and energy provisions. The rest were requested directly for their participation as they indicated they did not need permission from their employers. According to the code of ethics, their participation remained confidential.

3.7 Data analysis and interpretation

Data obtained from semi-structured interviews were transcribed, and themes were formulated with thematic analysis. Collective insights and experiences of participants are derived from thematic analysis (Braun & Clarke, 2012). According to Barrett et al. (2018, p. 63), “to develop such insights, qualitative research requires data which are holistic, rich and nuanced, allowing themes and findings to emerge through careful analysis”.

According to Vaismoradi et al. (2013), the two most commonly used qualitative research data analyses are thematic and content analysis. The thematic analysis attempts to identify and analyse emerging patterns. Content analysis is similar in attempting to identify patterns. It also attempts the quantification of data based on the frequency of occurrence (Vaismoradi et al., 2013). This study did not pursue quantification of themes, but thematic map analysis.

This study, therefore, followed thematic analysis as described by Braun et al (2012) based on a six-phase approach to thematic analysis in the following manner; a) familiarisation with data by perusing and understanding textual data emanating from interviews and listening to audio recordings; b) Generation of initial codes by systematic analysis of data; c) searching for themes by categorisation various codes into potential themes; d) reviewing potential themes by mapping to determine the correlation among themes; e) defining and naming themes; and f) producing the report, as concluding data analysis.

The audio-recorded data obtained from semi-structured interviews were transcribed and edited by using the Otter.ai automated transcription app. Once the data were transcribed and edited to satisfaction, a six-phase approach as described by Braun et al. (2012) was implemented.

The disadvantages of thematic analysis, according to Creswell (2009), are researcher biases and may include the preconceived observations of the researcher. It is of interpretivism nature; therefore, a researcher may misinterpret the remarks of others. The other disadvantage is language eloquence among participants.

3.8 Study limitations

Sampling has only considered the officials at a municipal level, provincial and national levels, and private sector participants; however, individuals who make a living by collecting usable material extracted from the waste disposed at landfill sites called scavenging, were not sampled. This practice of scavenging is illegal; however, it was allowed for ages to continue, and may be affected by WtE implementation. Communities were not considered; however, the sample would answer the research questions of this study and contribute to future research.

3.9 Trustworthiness

According to Elo et al. (2014), credibility, dependability, conformability, transferability, and authenticity are terms used to ascertain the trustworthiness of a qualitative study analysis. To enhance the validity, transferability and reliability of the study, triangulation was deployed with the semi-structured open-ended questions. The studies undertaken by the City, legislation and other government documents were used for this purpose. Member reflection was also employed, allowing inputs to the study findings from the participants (Tracy, 2010).

3.9.1 *Transferability*

Elo et al.(2014) contend that transferability can be assessed by understanding the criteria employed in the participants selection. In this study, the participants were selected based on their role of influence, experience, and expertise concerning energy, waste management, environment, finance, and WtE. This study intended to provide evidence that the research could be applied in various contexts, scenarios, and areas. The reader could implement the same participant selection criteria and principles employed in this study to research additional contexts or situations.

3.9.2 *Credibility*

According to Lincoln and Guba's cited in Elo et al. (2014), as the benchmark for credibility, establishment ensures the research participants are accurately identified and described. This study identified and described the participants concerning their functions and responsibilities.

The approach this study adopted to ensure credibility is member reflection and triangulation. According to Tracy (2010), member reflection is a method of allowing participants' input to the study findings. Tracy (2010) reveals this method encourages a dialogue between the researcher and the participants or even collaboration. The participants' involvement in critiquing and questioning or agreeing to the study's findings provided a level of credibility to this study, as described by Tracy (2010). Triangulation was deployed to enhance the quality and validity of the study. Triangulation involves multiple data sources to establish integrity and enhancement of the findings (Given, 2008).

Member reflection ensured participants were contributing to the study findings and critiqued misalignments or misrepresentation by enhancing the quality of the study. Conversely, triangulation ensured that the participants' observations were

compared or contrasted against published government documents selected for this purpose.

3.9.3 *Dependability*

Elo et al. (2014) emphasise that dependability observes stability of the study data over a certain period for similar research conducted under various conditions. Therefore, this study clearly described its path. If the same methodology is applied elsewhere by diverse researchers, it should yield the expected similar outcomes. Conversely, it is easy to follow and adopt the path undertaken to assess the dependability of this study. The records of how data was collected and used for analysis leading to research are well documented to follow a trail should another researcher conduct and perform the same research and analysis.

3.9.4 *Confirmability*

Confirmability can be established by accessing data emerging from the research with the interpretation thereof (Amin et al., 2020). This study ensured confirmability by allowing participant contribution in the study findings. This process defines member reflection, according to Tracy (2010). This would ensure that the data and information provided and analysed in the study is not a mere invention created by the study but presents the factual inputs provided by the participants.

3.10 Ethical considerations

The study ensured compliance with ethical research practices by following the guidelines of the University of Witwatersrand. This included obtaining an ethics clearance from the ethics committee. Participants were made aware they were

not compelled to participate instead, they needed to provide consent. The participants agreed and endorsed the consent form, indicating:

a) They consent to participate
b) They obtained permission from their organisation to participate (only for the City of Johannesburg)
c) They were informed and understood what the study involved
d) Their participation was voluntary, and they could withdraw as they considered it necessary
e) Their details would not be disclosed

Table 3: Consistency table: research questions, propositions, data collection, and data analysis

RQ #	Research question	Prop #	Proposition	Data collection detail	Data analysis method
1	What are the potential positive benefits the WtE implementation provides to the City?	1	WtE implementation would contribute to the catalysation of the circular economy in the City of Johannesburg.	Semi-structured interviews	Thematic analysis
2	What decision-making frameworks and actions are needed to implement WtE?	2	Adoption and implementation of decision-making frameworks would lead to WtE implementation.	Semi-structured interviews	Thematic analysis
3	What are the consequences if WtE would not be implemented in the City?	3	The City would encounter these consequences if WtE is not implemented: landfill airspace depletion, illegal dumping resulting in induced infectious diseases leading to poor health and environmental	Semi-structured interviews	Thematic analysis

RQ #	Research question	Prop #	Proposition	Data collection detail	Data analysis method
			degradation, and over-reliance on the national grid for electricity would not be curbed, and energy access would not be improved.		
4	Is WtE a commercial proposition?	4	Capital and O&M costs for WtE by incineration are expensive, leading to high tariffs; for WtE to be commercially viable, decision-makers should consider subsidisation, landfill tax and high landfill gate fees; this would discourage landfilling and support WtE deployment.	Semi-structured interviews	Thematic analysis
5	What are barriers to WtE implementation through thermal conversion?	5	Barriers to implementation include a) Financial, b) technological, c) institutional, and d) environmental barriers.	Semi-structured interviews	Thematic analysis

CHAPTER 4. PRESENTATION OF FINDINGS

4.1 Introduction

This chapter presents the research findings on the data collected from the semi-structured interviews with various sampled experts, based on a purposive sampling approach. Data were analysed by generating initial codes extracted from transcripts. This was followed by categorising codes into various themes. Last, mapping the correlation among themes, defining, and naming themes occurred.

This research report is based on a case study examining the opportunities and impediments to WtE implementation in the City of Johannesburg. Focus was on thermal conversion by mass-burn incineration and on how decision-making frameworks function in supporting the integrated solid waste management leading to WtE development and implementation.

The structure of this chapter firstly summarises the qualitative methodology to allow for an uninterrupted flow of reading. Second, the demographics of the participants are presented to demonstrate the level of maturity, experience, and expertise. Finally, the findings are presented for each proposition described in the literature review (Chapter 2).

4.2 Qualitative methodology

4.2.1 *Qualitative methodology*

This case study followed a qualitative research approach as informed by Creswell (2009), remarking that qualitative research bases are to explore a social or human problem. This research asserts that the waste collection, handling, and disposal challenges are societal problems and cause human problems, such as health hazards and environmental pollution. WtE would address energy poverty issues should it be implemented. This approach was preferred in this study, providing first-hand information based on the field experiences and observations from the officials or departments directly mandated and responsible for WtE implementation related projects and the private sector's participants, such as the IPPs, lenders and DFIs.

4.2.2 *Purposive sampling*

The sampling method employed in this study was purposive sampling. Campbell et al. (2020) state that purposive sampling, as used in a qualitative study, may select a sample to establish an understanding; therefore, in purposive sampling, participants are chosen, expecting that they would contribute useful information.

4.2.3 *Trustworthiness*

According to (Elo et al., 2014), the applicable term to assess qualitative research validity is still being debated, often for credibility assessment, the criteria for reliability and validity are used for both qualitative and quantitative research. Trustworthiness is deployed and preferred for qualitative studies to prove the findings are appreciable (Elo et al., 2014).

a) Validity and reliability

According to Saunders et al. (2016, p. 207), *"Validation is the process of verifying research data, analysis and interpretation to establish their validity/credibility/authenticity*". The two techniques for qualitative research validation are a) triangulation and b) member reflection validation (Saunders et al., 2016).

This study applied both techniques (triangulation and member reflection) to establish the research quality. The primary data obtained from semi-structured interviews were compared to the documents published by the City of Johannesburg, the Gauteng Provincial Government, and the South African National Government to establish credibility. Member reflection was also deployed.

Reliability attempts to establish if a researcher would achieve similar results if the research design was replicated (Saunders et al., 2016). This research involved a qualitative case study based on semi-structured open-ended questionnaires with the flexibility to adjust; therefore, difficult to replicate. The approach and steps are well defined and documented to achieve dependability.

4.2.4 *Data analysis*

This study followed thematic analysis described by Braun et al (2012) based on a six-phase approach to thematic analysis as follows; a) familiarisation; b) generation of initial codes; c) categorisation of various codes into potential themes; d) reviewing potential themes; e) defining and naming themes; and f) producing the report.

The audio-recorded data obtained from semi-structured interviews were transcribed and edited by using the Otter.ai automated transcription app. Once the data were transcribed and edited to satisfaction, a six-phase approach, as described by Braun et al. (2012) was adopted as a framework for data analysis, as illustrated in Figure 9 below.

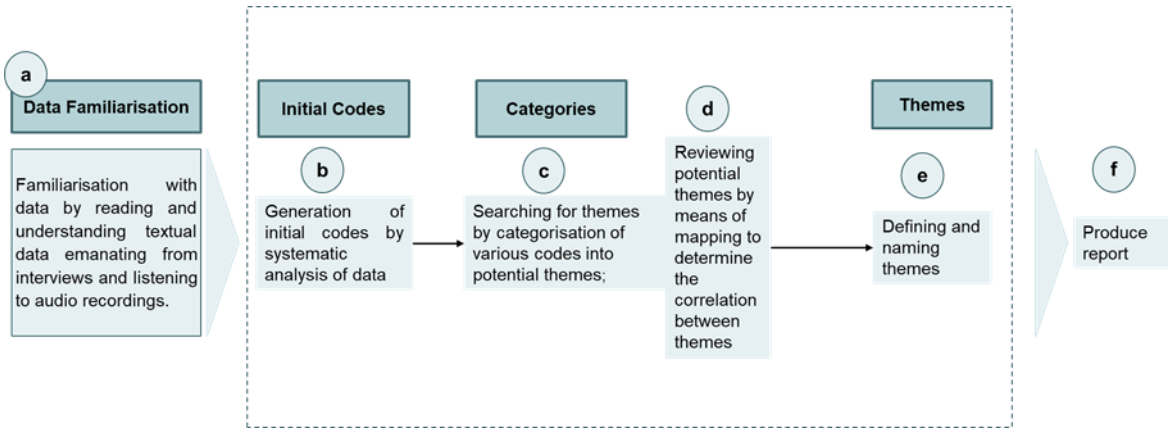


Figure 9: Framework for data analysis derived from Braun et al. (2012)

4.3 Demographic profile of participants

In this section, the characteristics of the interviewed participants are described to understand the background of the interviewees. Most of this information was collected through the interview and summarised.

Age of participants

According to Mashinini (2020), age is an important aspect of understanding the life stage of the participants. It provides a glimpse of their work experience. The average age category of the participants in this study is age 40 to 45 years with half (6) of the participants, followed by 35 to 40, a quarter (3) of the participants, followed by 45 to 50 years (two participants) and one (1) 55-60 years.

Position of seniority

Mostly the participants are at senior management /specialist levels with titles, such as HOD (1) vice president (1) director (3), senior manager (1), project manager (1), senior specialist (1), senior engineer (1), senior adviser (1) and specialist (2). The level of seniority and specialisations provides credibility to the observations in the semi-structured interviews. The average experience of participants combined is 20 years.

4.4 Proposition 1 findings

This section discusses findings and subsequent themes emerging from Proposition 1 (WtE implementation would contribute to catalysing the circular economy in the City of Johannesburg). Figure 10 below illustrates the findings on Proposition 1 from the semi-structured interviews.

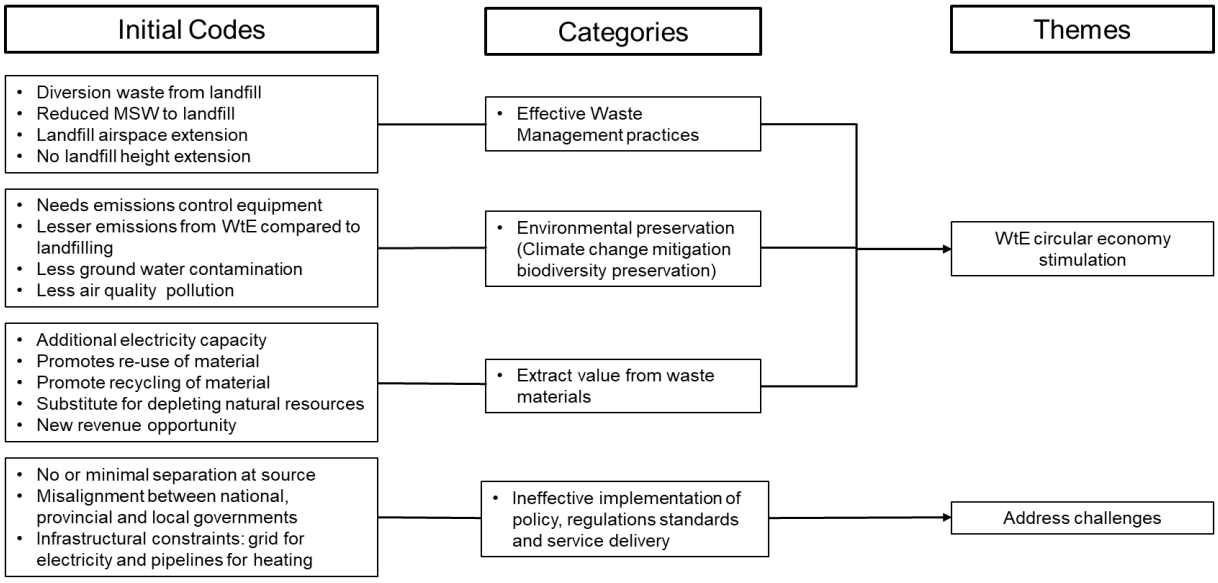


Figure 10: Findings on Proposition 1 from semi-structured interviews

Two themes (1 and 2) that emerged from Proposition 1 are a) WtE circular economy stimulation; and b) address challenges. These are discussed below.

4.4.1 *Theme 1: Waste-to-energy circular economy stimulation*

a) Effective waste management practices

All participants indicated that WtE implementation in Johannesburg would divert waste to landfill sites and extend landfill airspace lifespan, as much reduced waste would be landfilled. Participants with the knowledge of the landfill sites were concerned that airspace was depleting fast. Within the next few years, some would be closed. Exacerbating the problem, participants indicated that the population is also increasing rapidly as Johannesburg is the country's economic hub, attracting people all over the country. The general consent, therefore, was that WtE is a solution, addressing airspace depletion, and there would be no need for landfill height extensions and new landfill sites. This was supported by Participant 2 below.

> “The contribution will be more on the diversion of waste that goes to the landfill sites, and also as a solution to waste challenges, especially around the landfill sites that are running out of airspace rapidly”.

Participants 4 and 6 cautioned that WtE should be only after reuse and recycling steps were exercised, according to the waste hierarchy. Participant 4:

> “The first option should still be re-use and recycling of waste. So, we don't want the City to just collect waste from households and businesses and shove it into the thermal plant. We require them to follow the waste hierarchy to ensure that only residual waste will be going into this plant”.

Participant 6:

> “Waste-to-energy should be viewed as a solution to solve waste management problems, not electricity problems, and the waste hierarchy should be observed!”

b) Environmental preservation (climate change mitigation and biodiversity preservation)

Participants 7 and 8 felt, while the methane gas generated by the organic fraction of waste in landfills is more potent than carbon emission emitted by the WtE plant, technologies to reduce emissions, such as scrubbers, should be incorporated into the WtE plant. Participant 7:

> “We accept that methane from landfill is about 21 times more potent than CO_2. The developers of the WtE facility should ensure that scrubbing technology is incorporated”.

Participant 8:

> “The WtE facility will require proper management because if it is not well managed, it could contribute to climate change in terms of the greenhouse gases that would be coming from the process of turning waste into energy”.

According to Participant 1, landfill sites, if not well managed, cause groundwater contamination and air pollution. Other participants also mentioned that with waste diverted to the WtE plant, there would be less water contamination and air quality problems. Participant 1:

> “Reuse, recycling as well as the WtE plant will mean less waste to landfill and therefore reduction of leachate and air pollution”.

c) Extract value from waste material

The observation from the participants on electricity from the WtE plant was that it will cause additional capacity for the City and may not lead to an increase in electrification. Most non-electrified areas are informal settlements. This observation was stressed strongly, especially by Participants 3 and 5. Participant 3:

> “Most of the places that are not electrified are far from the grid and need maybe off-grid solutions, not typically, for a WtE sort of project. That electricity will be fed into the grid, or at the very least into a mini-grid”.

Participant 5:

> “The city had not planned the infrastructure development for informal settlements, they're not laid out in a way that allows for the rollout of electrical infrastructure. Some of the issues around informal settlements is not that you can't just get the wires; they said there are no roads to actually bring in the trucks to put up the poles to run the electricity lines in a uniform way in a safe way”.

Participants, especially those in the waste management and environmental sectors, felt strongly that the waste hierarchy should be followed. Agreeing with WtE development should be MRF to promote recycling and reuse of material. This would supplement using depleting natural resources according to Participant 4:

> “...as waste material will become a secondary commodity”.

Participant 3, however, believes that WtE would promote and motivate recycling. Participant 3*:*

> "To optimise your output on a waste-to-energy project, you obviously need to have the right feedstock, right? What this will do is that it will create a strong incentive for the sorting of the waste".

4.4.2 *Theme 2: Address challenges*

a) Ineffective implementation of policy, regulations, standards, and service delivery

According to Participant 2:

> "There is no or minimal separation at source in Johannesburg. Most of the MSW is mixed which makes it difficult to separate for the WtE facility to follow the waste hierarchy".

Some participants emphasised that a misalignment in policy among spheres of government waste management function is at the local government level and policy development is at a national level.

Participant 8:

> "Therefore, sometimes there is misalignment as the officials at national don't have full comprehension about what is happening at local government levels".

4.4.3 *Proposition 1 conclusions*

Two themes (1 and 2) that emerged from Proposition 1 are a) WtE circular economy stimulation; and b) Address challenges. The first theme seemed in alignment with a proposal that WtE would catalyse the circular economy. The second theme indicated remaining challenges in the waste management sector

and WtE, which should be addressed to leverage the circular economy opportunities.

4.5 Proposition 2 findings

This section discusses finding and subsequent themes emerging from Proposition 2 (Adoption and implementation of decision-making frameworks would lead to WtE implementation). Figure 11 below illustrates the findings on Proposition 2 from the semi-structured interviews.

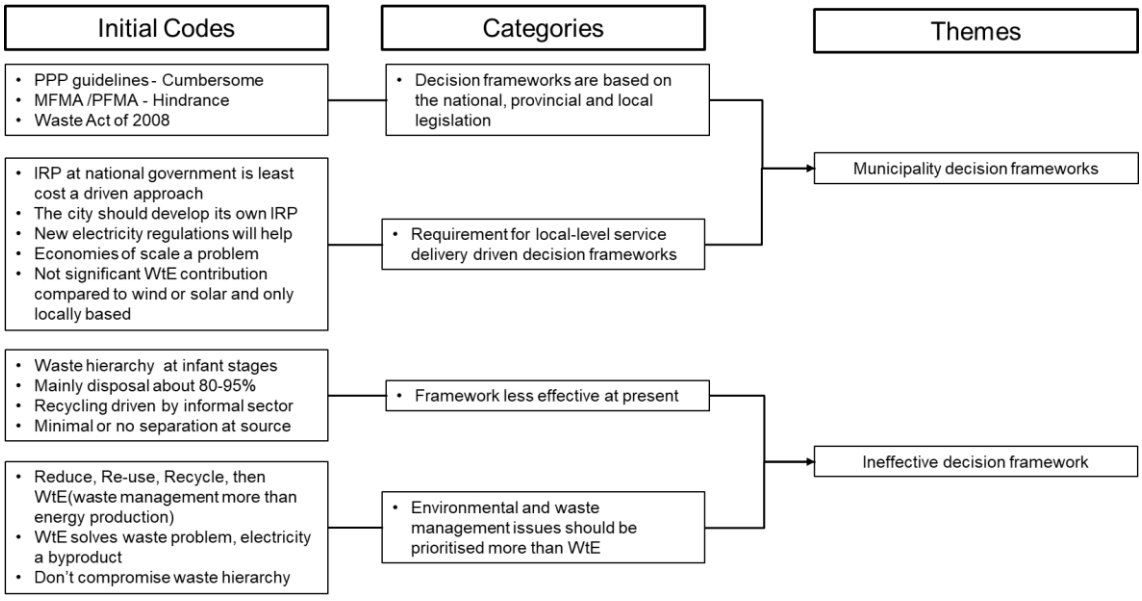


Figure 11: Findings on Proposition 2 from semi-structured interviews

Two themes (3 and 4) that emerged from Proposition 2 are a) Municipality decision frameworks; and b) Ineffective decision framework. These are discussed below.

4.5.1 *Theme 3: Municipality decision frameworks*

a) Decision frameworks are based on the national, provincial, and local legislation

Decision-making frameworks are based on the legislation applicable to all the spheres of government (national, provincial and municipalities). The prominent one from participants is the Waste Act of 2008, from which the waste hierarchy is legislated as a decision-making framework for waste management in South Africa. Participant 1 emphasised how the amendment of the Waste Act changed the manner where it was managed. Participant 1:

> "Before the amendment of the Waste Act, in the waste hierarchy triangle, disposal was not the last resort; this was mainly promoting disposal as the first option of managing waste. It was difficult for the country to even look at technologies like a waste-to-energy, but when that triangle was changed, and looking at the waste disposal as the last resort, it encouraged the country to look into alternatives, as it was discouraging the landfilling of waste".

The National Treasury PPP guidelines and MFMA were described as cumbersome and a hindrance by some participants. The feeling was that the PPP is complicated and lengthy, MFMA is a hindrance to implementing projects, to WtE.

Participant 8 observed on the PPP process:

> "PPP tools decide for big capital projects; however, the process is cumbersome to implement. No service delivery will be achieved following this process".

While confirming that the PPP process led to delays in the WtE project in Johannesburg, Participant 4 acknowledges that it ensures project financial viability. Participant 4:

> "That is why projects are mainly delayed in the City of Johannesburg because in order to get National Treasury approval for a PPP, it needs to demonstrate value for money in terms of the MFMA".

Regarding the MFMA, participants felt it was a hindrance. Participant 4 stating:

> "MFMA will then lead to that long approval processes from National Treasury. That's the only legislation that needs to be amended".

According to Participant 2, it is only a perception that MFMA is a hindrance or stumbling block. This is based on the hesitancy of municipalities to enter contracts beyond three years. Participant 2:

> "The guidelines are there, and National Treasury is a custodian of both PPP and MFMA and can assist municipalities to comprehend these".

> "MFMA which most people believe that is a hindrance with regard to these kinds of projects or long-term projects. Mostly municipalities enter into contracts for three years with the possibility of extension to five years they are reluctant to go beyond five years which is their term of political office. Reason being that there is no willingness to commit the upcoming local government council that will be coming after five years, as you know that the term of the local government is five years. So, there is that kind of perception".

The participants also clarified the function of the spheres of government concerning waste management and WtE. Participant 6 explains:

> “National government develops waste management policies as well as energy policy and planning, provincial government has no electricity mandate only waste and issues licenses for new landfills”.

b) Requirement for local-level service delivery driven decision frameworks

Some participants indicated the IRP is the electricity plan for South Africa, from a national government perspective and is not individually scrutinising the local government level electricity needs. It is also a least-cost driven approach. The observation was that the City of Johannesburg should develop their own IRP based on service delivery needs. Participants 3 and 9 elaborated on the IRP observations. Participant 3:

> “The IRP process is an outcome that favours the least cost solution at the national level, but you might find that at the community level, or at the City level, waste-to-energy has a different value proposition. I don't think, as far as I know, South Africa's decision-making frameworks recognise the value that waste-to-energy can bring at the local community and township levels”**.**

Participant 9*:*

> “The same way that you have a national level electricity plan, the IRP, I think cities should get into the habit of doing their own IRPs at city level”.

Participant 5 believes there is room for local government to influence the IRP at national government level when reviewed. Participant 5:

> “There is a room for municipal governments to input in the IRP in terms of their future energy demands. So, if you had a future electricity plan

> as the City of Johannesburg and the IRP is being updated. You could say, here is where we think we are going to need power in and the type of source and technology that can influence the IRP".

There was a consensus from participants that the new generation regulations allowing municipalities in good financial standing to buy their power from IPPs would enhance WtE prospects in Johannesburg and other municipalities. Up to 100MW can be generated without requiring a generation licence.

Some participants observe WtE competes with solar and wind at a national level and, therefore, has no competitive edge over wind and solar. Participant 3 observation:

> "IRP is a cost-driven approach, which is a good thing. There's nothing wrong with that. But it's at the national level, and that's not where waste-to-energy has its biggest strength. At national level it is competing with solar, and wind, and typically, solar and wind have much higher installed capacity than waste-to-energy. So already, it is down on the economies of scale. So that's why you don't see waste-to-energy acting at the national planning level".

4.5.2 *Theme 4: Ineffective decision framework*

a) Framework less effective at present

All participants observed that implementing the waste hierarchy is ineffective, and most municipalities implement disposal with less recycling and recovery of helpful material for reuse. The City of Johannesburg disposal rate is above 80%, and recycling is between 5% and 15%. No study confirmed the exact level of recycling more especially as it is highly dominated by informal recyclers. Participant 8 explains:

> “Recycling is minimal at around 5- 15% in Johannesburg; however, these values are estimates it could be worse as there are no studies which to indicate the waste stream flow especially within the informal sector. At present, it is mainly landfilling which dominates”.

All participants indicated little, or nothing is happening regarding separation at source, and this is not an entrenched culture in South Africa and the City of Johannesburg. The issue is also cost-related as there are underprivileged communities that cannot afford to buy three bins or three types of disposal bags. It is also an educational issue as several individuals lack knowledge on separation at source, according to the participants. Participants 11 and 4 on the separation at source are as stated below. Participant 11:

> “Regarding separation at source there is a cost issue, then there is a buy-in issue as well. So, this would need, like a type of culture shift”.

Participant 4*:*

> “The regulatory authority is developing a regulation to enforce waste separation at source in the Gauteng province, this currently under development”.

b) Environmental and waste management issues should be prioritised more than WtE

An intense observation among some participants indicated WtE is observed at the municipal level mainly as a waste management issue more than electricity production. The participants indicated that WtE solves waste problems and electricity is a by-product. Therefore, there was an intense observation that the waste hierarchy should not be compromised at the expense of WtE. The observations of Participant 4 are indicted below on WtE prioritisation:

> “Waste Act when you look at it, it requires that waste treatment (WtE) should come when there has been efforts done to recover, to recycle and to reduce but treatment (WtE) is still a better option than disposal in that waste hierarchy. Waste-to-energy then is utilised to resolve the City's problem firstly, it will be able to reduce the amount of waste going to landfill; secondly, the by-products, such as electricity to deal with access issues”.

Participant 6 emphasised:

> “Waste-to-energy should be viewed as a solution to solve waste management problems not electricity problems and the waste hierarchy should be observed!”

4.5.3 *Proposition 2 conclusions*

Two themes (3 and 4) that emerged from Proposition 2 are a) Municipality decision frameworks; and b) Ineffective decision framework. Theme 3 indicated there is a need for developing decision-making frameworks for service delivery based at the local government level. Theme 4 suggested remaining challenges regarding implementing of the waste hierarchy, a legislated decision-making framework for waste management.

4.6 Proposition 3 findings

This section discusses findings and subsequent themes emerging from Proposition 3 (The City would encounter these consequences if WtE is not implemented; landfill airspace depletion, illegal dumping resulting in induced infectious diseases leading to poor health and environmental degradation and

over-reliance on the national grid for electricity would not be curbed and energy access would not be improved).

Figure 12 below illustrates the findings on Proposition 3 from the semi-structured interviews.

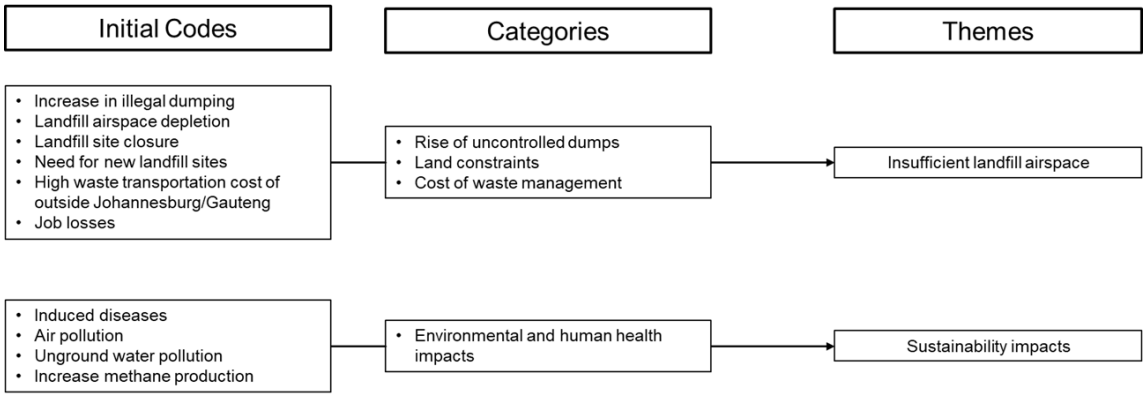


Figure 12: Findings on Proposition 3 from semi-structured interviews

Two themes (5 and 6), which emerged from Proposition 3 are: a) Insufficient landfill airspace; and b) Sustainability impacts. These are discussed below.

4.6.1 *Theme 5: Insufficient landfill airspace*

a) Rise of uncontrolled dumps

All participants observed that non-WtE implementation would increase illegal dumping, depletion of landfill airspace and landfill site closure, causing the need for new landfill sites. Some participants emphasised that WtE implementation would curb the issues mentioned above; however, it should be according to the waste hierarchy. Participant 6 emphasised that the problem regarding new landfill sites is that the Gauteng Provincial Government decided not to approve any new landfill licences. Participant 6:

> “The Gauteng Government has taken a decision not to issue any new licenses for landfill sites; this will mean that municipalities and City of Johannesburg will have to transport waste out of the municipality area or province. This will increase transportation cost or will simply increase illegal dumping”.

a) Land constraints

Participants 1 and 12 felt that land is a significant problem as developing new landfill sites in the City of Johannesburg is competing with other developments, such as housing, commercial buildings, and industrial developments. They observed the City would be constraints for land to develop new landfill sites, and this land would be expensive. Participant 1:

> “There are lot of developments currently in Johannesburg so any new landfill site will have to compete for the same land”.

Participant 12:

> “Landfill airspace is a concern; Johannesburg is a high-density City, so land is a premium”.

b) Cost of waste management

The participants indicated that the cost of waste management would increase should WtE and other initiatives are not implemented. According to Participant 1, the most significant cost factor would emanate from transportation to areas outside the City, sometimes even outside the province. Participant 1*:*

> “In waste management, transportation is one of the main costs should the City of Johannesburg fail to implement waste-to-energy and other

initiatives…. this will result in massive costs increase due to transportation out of the boundaries of the City".

4.6.2 *Theme 6: Sustainability impacts*

a) Environmental and human health impacts

The observation from participants was there would be a proliferation of illegal dumps, and the open burning of waste would be prominent as the City would struggle to collect, transport, and dispose of waste. The methane from landfill sites and air pollution from landfills and waste open burning would cause poor air quality. Below are the observations of Participants 2, 6, and 10:

Participant 2:

> "Some landfills are not well managed, and they cause environmental harm and will contaminate underground water sources".

Participant 6:

> "Methane gas generated in landfill sites is more harmful than greenhouse gases that will emanate from WtE plant, I think it's about 21 times more potent than carbon dioxide".

Participant 10:

> "There will be increase in air pollution and water contamination this will cause induced diseases for the nearby communities".

4.6.3 *Proposition 3 conclusions*

Two themes (5 and 6) that emerged from Proposition 3 are a) Insufficient landfill airspace; and b) Sustainability impacts. Theme 5 indicated that uncontrolled illegal dumps would emerge because of land constraints and an increase in the cost of waste management. Theme 6 suggested the negative influence on the environment and social sustainability because of mainly pollutants generated by landfills and illegal dumps.

4.7 Proposition 4 findings

This section discusses the findings and subsequent themes emerging from Proposition 4 (Capital and O&M costs for WtE by incineration are expensive, leading to high tariffs. For WtE to be commercially viable, decision-makers should consider subsidisation, landfill tax, and high landfill tipping fees. This would discourage landfilling and support WtE deployment). Figure 13 below illustrates the findings on Proposition 4 from the semi-structured interviews.

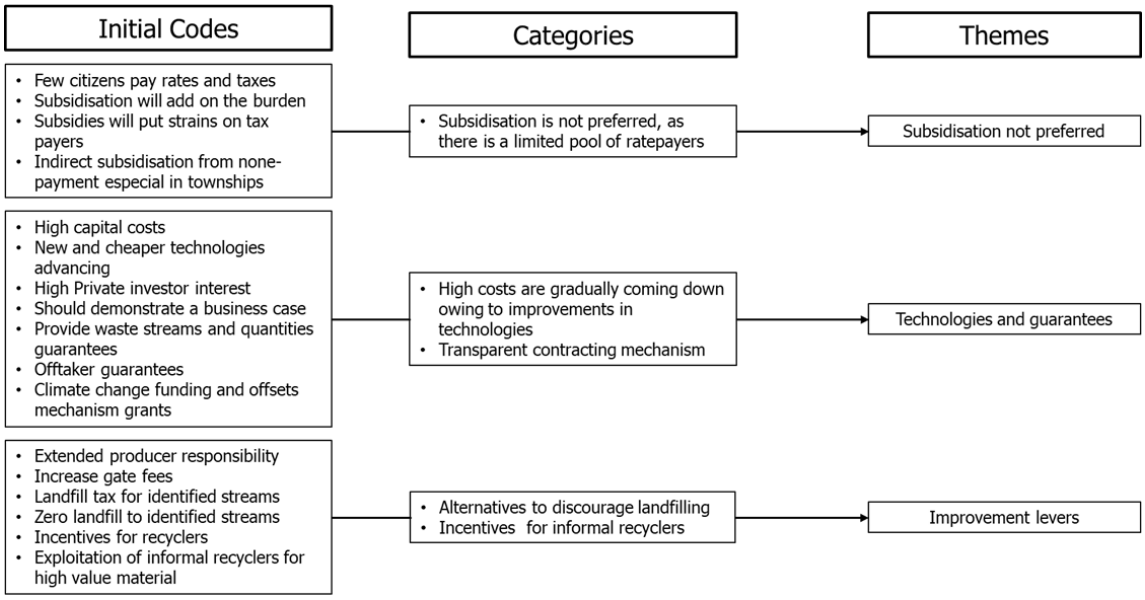


Figure 13: Findings on Proposition 4 from semi-structured interviews

Three themes (7, 8, and 9) that emerged from Proposition 4 are a) Subsidisation not preferred; b) Technologies and guarantees; and c) Improvement levers. These are discussed below.

4.7.1 *Theme 7: Subsidisation not preferred*

a) Subsidisation is not preferred, as there is a limited pool of ratepayers.

Mixed observations from participants about subsidisation were presented, with the majority (9) of the participants not convinced that it should be considered, the rest of the participants expressed that it may help the prospects of WtE in Johannesburg.

Views of Participants 5, 12, 9, and 2 on subsidies are indicated below:

Participant 5:

> "The question about subsidisation is, what does that do to the rates and taxes of the citizens? Does it then make the just transition and sustainability a financial burden?"

Participant 12:

> "Citizens are already on a limited sort of rate payer back basis, you know, just like our tax basis being on the shoulders of a very few portions of the society?"

Participant 9:

> “I think subsidies have worked in high tax countries that have centralised governments and have been able to provide these basic services quite well”.

Participant 2 observed that the subsidies could work, and they should be driven at national government levels:

> “I think, if there is a scheme that is being introduced to subsidise these initiatives that would stimulate the uptake of these facilities”.

4.7.2 *Theme 8: Technologies and guarantees*

a) High costs are gradually coming down owing to improvements in technologies

All participants confirmed WtE has high capital investment costs; however, the prices are dropping as new efficient technologies advance. Participant 8 indicated that technological advancement reduces the high cost of WtE equipment. Participant 8:

> “We have seen new technologies which are more efficient in energy output and emissions reduction, so technologies are getting cheaper as they improve”.

According to Participant 1, because of the history of a low tariff of coal-based electricity generation in the country, it was difficult for WtE to compete. Participant 1:

> “In fact, initially, when these technologies started, they were very expensive, affecting the cost of electricity, which was very low, it was not even comparable to your coal-generated electricity but now as the time went by, and the technology improved, the cost went down”.

b) Transparent contracting mechanism

Some participants emphasised a huge interest from private investors in developing WtE plants. The challenge is they need waste quantities guarantees to keep the plant running and offtake agreements in PPAs. The observation of Participant 2 is below:

> "I think one area that sort of bring contestation between the developers and the municipalities or the City is waste guarantees, municipalities are collectors of waste. They are not generators".

According to Participant 12, both waste and offtake guarantees must be handled at National Treasury. Participant 12:

> "If we can look at the Auditor General report now, it's only Ekurhuleni who got a clean audit amongst all Gauteng metros. Now, if you're going to then forecast on the balance sheet of the municipality, it may be a little bit difficult. So, I think that kind of guarantee from National Treasury is important as one of the main ministries which could assist in terms of that kind of guarantee".

4.7.3 *Theme 9: Improvement levers*

a) Alternatives to discourage landfilling

Most participants support the introduction of landfill tax not in existence in South Africa. This could help reduce waste going to landfill sites. The gate fees at landfill sites are low at R300/tonne when compared with average international fees at R800/tonne. The increased gate fees would increase WtE prospects, as it would be one of the revenue streams at a WtE facility.

Participant 6:

> "…clearly this low landfill gate fees encourages disposal more than anything because it's cheaper".

Participant 2 cautioned against using a blanket approach about landfill tax once developed, instead identify specific streams to impose the landfill tax on and declare those streams taxable should they be established in a landfill. For these streams, they should be reported as zero waste to landfill. Participant 2:

> "The zero waste to landfill site could be for certain material or waste streams, we could identify these streams and declare them as zero to landfill, but for streams like your ashes, your builder's rubble, you would still need those materials from time to time to go to landfill sites".

According to Participant 5 and Participant 2, should the landfill tax be obligatory and gate fees be increased to cost reflectivity, this may simply lead to waste collectors dumping waste, as they may not afford these fees. Alternatives should be offered, such as extended producer responsibility (EPR). Participant 5:

> "Extended producer responsibility initiative is good and will encourage good practices. The fact that the government is trying to impose more responsibility on the part of producers of goods sold, like the actual manufacturer of goods, needing to be responsible for the end of life of those goods".

b) Incentives for informal recyclers

Participants' observation of recycling in Johannesburg is that the informal waste pickers dominate space. The recycling mechanism deployed by the City is not effective, including separation at the source where there were few pilots across the City.

Participant 8 believes that informal waste recyclers should be incentives:

> "One way to incentives them would be to include them on a formal sector including in the material recovery facilities (MRFs) which will be integrated to the WtE project once developed".

Some participants indicated that whereas the informal waste recyclers play a pivotal role in recycling, they are still being exploited by their customers who do not pay them according to prices of recovered material. Participant 7 indicated that recyclers mainly handle high value recyclables but are still exploited. Participant 7:

> "These days, you hardly ever see material of high value being illegal dumped material such as scrap metals, bottles, plastics, and tins; this shows that recycling is starting to gain momentum but still at informal levels and exploitation is there".

The observation of the participants was that WtE with the MRF would encourage improved recycling and reuse of material.

4.7.4 *Proposition 4 conclusions*

Three themes (7, 8 and 9) that emerged from Proposition 4 are a) Subsidisation not preferred; b) Technologies and guarantees; and c) Improvement levels.

For Theme 7, it was clear from most participants they do not support subsidisation as a small pool of citizens pay rates and taxes; they are already overburdened. Theme 8 indicated investor interest; however, issues about off-taker agreements waste quantity guarantees are still a problem. The cost of WtE is gradually decreasing as technologies mature. Theme 9, what emerged is the portfolio of improvement levers to achieve commercial viability. Participants identified

options like cost-reflective gate fees landfill tax, which would complement WtE to manage a WtE tariff at competitive levels.

4.8 Proposition 5 findings

This section discusses findings and subsequent themes emerging from Proposition 5 (Barriers to implementation include a) Financial, b) technological, c) institutional, and d) environmental barriers). Figure 14 below illustrates the findings on Proposition 5 from the semi-structured interviews.

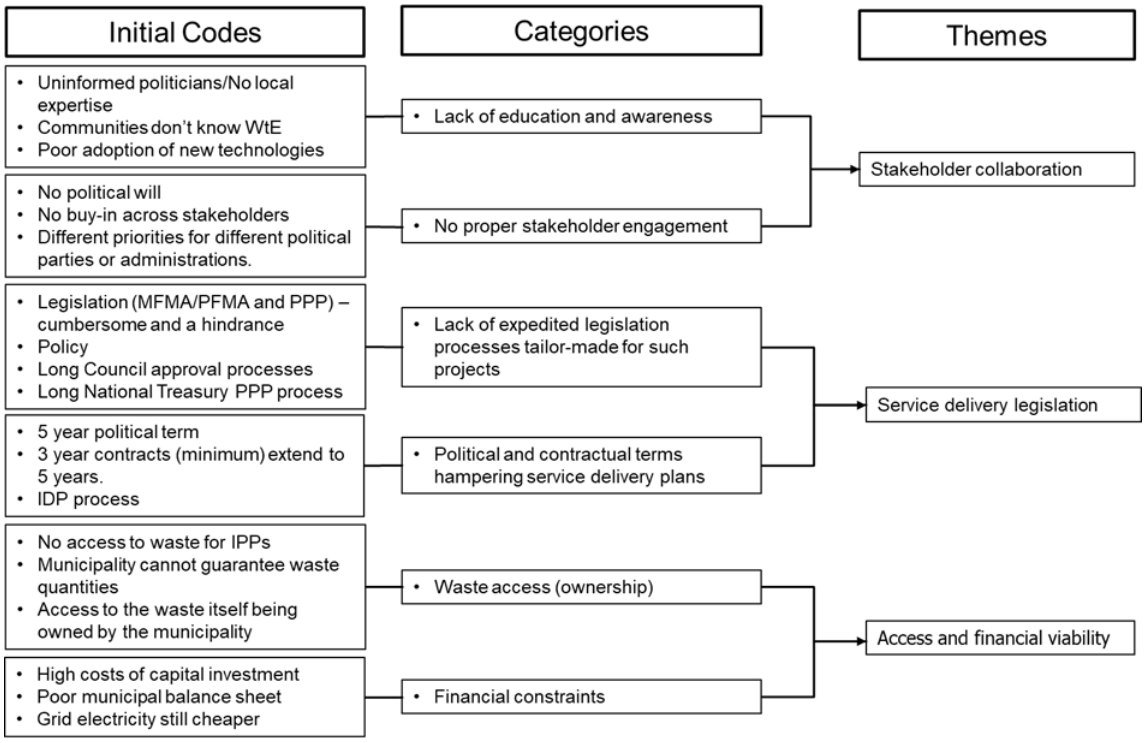


Figure 14: Findings on Proposition 5 from semi-structured interviews

Three themes (10, 11 and 12) that emerged from Proposition 5 are a) Stakeholder collaboration; b) Service delivery legislation; and c) Access and financial viability. These are discussed below.

4.8.1 *Theme 10: Stakeholder collaboration*

a) Lack of education and awareness

Most participants are of the observation there is a lack of awareness of the value WtE could bring to the City, especially among politicians. Since these plants are yet to be developed in Johannesburg and South Africa, there is a lack of expertise in the financial and technological know-how.

According to Participant 1, there is a technology vacuum between both officials and politicians, including communities:

> "I think the other barrier, I'll still say the issue of knowledge…. Knowledge, yes… As to what technologies are out there, and how they work".

Participant 8 continues:

> "There are delays with council approvals on these projects because politicians have no knowledge of these type of projects…. much education needs to be given to the City because these technologies add high value".

There were also observations regarding technology adoption with Participant 11, stating:

> "WtE technologies are developed abroad not in South Africa, there is generally poor technology adoption in South Africa we move too slowly".

b) No proper stakeholder engagement

Most participants emphasised there is no political will and buy-in across all stakeholders. Participants indicated often it is because of the change in administration and, therefore, change of priorities. Participant 3 indicated that the buy-in should be across the value chain, including council, top management, MOEs and communities.

Participant 3:

> "You have to get the buy-in that we spoke about, you have to get the council to support as well…. you know, the whole value chain. So many things have to come together, but I do think that waste-to-energy is one of those key ingredients that can incentivize at least one stakeholder to promote better solid waste management".

Participant 12 indicated that in the public participation processes, it might challenge to convince communities about the significance of WtE because they simply never had of it. Participant 12:

> "The point that I would make is that your average citizen doesn't know a lot about waste-to-energy in the first place…. You know this speaks to kind of awareness and education needed, right? So, I can be very, very honest with you. I don't think the average citizen has a view on waste-to-energy".

4.8.2 *Theme11: Service delivery legislation*

a) Lack of expedited legislation processes tailor-made for such projects

All participants were concerned by the long processes for project approvals. These processes are informed by legislation, such as MFMA and PPP guidelines. Participant 8 even went further and said it is a cumbersome process:

> “PPP tools decide for big capital projects however the process is cumbersome to implement no service delivery will be achieved following this process”.

According to Participant 1, PPP is lengthy and requires several approval gates:

> “National Treasury regulations and guidelines, you can go and look at it, if you ever want to. It requires about three approvals, so that is a legislative process and it’s long”.

This long-regulated process cannot be bypassed according to Participant 4, but some can be amended to expedite approval processes for these projects. Participant 4:

> “Because now you're going to be utilising a municipal facility for more than 20 years, remember? ….. So, the PPP regulations in the MFMA, is that regulated process that cannot be short-circuited”.

Participant 4 stressed on:

> “MFMA will then lead to that long approval processes from National Treasury. That's the only legislation that needs to be amended”.

b) Political and contractual terms hampering service delivery plans

All participants observe the five-year political term as a cause of severe delays to WtE implementation. Participant 6 was more concerned about the slow council process during the campaign times. Participant 6:

> “…when its election year you lose about three months as the politicians are campaigning, council is simple dysfunctional closer to the elections. No approval processes in council till after the elections”.

Participant 1 spoke about how the change of the administration would hamper the project progress. Participant 1:

> "Remember, you might find that the current government of the day in the municipality has got a buy-in into the waste-to-energy project development… if it changes, like one typical example I know of a case, one of the delays was caused by change in government".

4.8.3 *Theme 12: Access and financial viability*

a) Waste access (ownership)

Some participants expressed the frustration of private investors in trying to develop WtE projects, stating that the ownership of waste is not with the IPPs, but the municipality. Conversely, the municipality is reluctant to provide waste quantities guarantees. Participant 12 emphasised the risks of the shortfall in delivering the required waste quantities because of actions like labour strikes and go-slow. Participant 12:

> "If there is a labour strike for the whole month as it has happened previously then the waste quantities may not reach the WtE facility"

Participant 2 emphasised that even though the City is responsible for waste and takes ownership once it is collected, it cannot guarantee the waste quantities. Participant 2:

> "It tends to be very difficult for a municipal manager of the City, or any municipality to guarantee the certain quantities of waste that will be generated, because they go collect once it's generated".

Participant 9 emphasised that it may be the fear of the unknown, which scares the City, and this leads to delays or non-implementation of WtE.

b) Financial constraints

There was a general acknowledgement among participants that the capital investment of WtE is prohibitive costs. Some participants also emphasised that with technology advancement and improvements, the prices are coming down gradually. Participant 12 and Participant 3 were more concerned that the balance sheet of the City of Johannesburg or other municipalities are not good, referencing the auditor general report, which established only one Metro in Gauteng received a clean audit. Participant 12:

> "If we can look at the Auditor General report now, it's only Ekurhuleni who got a clean audit amongst all Gauteng metros. Now, if you're going to then forecast on the balance sheet of the municipality, it may be a little bit difficult. So, I think that kind of guarantee from National Treasury is important as one of the main ministries which could assist in terms of that kind of guarantee".

Participant 3:

> "We are saying that it seems what waste-to-energy will be solving is not so much the electricity access, we have already said that, but more so the waste problem. Now, if the City were to say that we don't want to buy the electricity ourselves, we know that our balance sheet is not good. No one is going to sign the PPA because the tariff will be higher than grid tariffs".

4.8.4 *Proposition 5 conclusions*

Three themes (10, 11 and 12) that emerged from Proposition 5 are a) Stakeholder collaboration; b) Service delivery legislation; and c) Access and financial viability. Theme 10 identified a lack of proper engagement among stakeholders and a lack of awareness about WtE projects among stakeholders. Therefore, to realise WtE implementation, stakeholder collaboration would be essential. Theme 11 advocated for alignment in all three spheres of government; more important that at local government levels, the concentration should be the independence of service delivery from political terms cycles, therefore, local-level legislation should focus on service delivery. Theme 12 identified constraints concerning waste access for private parties and the financial viability of WtE.

4.9 Data triangulation

Triangulation is using multiple data sources to establish integrity and enhancement of the findings (Given, 2008). This observation is supported by Saunders et al. (2016), contending that in a qualitative study, triangulation is a technique to establish credibility/validation. Therefore, this study used triangulation based on the government documents including legislation, acts, frameworks, and reports to compare with information obtained from semi-structured interviews.

The documents used were chosen based on what was indicated by the participants regarding legislation, processes, frameworks and, where applicable, stats. Table 4 below shows data triangulation in comparison with information from semi-structured interviews.

Table 4: Data triangulation

RSA Government Document (source)	Document description	Issue	Comparison to interviews
National Treasury Municipal Service Delivery and PPP Guidelines. (GTAC, 2018)	Guidance on developing a municipal and other local spheres PPP - It describes the process and legislation applicable for PPP.	**MFMA Act of 2003** - Section 120 on PPPs. - Section 33 on long term contracts. **Municipal Systems Act of 2003** - Section 76, 77, 78 on various delivery mechanisms, including PPPs. **Municipal PPP Regulations (2005)** **Supply Chain Regulations (2005)**	The participants described the legislation, such as MFMA, PPP regulations, and procurement supply chain regulation. The divergence was on the Municipal Systems Act (MSA), with little emphasis; however, this was covered in consultation processes. This shows the participants' level of understanding of this applicable legislation and frameworks and enhances credibility and validity.
Local Government: Municipal Finance Management Act (MFMA) 56 of 2003 (South Africa, 2003)	*"To sound and sustainable management of the financial affairs of municipalities and other institutions in the local sphere of government; to establish treasury norms*	Regulates PPP framework in relation to local government and other institutions in the local sphere: **Section 120 of the MFMA Act 2003 -** Conditions and process for PPP	MFMA was described by participants as a hindrance and cumbersome to WtE projects as its processes inform the PPP framework with its long processes. There were clear suggestions this part of the legislation needs to be amended. There were also

RSA Government Document (source)	Document description	Issue	Comparison to interviews
	and standards for the local sphere of government; and to provide for matters connected therewith" (South Africa, 2003, p. 2).	**Section 168 of the MFMA Act 2003 Treasury regulation and guidelines -** Municipal PPP Regulations **Section 33 of the MFMA Act 2003 -** Contracts longer than three years require approval from the council.	concerns by participants on the contracts longer than three years, which the council can extend to five years. This aligns with the processes as described by the MFMA documents/sections. This shows the participants' level of understanding of these processes and enhances credibility and validity.
PPP Framework (South Africa, 2003) (National Treasury, 2021)	**PPP Framework is informed by these documents:** - MFMA 2003 - MSA 2003 - Municipal PPP regulations - Supply chain regulation	The crucial issues of the PPP are with the MFMA and the process, as below: (1) Inception (2) Feasibility (3) Procurement (4) PPP agreement management. Besides these: (1) Treasury Views and Recommendation (TVR),	The main concern was that the process was extended with several approvals from various government departments. There are three National Treasury Views and Recommendations (TVR 1, TVR 2 and TVR3). Annexure E of the 2021 Budget Review National Treasury indicated it intends to reduce time to complete

RSA Government Document (source)	Document description	Issue	Comparison to interviews
		(2) Views and recommendation of the Department of Cooperative Governance and Traditional Affairs (CoGTA) and sector department (3) Public participation (4) Council decision	planning and procurement of such projects and reduce the number of public consultations (National Treasury, 2021). This aligns with the observations of the participants who stressed the long processes of the PPP framework.
SALGA Study on Private Public Partnership Uptake by SA municipalities (SALGA, 2020)	The report was to investigate the reasons behind the low uptake of PPPs in South Africa, particularly among the municipalities (SALGA, 2020) The report identified problems and challenges constraining the uptake of	Several municipalities, experiencing the PPP implementation process, attempted to complain about the long and complex process. They contend a process could take about five years. Besides this, there is long National Treasury approval process. This causes significant delays to service delivery needs (SALGA, 2020). Some of the report recommendations are:	The participants were concerned about the long PPP framework processes and stringent National Treasury approval processes. They indicated that some of these processes need to change and align with service delivery levels in pace. The participants also indicated problems with the three-year term contracting timeframe as WtE projects normally are contracted around 20 years PPAs.

RSA Government Document (source)	Document description	Issue	Comparison to interviews
	PPPs in South African municipalities	• Simplified legislative framework • Streamlining decision-making • Increase beyond three-year timeframe • Awareness programmes • More support and advice from government agencies • Capacity and skills The report emphasises that 34 PPP projects are registered; only four are at procurement stages, the rest at inception or feasibility.	The concerns and challenges raised in the SALGA report align with most observations from the participants and enhance credibility and validity.
NEMA Act 59 of 2008 (South Africa, 2008) (South Africa, 1996) (DEA, 2011)	The legislative framework for enforcing Section 24 of the Constitution of the Republic of South Africa. Section 24 stipulates the right to *"an environment that*	The Waste Act of 2008 refers to prioritising reduction, reuse, recycling, and recovery of waste, according to the waste hierarchy and the establishment of the National Waste Management Strategy. This strategy	The participants emphasised the importance of the waste hierarchy, according to the Waste Act and mentioned that EPR for selected items would be critical for reuse and recycling.

RSA Government Document (source)	Document description	Issue	Comparison to interviews
	is not harmful to their health or wellbeing" (South Africa, 1996, p. 10)	stipulates the prioritisation of the waste hierarchy (DEA, 2011).	This aligns with the government legislation.
City of Johannesburg Feasibility Study 2017 (City of Johannesbug, 2017)	Feasibility study for AWTT for City of Johannesburg	The report proposes a 25 MW WtE incorporated with MRF at Robinson Deep Landfill site and another MRF at Marie Louise landfill site.	The participants indicated that to prioritise the waste hierarchy, the WtE plant should be integrated with MRF. This also aligns with the latest feasibility proposed for Johannesburg.
City of Johannesburg Integrated Annual Report 2018/19 (City of Johannesbug, 2019)	The report of the integrated performance of the City of Johannesburg from 01 July 2018 to 30 June 2019	The report relates the performance of MSW management as 15, 7% (reduction, reuse, and recycling) and 84, 3% disposal. Showing that the waste hierarchy is still ineffective. In addition, it mentions that the WtE plant is still under development following the PPP process.	The participants estimated a disposal rate of around 80%, 7-15% recycling and the ineffectiveness of the waste hierarchy. This is aligned with the City's annual report for 2018/19.

4.10 Member reflection

According to Tracy (2010), to ensure confirmability of the study, the participation of participants in the study findings is deployed. These processes are defined as member reflection. This process also enhances the quality and establishes validation of the qualitative research (Saunders et al., 2016). Therefore, this study used member reflection as analysed in Table 5 below.

Table 5: Member reflection

Participants in the Study	Agreed to participate in member reflection	Replied with comments	Answered with (yes, correct information is captured)	Did not respond
12	**8**	**2**	**3**	**3**
100%	**67% (8/12)**	**25% (2/8)**	**38% (3/8)**	**38% (3/8)**

4.10.1 *Member reflection analysis*

The member reflection was deployed to increase the credibility of the qualitative study. There was 67% agreement to participate; however, only five participated, which equates to 42% from the original 12. None of those who responded emphasised disagreement but re-emphasis some points. The exercise achieved its objectives to confirm or validate the observations of the participants.

Notable additional comment:

Original comment on waste transportation:

> "In waste management, transportation is one of the main costs should the City of Johannesburg fail to implement waste-to-energy and other

initiatives…. this will result in massive costs increase due to transportation out of the boundaries of the City".

Additional comment from member reflection:

> "With the increase of petrol prices in SA, longer distances to transport waste will prove to be costly for the City".

4.10.2 *Member reflection conclusions*

The aim of the member reflection was to ensure viability according to the observations of participants, and 100% of the participants who participated confirmed their views; therefore, the exercise achieved its objectives.

4.11 Summary of the findings

Twelve themes emerged from five propositions. Some themes suggest the progressive action that should implement WtE in the City of Johannesburg. Conversely, some themes suggest what the challenges to WtE implementation are and identify opportunities to catalyse WtE implementation. These are now summarised below:

The themes emphasised developments needed to implement WtE, and these would lead to catalysing the circular economy. It was evident from the participants' observations that the waste hierarchy should be prioritised, and one way of doing so is incorporating the MRF with the WtE facility to ensure the extraction of recyclable material to reusable status. The challenges that should be addressed to leverage circular economy opportunities include the ineffectiveness of current policy, regulation, standards, and planning. These

challenges could curb improvements realised by adopting the circular economy models, of which WtE is expected to play an integral part.

Development of local government-based decision frameworks is required as the decision frameworks are mainly based on the national government legislation and do not cater to the fast-paced service delivery requirements at local government levels. The observation of the participants is that local government should develop tailor-made decision frameworks based on service delivery demands or amendment to national legislation in alignment with the Constitution to suit their needs at local levels.

Waste hierarchy prioritisation is not yet effective. According to the participants, the waste hierarchy prescribed in the Waste Act 2008 is a good decision-making tool, also adopted abroad by developed countries. Participants say in South Africa, and Johannesburg, waste hierarchy is still at infant stages and not that effective, and it should be promoted. In Johannesburg, the estimated recycling is at 5% to 15%. Participants say WtE incorporated with MRF would promote the hierarchy effectiveness.

According to the participants, the landfill sites in Johannesburg are fast reaching the end of their life span, therefore, these challenges could happen soon if nothing is done. One participant remarked that WtE would serve as an incentive to effective waste management, resulting in the extended life span of landfill sites. Should business as usual of landfill disposal culture continue in the City, airspace would be insufficient and depleted. This would cause the emergence of various induced diseases and environmental degradation caused by air pollution, underground water contamination and greenhouse gases if WtE is not implemented in the City.

WtE technology subsidisation is not preferred, as the burden of rates and taxes would increase on a shrinking tax base of citizens. There were vital observations of already indirect subsidisation for those not paying for services. Participants emphasised technologies are reaching maturity, and the traditionally high WtE capital costs gradually decrease.

To achieve commercial viability, the levers identified by participants are increasing landfill gates fees, introducing landfill tax and formalisation of the recycling sector. These levers would contribute to the revenues of the integrated WtE facility (with MRF), therefore, decreasing tariff to competitive levels. There were cautions, however, from participants that alternatives should also be provided an example is the EPR. Participants reflect that imposing taxes and increasing fees may cause an illegal dumping culture if alternatives are not provided.

Collaboration among stakeholders is important. This should take place as engagement through educational and awareness campaigns. This would encourage stakeholder buy-in into WtE projects. Alignment among spheres of government and independence of service delivery planning from political cycles should be prioritised even if it means amending legislation to cater for local government level service delivery needs.

There were concerns from some participants concerning limitations for the private investors (IPPs) as they do not have ownership of the feedstock (MSW). The ownership is with the City once it collects it. The City is also reluctant to provide waste quantity guarantees. The balance sheet of the City is not in good standing, according to the auditor general report. It will, therefore, become difficult for the City to sign PPAs unless National Treasury provides guarantees.

Data triangulation deployed indicated that the participants were knowledgeable on the matters discussed and understood legislation and processes. The data used in triangulation also confirmed the need for a change of legislative framework to suit local government service delivery requirements. Member reflection was used to reflect and confirm the participants' observations on the findings. Data triangulation and member reflection were used to enhance the quality and credibility and establish the validity of this qualitative study.

4.12 Comparison of literature review and own findings

Table 6 below illustrates the literature review comparison to the findings obtained from research questions.

Table 6: Comparison of literature review and findings

RQ #	Research Question	Prop #	Proposition	Findings
1	What are the potential positive benefits the WtE implementation brings into the City?	1	WtE implementation would contribute to the catalysation of the circular economy in the City of Johannesburg.	WtE would stimulate a circular economy in the City of Johannesburg; it should be incorporated with MRF to promote other aspects of the waste hierarchy like recycling and reuse of material.
				Ineffectiveness of current policy, regulation, standards, and planning should be addressed to leverage circular economy opportunities.
2	What decision-making frameworks and	2		Decision frameworks are based on the national government legislation and do not accommodate the fast-paced service delivery requirements at local government

RQ #	Research Question	Prop #	Proposition	Findings
	actions are needed to implement WtE?		Adoption and implementation of decision-making frameworks would lead to WtE implementation.	levels; therefore, developing local government-based decision frameworks is required.
				Waste hierarchy prioritisation is not yet effective; WtE incorporated with MRF would promote the hierarchy effectiveness.
3	The consequences if WtE were not implemented in the City?	3	The City would encounter these consequences if WtE is not implemented; landfill airspace depletion, illegal dumping resulting in induced infectious diseases leading to poor health and environmental degradation and over-reliance on the national grid for electricity would not be curbed, and energy access would not be improved.	Insufficient landfill airspace would emerge because of WtE non-implementation in the City; this would lead to illegal uncontrolled dumps and increased waste management costs.
				Non-WtE implementation in the City would cause a negative influence on environmental and social sustainability, leading to the emergence of various induced diseases and environmental degradation caused by air pollution, underground water contamination and greenhouse gas emissions.
4		4	Capital and O&M costs for WtE by incineration are expensive, leading to	Subsidisation would increase the burden of rates and taxes on the shrinking tax base of citizens.

RQ #	Research Question	Prop #	Proposition	Findings
	Is WtE a commercial proposition?		high tariffs; for WtE to be commercially viable, decision-makers should consider subsidisation, landfill tax and high landfill gate fees. This would discourage landfilling and support WtE deployment.	WtE technologies are reaching maturity, leading to a gradual decrease in capital costs. Investor confidence would be inspired by guarantees in required waste streams and offtake agreements.
				Portfolio of improvement levers to commercial viability is increasing landfill gates fees, introducing landfill tax and formalisation of the recycling sector to contribute to the revenues of the integrated WtE facility (with MRF), therefore, decreasing tariff to competitive levels.
5	What are barriers to WtE implementation through thermal conversion?	5	Barriers to implementation include a) Financial, b) technological, c) institutional, and d) environmental barriers.	Collaboration and stakeholders' engagements through educational and awareness campaigns would play a pivotal role and encourage stakeholder buy-in into WtE projects.
				Alignment among spheres of government and independence of service delivery planning from five-year political term cycles would ensure that service delivery should be prioritised even is if it means amending legislation to accommodate local government level needs.

RQ #	Research Question	Prop #	Proposition	Findings
				Access to waste by IPPs to guarantee feedstock availability and financial viability of projects depends on guarantees provided by the National Treasury, as the City's balance sheet is not in good financial standing.

CHAPTER 5. DISCUSSION OF THE FINDINGS

5.1 Introduction

This chapter discusses the qualitative study findings within the context of the literature review conducted in Chapter 2, integrated with the findings in Chapter 4. The five propositions of the study are discussed per section concerning the findings from semi-structured interviews.

5.2 Proposition 1 discussion

This section discusses findings arising from Proposition 1 (WtE implementation would contribute to catalysing the circular economy in the City of Johannesburg). The question concerning the proposition was: What are the potential benefits of WtE implementation for the City*?*

The findings indicated alignment with the literature review regarding circular economy catalysation. Results from findings indicated that WtE implementation would stimulate the circular economy in the City of Johannesburg. According to Malinauskaite et al. (2019), there is a substantial weighting and prioritisation on the waste hierarchy making recovery technologies, such as WtE placed below, prevention, reuse and recycling, even though it is accepted that WtE would play a critical role in a circular economy.

The findings strongly support this observation, indicating that for WtE to provide a circular economy, it should be integrated with MRF to align and promote the waste hierarchy, a globally accepted best practice and decision-making framework for waste management. The observation from findings that natural

resources are depleting and WtE implementation as a promoter of the circular economy would cause waste to be a secondary commodity to supplement natural resources use. This is aligned with Malinauskaite et al. (2019), contending that in the circular economy environment, waste is circulated back to the system as a useful raw material contributing to energy generation and reducing GHG emissions.

While there was clear consistency between the findings and literature, the findings indicated that in the City of Johannesburg, the policies, regulations, standards, and planning are ineffective, and should be addressed to leverage circular economy opportunities. According to Culwick (2018), electricity access levels in the City of Johannesburg are at 90%, therefore, leaving 10% of citizens of the City without electricity access.

According to Rasmeni et al. (2019), several studies confirm that 90% of MSW in the City of Johannesburg is disposed-off landfill sites. This indicated that both universal electricity policy and waste hierarchy are ineffective. The waste hierarchy stipulates that landfilling is the last resort, where the only limited waste residue is disposed of that addresses both land availability and reduction of GHG normal resulting from landfill sites.

5.3 Proposition 2 discussion

This section discusses findings arising from Proposition 2 (adoption and implementation of decision-making frameworks would lead to WtE implementation). The question concerning the proposition was: *What decision-making frameworks and actions are needed to implement WtE?*

Findings indicated that the decision-making frameworks are derived from the national government and adopted and implemented at municipality levels. These decision frameworks contradict the service delivery requirements of local government as they include prolonged processes, whereas service delivery on the ground is fast-paced and needs urgent solutions. One of the essential planning devices in the country, the IRP 2019, excluded WtE, indicating misalignment concerning the national and local governments.

According to Mqadi et al. (2018), the IRP is the electricity planning device for the country, identifying technologies and sources to be deployed. Mqadi et al. (2018) contend that the IRP adopts the most minor cost scenario while considering other aspects, such as environmental preservation, electricity access, and reliability. This aligns with Fetanat et al. (2019) and WEC (2019), stating that in energy development, three critical factors should be considered, indicating energy security, energy affordability, and environmental sustainability.

The observation from findings indicates more emphasis on the least-cost on the IRP 2019, and WtE is more expensive in comparison with competing alternatives, such as wind and solar technologies. WtE succumbs with economies of scale compared with competing technologies. This further disadvantages WtE; therefore, the findings suggested developing IRP at the local government level. The City of Johannesburg should establish its own IRP to accommodate its needs. Another observation emanating from findings was that the IRP is reviewed frequently, therefore, municipalities and the City of Johannesburg, should present their observations firmly in the IRP participation process to lobby for WtE and other opportunities at the local government level.

Findings and literature review aligned that the decision-making framework for MSW management adopted by the City of Johannesburg is the waste hierarchy

prescribed by the Waste Act of 2008. Findings indicated that MSW management implementation, according to waste hierarchy, remains ineffective, as WtE is difficult to implement. This follows Kumar et al. (2017), who contend that the main countries, which embrace and implement recycling, hold effective WtE projects.

The findings affirmed that WtE incorporated with MRF would promote the hierarchy effectiveness, as MRF encourages recycling and reuse of recoverable useful materials. The recycling rate is minimal in the City of Johannesburg, with the findings providing estimates of between 5 to 15%. Waste disposal remains the dominant aspect in the City, with findings estimation of 80% disposal rates indicating the ineffectiveness of the waste hierarchy prioritisation. Malinauskaite et al. (2019) support the observations of Kumar et al. (2017) contending that countries, such as Denmark, the Netherlands, and Sweden, apply effective recycling and are leading with WtE technologies.

There is a misalignment among the spheres of government with decision-making frameworks. The priorities differ from national government looks holistically from a broader national perspective. However, at local government levels, various municipalities have various challenges and, therefore, service delivery requirements are not uniform. In adopting national legislation, the City of Johannesburg should investigate its own requirement and amend the frameworks as the Constitution allows. Pan et al. (2015) contend that decision and policymakers should have to understand who they are developing the framework for, as various communities and localities have varying needs regarding the environment, energy access and affordability. Therefore, decision frameworks must be developed to ensure compatibility and viability with requirements (Pan et al., 2015).

In developing its own decision-making frameworks for WtE, the City of Johannesburg should ensure that it balances the energy trilemma, according to its needs. What emerged from the finding was that while WtE is embraced as one solution for waste management more than it is an electricity solution. Therefore, prioritisation should support the waste hierarchy with recycling and recovery for reuse being high up hierarchal than WtE. The least-cost scenario intended for the IRP should not be adopted, as necessary. Even the IRP 2019 eventually adopted a policy adjusted scenario and did not adopt the least-coast approach (DMRE, 2019). The findings strongly indicate that environmental preservation is more prioritised and, therefore, for WtE to succeed, it should demonstrate what its role should be in GHG emissions reduction and other environmental aspects. It is, therefore, critical that all these aspects be ranked and prioritised in the order of importance on the City of Johannesburg developed decision-making framework for WtE.

5.4 Proposition 3 discussion

This section discusses findings arising from Proposition 3 (the City would encounter these consequences if WtE is not implemented; landfill airspace depletion, illegal dumping resulting in induced infectious diseases leading to poor health and environmental degradation and over-reliance on the national grid for electricity would not be curbed and energy access would not be improved). The question concerning the proposition was: What are *the consequences if WtE were not implemented in the City?*

There was a strong alignment between the findings and literature review about the consequences of WtE non-implementation in the City of Johannesburg. The findings indicated that because of the rapid population increase in Johannesburg

and no approvals for new landfill sites, the waste quantities would continue to increase. This would cause insufficient landfill airspace should WtE not be implemented in the City. Abrahams et al. (2018) contend that Johannesburg has the highest population compared to other cities in South Africa. As of 2017, the population was estimated to be 5.4 million.

There is an increase in the proliferation of illegal, unplanned, informal settlements (Lekalakala, 2019). Simelane (2017) contends that rapid growth of uncontrolled and unplanned urbanisation leads to increased service delivery provisions problems. The findings revealed that poor service delivery and insufficient landfill airspace would lead to illegal uncontrolled dumps and increased waste management costs. Dlamini (2019) contends that illegal dumping results from insufficient infrastructure provisions as population increases and economic activity ramp up within cities.

The findings indicated that non-WtE implementation in the City would cause a negative influence on environmental and social sustainability, leading to the emergence of various induced diseases and environmental degradation caused by air pollution, underground water contamination and greenhouse. This observation from the findings supported Kubanza et al.(2020), contending that MSW mismanagement is one of the major causes of environmental degradation problems and can lead to issues related to poor health, economic, and social concerns.

Kearns (2019) contends that both landfilling and dumping are unsustainable methods of waste management contributing to GHG, such as CO_2 and CH_4, leading to the climate change problem.

About electricity provisions, there was a clear perspective from findings that WtE implementation and the resulting electricity would contribute to additional

electricity access; however, this is not the main priority to address the waste management problems. Any electricity would be a by-product of the effective waste management system.

5.5 Proposition 4 discussion

This section discusses findings arising from Proposition 4 (Capital and O&M costs for WtE by incineration are expensive, leading to high tariffs. WtE, to be commercially viable, decision-makers should consider subsidisation, landfill tax and high landfill tipping fees. This would discourage landfilling and support WtE deployment). The question concerning the proposition was: *Is WtE a commercial proposition?*

Findings were not in alignment with the literature review about subsidisation. They indicated that subsidisation would increase the burden of rates and taxes on the already shrinking tax base of citizens in Johannesburg. Whereas literature review conversely indicated they could play an essential role in developing WtE, where projects are not financially viable. According to Amsterdam et al. (2017), the government should consider subsidisation of WtE more, especially as it is still in its early stages of development in the country. Findings revealed existing indirect subsidisation where those paying are subsidising those who do not pay besides basic free electricity provisions.

Regarding the landfill gate fees and landfill tax, there was clear consistency between the findings and literature review, with findings indicating that the landfill gates fees are low in Johannesburg at below R300/tonne compared to an international average of R800/tonne. This agreed with Adeleke et al. (2021), who contend that cheap landfill gate fees in South Africa discourage diversion of the waste away from landfill sites. The findings indicate that introduction of landfill tax

would discourage landfilling in Johannesburg. This aligns with a literature review, asserting that landfills would discourage developing new landfill sites, and waste would be diverted to the WtE facilities.

Findings indicated that revenues derived from cost-reflective gate fees and carbon credits/tax could be the additional revenue means for the WtE plant, offsetting the high tariff of the WtE plant. This aligned with Maisiri et al. (2015), contending that for the WtE plant, revenue streams could be derived from gates fees, recycling material sales, energy sales and carbon credits. The findings concluded that the WtE facility should be incorporated with an MRF to encourage recycling and reuse of recovered material, as these would also contribute to the revenues of the integrated WtE/MRF facility.

Concerning the grid tariff, the findings indicated that in the past, the coal-based electricity generation tariff was too low even to consider competing technologies. With the tariff that increased over 460% nominal since 2007, the prospects of WtE increased as it can now compete with other interventions, such as gate fees and recycling revenues. This aligned with the trends in literature with Amsterdam et al. (2017) arguing that the electricity tariff increased considerably in the last decade but was still cheap compared to WtE.

The findings concluded that the WtE capital investment costs were high traditionally, which followed the literature review with Young (2010) arguing that WtE incineration has the highest capital investment costs and O&M costs. The findings emphasised that the WtE technologies are reaching maturity, leading to a gradual decrease in capital costs.

Concerning the private investor interest in WtE development, the findings confirmed a high investor interest; however, investor confidence would be inspired by guarantees in required waste streams and offtake agreements.

According to the findings, WtE plant ownership should be with private IPPs. This observation aligns with Pan et al. (2015), asserting that WtE operations would optimise with private ownership rather than with the government.

There was a general alignment between the findings and the literature review, except for subsidisation. More important findings identified (aligned with literature) a portfolio of improvement lever to commercial viability increasing of landfill gates fees, introducing landfill tax and formalisation of the recycling sector to contribute to the revenues of the integrated WtE facility (with MRF); therefore, decreasing tariff to competitive levels.

5.6 Proposition 5 discussion

This section discusses findings arising from Proposition 5 (barriers to implementation include a) financial, b) technological, c) institutional, and d) environmental barriers). The question concerning the proposition is: *What are the barriers to WtE implementation through thermal conversion?*

The findings identified a lack of collaboration and stakeholder engagements of participants in the City of Johannesburg. There is a general lack of awareness of the potential role and benefits that WtE could bring forth in the City. The stakeholders involve political principals from the city council, city officials, and other spheres of government, communities, and private investors. In contrast, the literature review identified institutional misalignment within the City departments and MOEs, such as electricity and waste management departments. Conflicts exist concerning prioritisation among entities and departments. According to Sustainable Energy Africa (2017), the challenge with WtE is the involvement of various parties and disputes in priorities arise; therefore, roles and responsibilities should be defined to avert conflicts and misalignment. According to Pan et al.

(2015), the progress of WtE implementation is often hindered by the lack of awareness among stakeholders; therefore, collaboration and knowledge sharing is a vital cog to achieve implementation.

The findings indicated that the legislation is unsuitable for service delivery-based projects at the local government level. The processes of MFMA PPP guidelines are long and cumbersome and a hindrance to WtE implementation. This aligns with the observations of Sustainable Energy Africa (2017) in the literature review, remarking that the approval processes involve multiple government entities and departments. It could, therefore, the process could involve a range of three to eight years for approving WtE projects.

The City of Johannesburg (2017) indicates that NERSA, DMRE, DFFE and the city council are all involved in both electricity generation and waste treatment legislation and regulation. This adds to the long and delayed processes to approve and implement WtE projects. Besides long multiple government entities processes and approval requirements, the findings indicated that the five-year political term and three-year contractual terms and the Integrated Development Plan (IDP) process are a barrier to WtE implementation.

The political principals are reluctant to approve contracts over three years. At the least, they could extend to five years but are unwilling to commit beyond their political term of office to over five years. The findings concluded that an expedited service delivery-based legislation should be developed and adopted for the City of Johannesburg. This legislation should ensure independence from political office terms to encourage and ensure continuity beyond political terms.

The findings identified access to waste and financial viability as barriers that should be addressed to realise WtE implementation. The financial viability barrier aligns with the literature review, emphasising that the cost of transportation,

landfilling, and carbon penalties should outweigh the tariff for WtE to be workable. Coelho (2020) contends that capital investment and O&M for WtE are expensive. The findings also indicate that the balance sheet of the City of Johannesburg is not reasonable based on the 2020/2021 Auditor-General report; therefore, they would also need guarantees from National Treasury for IPPs to sign PPAs.

The findings indicated concerns among IPPs regarding waste access and quantity guarantees for the WtE facility from the City of Johannesburg; however, there is a reluctance to provide such guarantees as the City only collects waste once it is generated.

There was alignment between the findings and literature on collaboration and stakeholders' engagements through educational and awareness campaigns. These could play a pivotal role and encourage stakeholder buy-in into WtE projects. Findings identified the need for alignment among spheres of government and independence of service delivery planning from five-year political term cycles to ensure that service delivery should be prioritised. This would include amending legislation where applicable to cater for local government level needs.

Finally, the findings identified access to waste by IPPs to guarantee feedstock availability and financial viability of projects as a barrier that could be resolved by guarantees provided by the National Treasury, as the City's balance sheet is not in good financial standing.

5.7 Conclusions

The findings established WtE would play a critical role in stimulating the circular economy in Johannesburg. Findings demonstrated remaining challenges of

ineffective policy, standards, regulations, and planning. The findings were aligned with the literature review regarding WtE catalysation of the circular economy. The findings emphasised that to respect and promote the waste hierarchy, a legislated decision-making framework for waste management. The MRF should be integrated into the WtE facility. This MRF would then encourage recycling and recovery of material for reuse back in the economy and only then would WtE be considered completing the circular loop before disposing of the residue to landfills.

The findings stressed the need for local government-based decision-making frameworks, which would complement the waste hierarchy and other legislated frameworks, according to the Constitution of the country. The literature review also identified the waste hierarchy as an important decision framework and best practice globally. Contrary to the literature review, which emphasised subsidisation as one of the important mechanisms to ensure commercial viability, the findings demonstrated that subsidisation would add burden to the few taxes and ratepayers. There were consistencies between the findings and literature review regarding the introduction of landfill tax and gates fees, with findings advocating for cost-reflective gates fees in the City of Johannesburg.

Both the findings and the literature were aligned regarding non-WtE implementation, leading to insufficient landfill airspace, uncontrolled illegal dumping, and the emergence of induced diseases as environmental degradation. Finally, the findings emphasised a need for collaboration and awareness among stakeholders to align and support WtE initiatives. The literature review identified long processes for approval, as confirmed by the findings. In conclusion, the findings also identified a barrier between waste access quantity guarantees and PPA, which National Treasury should guarantee.

CHAPTER 6. CONCLUSIONS & RECOMMENDATIONS

6.1 Introduction

This chapter integrates findings of the propositions into the original research questions in Chapter 1, responding to each research question. Second, the chapter suggests recommendations to each stakeholder identified in Chapter 1 under the significance of the study. These include the City of Johannesburg and its entities, government policymakers and administrators, private sector IPPs, and the academic fraternity.

6.2 Research Question 1 conclusions

The first question investigated potentially positive benefits the WtE implementation brings into the City. The findings have established that WtE would stimulate the circular economy in the City of Johannesburg. The findings indicate that even though WtE would play a critical role in the stimulation of the circular economy, it should be integrated with MRF, enabling MSW management according to the waste hierarchy, which is a legislated decision-making framework in South Africa and the global renowned best practice.

Promoting and implementing the waste hierarchy could be accelerated by incorporating the MRF with the WtE plant. This could be an effective way to recycle and recover useful material for reuse back into the economy to complete the loop for the circular economy. The findings indicated the benefits of WtE implementation are reduced waste to landfill sites resulting in extending landfill airspace, reduction of carbon emissions and additional electricity capacity. These findings align with the literature, indicating that WtE could be the sustainable way

to implement the circular economy while resolving the predicament of energy shortages, waste management challenges, and climate change.

The findings identify the ineffectiveness of current policy, regulation, standards, and planning to leverage circular economy opportunities. These challenges should be addressed. This is contrary to the developed economies, where these are effective. According to the literature, in these countries, WtE is effective, contributing to the circular economy.

6.3 Research Question 2 conclusions

The second question regards the decision-making frameworks and actions needed to implement WtE. The findings established that decision frameworks adopted in the City of Johannesburg are based on the government legislation at national and provincial government levels. The findings indicated these were not suitable for local government levels because of the prolonged multilevel approval processes; these include the MFMA and PPP framework. While these are necessary to ensure financial viability, the local government service delivery matters need expedited approval processes. The findings confirmed these laws should be amended to accommodate the local government level. The City of Johannesburg should develop its own IRP to align its electricity plans to service delivery requirements.

The main decision framework for waste management, the waste hierarchy, is ineffective as recycling levels remain low with limited separation at source. Landfill disposal still dominates in Johannesburg with 80% disposal levels. This aligns with the literature, confirming high disposal levels. The decision frameworks in the literature indicated that decision frameworks, such as AHP and

MCDM, are incorporated to determine the suitable paths and options and the best implemented solution.

These frameworks are implemented in developed countries which have already had effective waste management systems. This study proposes the decision framework for Johannesburg based on the needs at local government levels, with particular emphasis on the developing countries where the level of the waste hierarchy remains ineffective, as discussed in the recommendations section.

6.4 Research Question 3 conclusions

The third question investigated the consequences if WtE were not implemented in the City of Johannesburg. The findings indicated that since there are already constraints on the landfill airspace availability, no new landfill licences are issued by the Gauteng Province, therefore, WtE non-implementation in the City of Johannesburg would cause insufficient landfill airspace leading to illegal uncontrolled dumps and increased waste management costs. The findings indicated that non-WtE implementation in the City would harm environmental and social sustainability, leading to the emergence of various induced diseases and environmental degradation caused by air pollution, underground water contamination and greenhouse.

The findings mostly align with the literature contents; however, on the costs, the findings indicated it would continue to increase, particularly concerning transportation costs as fuel prices continued to grow exponential in the past 10 years.

6.5 Research Question 4 conclusions

The fourth question investigated if WtE is a commercial proposition. The findings indicated that technology maturity lowers the capital and O&M prices. The findings indicated that owing to the grid tariff, which increased 460% since 2007, this increased competitiveness of WtE compared with grid and emerging renewable technologies.

To improve viability and competitiveness, the findings indicated that portfolio of improvement levers including increasing of landfill gates fees to cost reflectivity, introducing landfill tax and formalisation of the recycling sector to contribute to the revenues of the integrated WtE facility (with MRF), decreasing tariffs to competitive levels. The literature also indicated that increasing gates fees and landfill tax would improve viability. They aligned with the literature, advocating for prevention, reuse, and recycling, then energy recovery, and lastly disposal.

Last, investor confidence would be inspired by guarantees in required waste streams and offtake agreements. The contrasting observation based on the literature review indicates that subsidisation is a device that led to the commercialisation of WtE in developed countries. The findings, however, indicated that with Johannesburg, subsidisation would not lead to commercial viability as there is already eroded rates and taxes contributions from the limited citizenry.

6.6 Research Question 5 conclusions

The fifth question investigated barriers to WtE implementation through thermal conversion. The findings indicated a lack of education, awareness, and a lack of proper stakeholder engagement on WtE. Findings indicated a lack of expedited

legislation processes tailor-made for projects, such as WtE and five-year political terms, hampering service delivery plans. Findings also identified access to waste by IPPs and the City of Johannesburg and poor balance sheets as barriers that should be addressed to realise WtE implementation.

The barriers identified in the literature were financial, technological, institutional, and environmental. These barriers align with findings except for the expedited legislative processes, aligning with service delivery projects, such as WtE. This point would be aligned with findings in Proposition 4, emphasising this problem. Therefore, the same topic should be incorporated into the recommended decision-making framework for the City of Johannesburg as discussed in Section 6.3.

Table 7: Consistency table: research questions, conclusions, and contribution to knowledge

RQ #	Research question	Literature-based proposition	Conclusion or answer based on own research	Key differences between initial propositions and findings
1	What are the potential benefits of WtE implementation for the City?	WtE implementation would contribute to catalysing the circular economy in the City of Johannesburg.	WtE would play a crucial role in the stimulation of the circular economy; however, consideration should be to ensure that waste hierarchy is adhered to by incorporation of MRF.	The findings align with the proposition regarding the WtE as a contributor to catalysing the circular economy. The difference was that on the literature, MRF was proposed as standalone, and waste streams should be parallel directed to both the WtE and MRF facilities. Findings indicate that with Johannesburg, lacking effective separation, these facilities should be integrated, or when separated, MRF should be prioritised.
2	What decision-making frameworks and actions are needed to implement WtE?	Adoption and implementation of decision-making frameworks would lead to WtE implementation.	The waste hierarchy is the main decision-making framework adopted, based on	Findings align with the proposition about waste hierarchy prioritisation as its world-renowned best practice.

RQ #	Research question	Literature-based proposition	Conclusion or answer based on own research	Key differences between initial propositions and findings
			the Waste Act of 2008 and is ineffective. Other legislated guiding the WtE development, such as MFMA and PPP framework. These are to ensure process compliance; however, they are leading to delays to WtE implementation.	The findings emphasised the need for local government service delivery aligned decision-making frameworks.
3	The consequences if WtE were not implemented in the City?	The City would encounter these consequences if WtE is not implemented, indicating landfill airspace depletion, illegal dumping resulting in induced	Depletion of landfill airspace leading to uncontrolled illegal dumps and increases costs of waste management. Emergence of various induced diseases and environmental degradation caused by air pollution,	The findings align with the proposition regarding landfill airspace depletion, illegal dumping resulting in induced communicable diseases leading to poor health and environmental degradation. However, the findings show that WtE energy is not an energy solution any electricity

RQ #	Research question	Literature-based proposition	Conclusion or answer based on own research	Key differences between initial propositions and findings
		communicable diseases leading to poor health and environmental degradation and over-reliance on the national grid for electricity would not be curbed and energy access would not be improved.	underground water contamination and greenhouse.	generation will be a by-product emanating from a waste management solution.
4	Is WtE a commercial proposition?	Capital and O&M costs for WtE by incineration are expensive, leading to high tariffs, for WtE to be commercially viable decision-makers should	WtE technology maturity and massive grid tariff escalations since 2007 increased competitiveness of WtE,	The crucial difference was about subsidisation. The findings indicated that with Johannesburg, subsidisation would not lead to commercial viability as there are already eroded rates and taxes contributions from limited citizenry. Whereas the proposition indicated that

RQ #	Research question	Literature-based proposition	Conclusion or answer based on own research	Key differences between initial propositions and findings
		consider, subsidisation, landfill tax and high landfill gate fees. This would discourage landfilling and support WtE deployment.	therefore, commercial viability. Other aspects, such as cost-reflective gate fees and landfill tax, would further enhance the prospects of WtE.	subsidisation is one tool, leading to commercialising WtE in developed countries.
5	What are barriers to WtE implementation through thermal conversion?	Barriers to implementation include a) financial, b) technological c) institutional, and d) environmental barriers.	The findings indicated a lack of education, awareness and no proper stakeholder engagement regarding WtE. Findings indicate a lack of expedited legislation processes tailor-made for projects, such as WtE and five-year political terms hampering service delivery	The findings align with the proposition except for the expedited legislative processes which align with service delivery aligned projects, such as WtE, which emerged from the findings. The findings recommend that the City of Johannesburg should develop its own decision framework, aligned with legislation.

RQ #	Research question	Literature-based proposition	Conclusion or answer based on own research	Key differences between initial propositions and findings
			plans. Findings also identified access to waste by IPPs and the City of Johannesburg financial viability as a barrier that should be addressed to realise WtE implementation.	

6.7 Recommendations

This section emphasises the recommendations of the research based on the significance of the study, Section 1.6 (Chapter 1). The study sets to contribute to the area of the impediments or barriers to WtE implementation and opportunities. The study assessed existing decision-making frameworks and why they are not implemented or adopted and whether there are any amendments required which may help WtE implementation. Therefore, the recommendations are:

a) The City of Johannesburg and government policymakers

The study identified the need of local government level service delivery based decision-making frameworks. The recommendation, therefore, is that the City of Johannesburg develops its own decision-making frameworks in alignment with the current legislated ones. The government policymakers should consider complexities, including political tenures, contractual terms, and IDP planning processes when developing decision frameworks affecting local governments. Finally, according to the study findings, the City of Johannesburg should develop its own IRP, based on the service delivery requirements.

Besides the recommendation of developing its decisions frameworks, it is further recommended that the City adopts MCDM frameworks, such as the one developed (Farooq et al., 2021). The framework incorporated the waste hierarchy prioritisation and energy access, according to the research. This is illustrated in Figure 15 below.

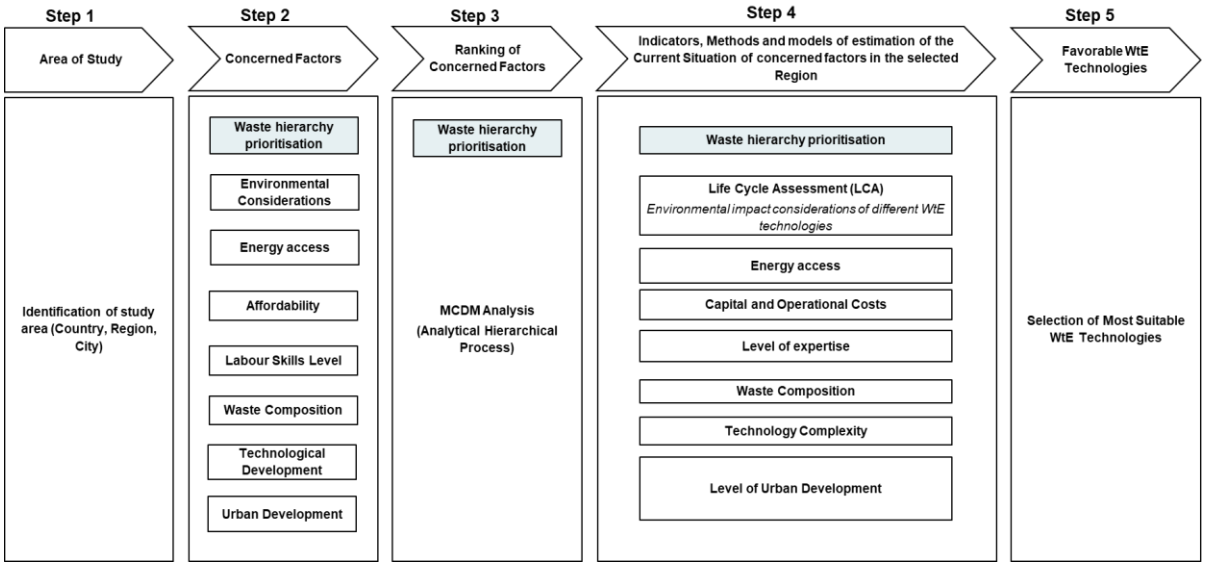


Figure 15: Recommended decision-making framework for waste-to-energy suitable technology adapted from (Farooq et al., 2021)

b) Private sector, in particular IPPs

The study identified the commercial viability of WtE based on technology maturity and grid tariff escalations. Gate fees and landfill tax would add to the incentives, making it more viable. The IPPs should actively attempt to contract with municipalities and the City of Johannesburg to develop WtE into acceptable business and commercial proposition.

c) Academic fraternity

The study identified barriers and opportunities of WtE in City of Johannesburg. Most of these could apply to metropolitan municipalities in the developing world, particularly in Africa, with limited WtE implementation. These barriers and opportunity identified in the study are further recommended for future studies in the next section.

6.8 Suggestions for further research

The study was limited to the City of Johannesburg Metropolitan Municipality to identify barriers and opportunities to WtE implementation by thermal conversion technologies in the City. The study established the barriers but did not rank these per technology and refrained from identifying the WtE optimal solution based on the current and future developments. The suggested research path, therefore, would be the most optimal WtE technology for the metropolitan municipalities in South Africa or in Johannesburg and would address the barriers and decision frameworks identified by the study, to apply in other metropolitan areas in South Africa.

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APPENDIX A – City of Johannesburg permission letter

City of Johannesburg
Environment & Infrastructure Services Department

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MEMORANDUM

TO : **Nkumbulo Sithole**
School of Business Administration, University of the Witwatersrand,

FROM : **Christiaan Ehlers**
Executive Director: EISD

DATE : **10 February 2022**

Re : **Permission to conduct research for assignment**

Dear Sir

I acknowledge your request for information towards your course assignment on your letter to our department on 13th October 2021.

The City of Joburg, Environment and Infrastructure Services Department (EISD) hereby grant you permission to conduct research on your topic **"Thermal conversion of waste to energy by incineration in Johannesburg".** The permission includes interviewing staff, make observations, send out a questionnaire, and access contact details of organization members. Please note that the City Alternative Waste Treatment Technologies project is still at preparatory stage, so there is confidential information that for now would not be shared with public. I have therefore requested the following officials from the City of Johannesburg within the Environment & Infrastructure Services Department to be the contact person on behalf of the City: [redacted] and [redacted]

Upon completion of the research, you are required to provide the City with copy of thereof.

Thank you,

22/02/2022

Mr. Christiaan Ehlers
Executive Director:
Environment and Infrastructure Service

APPENDIX B – Consent form

Research title: Thermal conversion of waste-to-energy by incineration in Johannesburg

Student name: Nkumbulo Sithole

I, ……., agree to participate in the research project named above. The study has been explained to me and I understand what my participation will involve. Please circle the relevant options below.

a.	I agree that my participation will remain confidential	YES NO
b.	I agree that my participation is voluntary and that I can withdraw at any time without consequence	YES NO
c.	I agree that the researcher may use anonymised quotes from my interview in the research report and publications	YES NO
d.	I agree that the interview may be audio-recorded	YES NO
e.	I agree that I will not be remunerated for participating in the study	YES NO

Signature: ……..…

Name (optional) ……

Date ……..…….

APPENDIX C – Research instrument

Proposition 1

WtE implementation will contribute to the catalysation of the circular economy in the City of Johannesburg.

Questions:

1. What contribution, if any, will WtE bring to solid waste management in the City?
2. How would WtE contribute to reducing electrification backlogs and help reduce load shedding impact?
3. In your view, how would WtE contribute to climate change mitigation and a lower carbon economy?
4. What contribution will it bring to the circular economy concept?

Proposition 2

Adoption and implementation of decision-making frameworks will lead to WtE implementation.

Questions:

1. What is your understanding regarding decision-making frameworks and its applicability to WtE?
2. What decision-making framework is used for waste management by the City of Johannesburg?
3. In your view, is there any policy or legislation that needs to be amended or introduced to fast track the WtE implementation by thermal conversion?

4. The waste hierarchy which prioritises (prevention, reuse, recycle, WtE and disposal) is adopted and accepted globally as the best way to MSWM, in your view how close is the City to alignment with the hierarchy?
5. In decision-making including energy policy development e.g., the IRP 2019, WtE is not included, why is it left out even though it has such potential both in energy generation and climate change mitigation?
6. How would WtE help balance the energy trilemma for the City (that is the energy just criteria; environment, energy access and affordability)?
7. Which stakeholders are driving the WtE agenda?
8. Do you think the decision to unbundle Eskom into three entities and the creation of the Independent System Operator will enhance WtE prospects?
9. Any other additional decisions and actions required to produce WtE implementation?

Proposition 3

The City would encounter these consequences if WtE is not implemented. Landfill airspace depletion illegal dumping resulting in induced infectious diseases leading to poor health and environmental degradation and over-reliance on the national grid for electricity would not be curbed, and energy access would not be improved.

Questions:

1. What would be the consequences regarding the landfill airspace if WtE were not implemented?
2. What social consequences can arise because of non-implementation of WtE?
3. What social consequences can arise because of implementation of WtE?

4. What would be the consequences that the City could incur in relation to penalties or carbon tax as result of emissions from waste?
5. How would WtE curb the reliance of the City to Eskom supply?

Proposition 4

Capital and O&M costs for WtE by incineration are expensive, leading to high tariffs; for WtE to be commercially viable, decision-makers should consider subsidisation, landfill tax, and high landfill gate fees, discouraging landfilling and supporting WtE deployment.

Questions:

1. Globally, WtE is subsidised, how would the introduction of subsidies increase chances of WtE implementation in the City?
2. How would the increase of gate fees and introduction of landfill tax discourage the continued landfilling and development of new landfill sites?
3. The costs of grid electricity have risen above 460% since 2007, would this present WtE an advantage if it reaches grid parity?
4. In your view is WtE attractive enough to investors and will bring good return on investment?

Proposition 5

Barriers to implementation include a) Financial, b) technological c) institutional, and d) environmental barriers.

Questions:

1. In your view what are the top five barriers to WtE? And why are they barriers?

2. Why does the City not follow the IPP office processes or acquire them to do it for the City?
3. What is your view on the function of emissions emanating from WtE plants as a hindrance to WtE implementation?
4. Municipal elections are every five years; how is this affecting developing WtE?
5. What are the perceptions of the citizen regarding WtE incineration in the City?

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/EL2287535/682
This certificate is only valid with a legitimate ethics protocol number and signed by the Researcher (below).

This certificate is only valid if accompanied by formal permission from the relevant stakeholder(s).

Project title	Thermal conversion of waste to energy by incineration in Johannesburg
Investigator / Researcher	Mr Nkumbulo Sithole
Nature of Project	MM (Energy Leadership)
Decision of the Committee	Approved, provided stakeholders and participants are guaranteed confidentialty.
Issue Date of Certificate	2022-02-10
Expiry date	Date of submission of the project report
Chairperson	Prof Anthony Stacey ☎ +27 11 717 3587 +27 82 880 4531 anthony.stacey@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

28/02/2022
Date:

APPENDIX D – Certificate from language editor

Nr: 20182

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LANGUAGE EDITING CERTIFICATE

Research report title:	Thermal conversion of waste to energy by incineration, in Johannesburg
Authors:	Nkumbulo Sithole
Institution:	WITS
Date Issued:	24 March 2022

This document certifies that the manuscript listed above was edited for proper English language, grammar, punctuation, spelling, and overall style. Neither the research content nor the author's intentions were altered in any way during the editing process. Documents receiving this certification should be English ready for publication; however, the author has the ability and choice to accept or reject our suggestions and changes.

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Warm regards

Elizabeth Marx

Attended the EFA International Editors' Conference – Chicago: August 2019 https://www.the-efa.org/efas-2019-conference-announcement/